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Physics

ICSE 10

Focused Theory | In-Text Exercises | Chapter Exercises | Past Exams' Questions | Sample Papers

Edition 2022-23

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ARIHANT PRAKASHAN (School Division Series)

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A WORD
With The Readers

Allinone ICSE Physics Class 10 has been written keeping in mind the needs of students studying in 10th ICSE. This book has been made in such a way that students will be fully guided to prepare for the exam in the most effective manner, securing higher grades.

The purpose of this book is to aid any ICSE student to achieve the best possible grade in the exam. This book will give you support during the course as well as advice you on revision and preparation for the exam itself. The material is presented in a clear & concise form and there are ample questions for practice.

KEY FEATURES

- **Focused Theory** It contains the necessary study material well supported by Definitions, Facts, Figure, Flow Chart, etc.
- **Check Point** These are intext exercises given between the text material. These exercises have 4-5 questions based on the related concept.
- **Summary** At the end of each chapter, Summary is given. It contains crux of the chapter in pointer form that provides the quick revision of the whole chapter.
- **Exam Practice** The Exercise contains questions in that format in which these are asked in the examinations. Questions have been categorised as 2 marks questions, 3 marks questions, 4 marks questions and Numerical based questions. All the questions given here are fully solved.
- **Chapter Exercise** It is the Assessement exercise for the complete chapter. With this exercise, students can assess their understanding of the chapter and can prepare for it accordingly.
- **Challengers** It includes some special questions based on the pattern of olympiad and other competitions to give the students a taste of the questions asked in competitions. These are not meant for school examinations.
- To make this book complete in all aspects, **Experiments and 5 Sample Questions Papers** based on the exam pattern & Syllabus have also been given.
- At the end of book, there are **Latest ICSE Specimen Question Paper** and **ICSE Examination Paper**.

At the end it can be said that **Allinone** Physics for ICSE 10th has all the material required for examination and will surely guide students to the Way to Success.

We are highly thankful to ARIHANT PRAKASHAN, MEERUT for giving us such an excellent opportunity to write this book. Huge efforts have been made from our side to keep this book error free, but inspite of that if any error or whatsoever is skipped in the book then that is purely incidental, apology for the same, please write to us about that so that it can be corrected in the further edition of the book. The role of Arihant DTP Unit and Proof Reading team is praise worthy in making of this book. Suggestions for further improvement of the book will also be welcomed.

In the end, we would like to wish BEST OF LUCK to our readers!

Authors

PREVIEW

CHAPTER THEORY

Each chapter Contains the necessary study material well supported by Definitions, Facts, Figure, Flow chart, etc.

CHAPTER 1

Force

Force may be defined as an external agency or cause (a push or a pull), which changes or tends to change the state of rest or of uniform motion or the direction of motion of a body.

In mathematical form, it is defined as the rate of change of linear momentum,

i.e., $F = \frac{dp}{dt} = \frac{d(mv)}{dt}$ or $F = ma$

Force is a vector quantity and its SI unit is newton (N) or kilogram-force (kgf), where 1 kgf = gN. If g is the acceleration due to gravity $= 9.8\ \text{ms}^{-2}$.

A force applied on an object can produce four types of effects such as

(i) Force can start a stationary object and can stop a moving object.
(ii) Force can change speed of a moving object making it to move slower or faster.
(iii) Force can change the direction of motion of an object.
(iv) Force can change the shape of an object.

Chapter Objectives
- Rigid Body
- Turning Force
- Torque or Moment of a Force
- Moment of Couple
- Equilibrium of an Object
- Principle of Moment
- Centre of Gravity
- Uniform Circular Motion

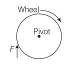
Rigid Body

Every material object is made up of a large number of particles. A rigid body is one whose size and shape remains the same whatever force be applied to different parts of it.

A rigid body has two types of motion

(i) **Translational Motion** When a force is applied on a stationary rigid body, the body starts moving in a straight path in the direction of applied force, this type of motion is called translational motion.
e.g., On pushing a ball lying on a floor it starts moving.

(ii) **Rotational Motion** When a force is applied on fixed point of a body which is pivoted at a point, then body starts rotating about that point. This is called a rotational motion.
e.g., If a wheel is pivoted at its centre and a force is applied tangentially on its rim as shown in figure, the wheel rotates about its centre.



Rotational motion of a wheel

CHECK POINT 01

1. What is the basic difference between pure translational motion and pure rotational motion?
2. A door is hinged at one end and is free to rotate about a vertical axis. Does its weight cause any torque about its axis? Give reason for your answer.
3. The stone of a hand flour grinder is provided with a handle near its rim. Give reason.
4. A faulty balance with unequal arms has its beam horizontal. Are the weights of the two pans equal?
5. What is the principle of moment?

CHECK POINT

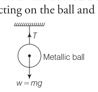
There are intext exercises given between the text material. These exercises have 4-5 questions based on the related concept.

EXAM PRACTICE

a 2 Marks Questions

1. A metallic ball is hanging by a string from a fixed support. Draw a neat labelled diagram showing the forces acting on the ball and the string. *[2014]*

Sol.



where, T is tension in the string and w is weight of the ball, $T = mg$ or $T = w$ *[2]*

2. (i) Define one newton.
(ii) Write the relation between SI unit and CGS unit of force.

Sol. (i) One newton is the amount of force required to produce an acceleration of 1 m/s^2 in a body of mass 1 kg. *[1]*
(ii) *The relation between SI unit and CGS unit of force is*
$1\text{N} = \text{kg} \times 1\ \text{m/s}^2 = 10^3\ \text{g} \times 10^2\ \text{cm/s}^2$
$(\because 1\ \text{kg} = 10^3\ \text{g}, 1\ \text{m} = 10^2\ \text{cm})$
$\therefore\ 1\text{N} = 10^5$ dyne *[1]*

3. (i) Define 1 kgf.
(ii) How is it related to the SI unit of force?

Sol. (i) 1 kgf is the force with which the earth pulls an object of mass 1 kg towards itself. *[1]*
(ii) It is related by, 1 kgf = mg = 9.8 N
$(\because m = 1\ \text{kg}, g = 9.8\ \text{m/s}^2)$ *[1]*

5. Give any two effects of a force on a non-rigid body. *[2013]*

Sol. The two main effects of a force on a non-rigid body are
(i) It can change the state of rest or of motion of the body.
(ii) It can change the size or shape of the body. *[1+1]*

6. In which condition, the following are produced by a force?
(i) Translational motion
(ii) Rotational motion

Sol. The conditions are as follows
(i) **For Translational Motion** When the body is free to move in a straight path. *[1]*
(ii) **For Rotational Motion** When the body is pivoted at a point. *[1]*

7. (i) Give one example of pure rotational motion.
(ii) Comment on the movement of particles on the axis of rotation in pure rotational motion.

Sol. (i) Rotation of a potter's wheel. *[1]*
(ii) The particles on the axis of rotation are stationary in pure rotational motion. *[1]*

8. (i) What is meant by the term moment of force?
(ii) If the moment of force is assigned a negative sign, then will the turning tendency of the force be clockwise or anti-clockwise? *[2012]*

Sol. (i) The turning effect produced by a force on a rigid body about a point, pivot or fulcrum is called the moment of force. *[1]*
(ii) If moment of the force is negative, then turning tendency of the force is clockwise *[1]*

CHAPTER EXERCISE

2 Marks Questions

1. Write an expression to show the relationship between mechanical advantage, velocity ratio and efficiency for a simple machine. *[2007]*

2. Which class of levers has a mechanical advantage always greater than one? What change can be brought about in this lever to increase its mechanical advantage? *[2007]*

3. What is the relationship between the mechanical advantage and the velocity ratio for
(i) ideal machine (ii) practical machine ?

3 Marks Questions

9. Name the type of single pulley that can act as a force multiplier. Draw a labelled diagram of the above named pulley. *[2006]*

10. Draw a labelled sketch of a class II lever. Give one example of such a lever.

4 Marks Questions

14. Draw diagrams to illustrate the positions of fulcrum, load and effort in each of the following.
(i) A common balance (ii) A see-saw
(iii) Forceps (iv) A nut-cracker

15. Define the following.
(i) Machine
(ii) Efficiency

Numerical Based Questions

16. A woman draws water from a well using a fixed pulley. The mass of the bucket and water together is 6.0 kg. The force applied by the woman is 70 N. Calculate the mechanical advantage. (Take, $g = 10\ \text{m/s}^2$) *[2007]*
Ans. 6/7 = 0.857

17. The alongside figure shows the combination of a movable pulley P_1 with a fixed pulley P_2 used for lifting up a load W. *[3]*

EXAM PRACTICE

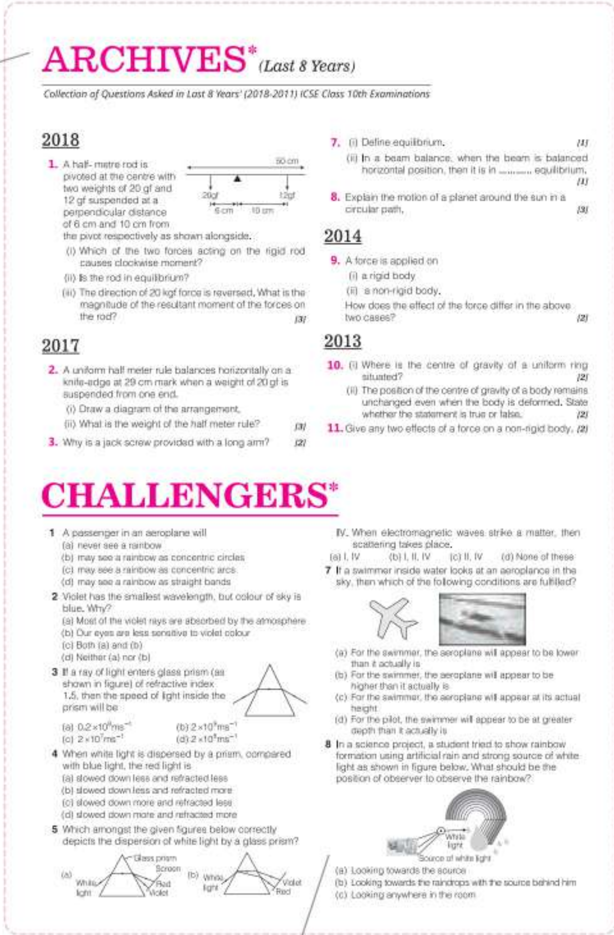
It contains questions in that format in which they are asked in the examinations, *i.e.,* 2 marks questions, 3 marks questions, 4 marks questions and Numerical based questions. All the questions are fully explained.

The explanations given here teach the students, how to write the explanations in the examinations to get full marks. Students can use these questions for practice and assess their understanding & recall of the chapter.

CHAPTER EXERCISE

At the end of the chapter, these unsolved questions are given for assessment of students. By practicing these questions, students can assess their preparation level of the chapter.

for ICSE 10th Examination is a complete book which can give you all; Study, Practice & Assessment. It is hoped that this book will reinforce and extend your ideas about the subject and finally will place you in the ranks of toppers.



ARCHIVES* (Last 8 Years)

Collection of Questions Asked in Last 8 Years' (2018-2011) ICSE Class 10th Examinations

2018

1. A half- metre rod is pivoted at the centre with two weights of 20 gf and 12 gf suspended at a perpendicular distance of 6 cm and 10 cm from the pivot respectively as shown alongside.
   (i) Which of the two forces acting on the rigid rod causes clockwise moment?
   (ii) Is the rod in equilibrium?
   (iii) The direction of 20 kgf force is reversed. What is the magnitude of the resultant moment of the forces on the rod? *[3]*

2017

2. A uniform half meter rule balances horizontally on a knife-edge at 29 cm mark when a weight of 20 gf is suspended from one end.
   (i) Draw a diagram of the arrangement.
   (ii) What is the weight of the half meter rule? *[3]*
3. Why is a jack screw provided with a long arm? *[2]*

7. (i) Define equilibrium. *[1]*
   (ii) In a beam balance, when the beam is balanced horizontal position, then it is in .... equilibrium. *[1]*
8. Explain the motion of a planet around the sun in a circular path. *[3]*

2014

9. A force is applied on
   (i) a rigid body
   (ii) a non-rigid body.
   How does the effect of the force differ in the above two cases? *[2]*

2013

10. (i) Where is the centre of gravity of a uniform ring situated? *[2]*
    (ii) The position of the centre of gravity of a body remains unchanged even when the body is deformed. State whether the statement is true or false. *[2]*
11. Give any two effects of a force on a non-rigid body. *[2]*

CHALLENGERS*

1 A passenger in an aeroplane will
(a) never see a rainbow
(b) may see a rainbow as concentric circles
(c) may see a rainbow as concentric arcs
(d) may see a rainbow as straight bands

2 Violet has the smallest wavelength, but colour of sky is blue. Why?
(a) Most of the violet rays are absorbed by the atmosphere
(b) Our eyes are less sensitive to violet colour
(c) Both (a) and (b)
(d) Neither (a) nor (b)

3 If a ray of light enters glass prism (as shown in figure) of refractive index 1.5, then the speed of light inside the prism will be
(a) $0.2\times10^8 ms^{-1}$ (b) $2\times10^8 ms^{-1}$
(c) $2\times10^7 ms^{-1}$ (d) $2\times10^9 ms^{-1}$

4 When white light is dispersed by a prism, compared with blue light, the red light is
(a) slowed down less and refracted less
(b) slowed down less and refracted more
(c) slowed down more and refracted less
(d) slowed down more and refracted more

5 Which amongst the given figures below correctly depicts the dispersion of white light by a glass prism?

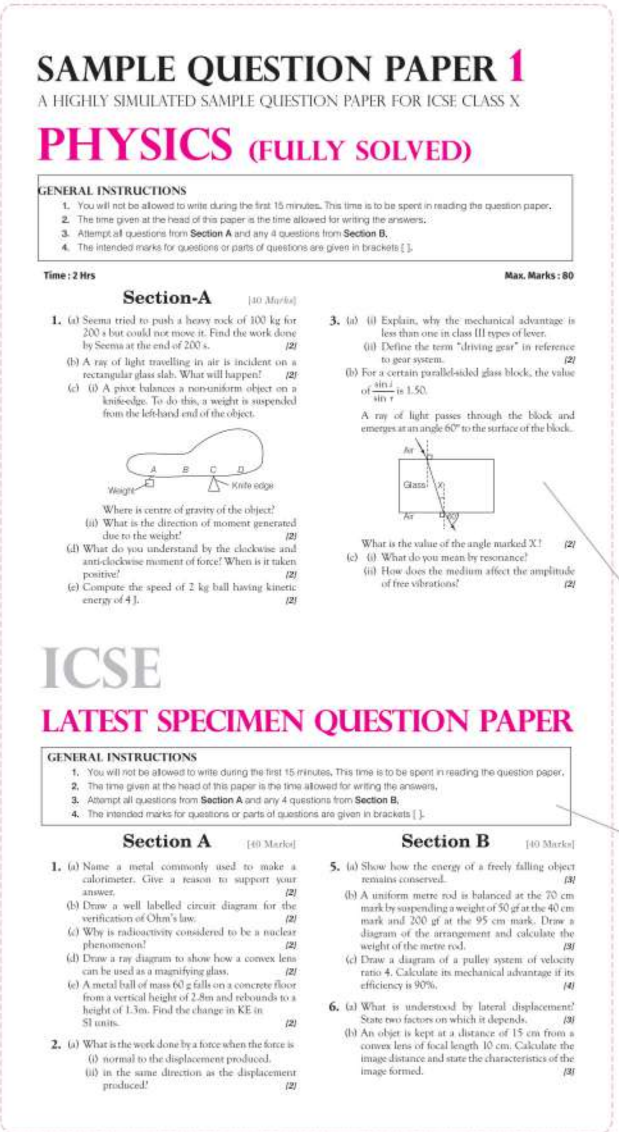
IV. When electromagnetic waves strike a matter, then scattering takes place.
(a) I, IV (b) I, II, IV (c) II, IV (d) None of these

7 If a swimmer inside water looks at an aeroplane in the sky, then which of the following conditions are fulfilled?
(a) For the swimmer, the aeroplane will appear to be lower than it actually is
(b) For the swimmer, the aeroplane will appear to be higher than it actually is
(c) For the swimmer, the aeroplane will appear at its actual height
(d) For the pilot, the swimmer will appear to be at greater depth than it actually is

8 In a science project, a student tried to show rainbow formation using artificial rain and strong source of white light as shown in figure below. What should be the position of observer to observe the rainbow?
(a) Looking towards the source
(b) Looking towards the raindrops with the source behind him
(c) Looking anywhere in the room

ARCHIVES

To have a look on the examination questions, at the end of each chapter, last 8 years' ICSE questions have been compiled, all these questions are completely covered in Exam Practice .



SAMPLE QUESTION PAPER 1

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS X

PHYSICS (FULLY SOLVED)

GENERAL INSTRUCTIONS
1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

Section-A [40 Marks]

1. (a) Seema tried to push a heavy rock of 100 kg for 200 s but could not move it. Find the work done by Seema at the end of 200 s. *[2]*
   (b) A ray of light travelling in air is incident on a rectangular glass slab. What will happen? *[2]*
   (c) (i) A pivot balances a non-uniform object on a knife-edge. To do this, a weight is suspended from the left-hand end of the object.
   Where is centre of gravity of the object?
   (ii) What is the direction of moment generated due to the weight? *[2]*
   (d) What do you understand by the clockwise and anti-clockwise moment of force? When is it taken positive? *[2]*
   (e) Compute the speed of 2 kg ball having kinetic energy of 4 J. *[2]*

3. (a) (i) Explain, why the mechanical advantage is less than one in class III types of lever.
   (ii) Define the term "driving gear" in reference to gear system. *[2]*
   (b) For a certain parallel-sided glass block, the value of $\frac{\sin i}{\sin r}$ is 1.50.
   A ray of light passes through the block and emerges at an angle 60° to the surface of the block.
   What is the value of the angle marked X? *[2]*
   (c) (i) What do you mean by resonance?
   (ii) How does the medium affect the amplitude of free vibrations? *[2]*

ICSE

LATEST SPECIMEN QUESTION PAPER

GENERAL INSTRUCTIONS
1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Section A [40 Marks]

1. (a) Name a metal commonly used to make a calorimeter. Give a reason to support your answer. *[2]*
   (b) Draw a well labelled circuit diagram for the verification of Ohm's law. *[2]*
   (c) Why is radioactivity considered to be a nuclear phenomenon? *[2]*
   (d) Draw a ray diagram to show how a convex lens can be used as a magnifying glass. *[2]*
   (e) A metal ball of mass 60 g falls on a concrete floor from a vertical height of 2.8m and rebounds to a height of 1.3m. Find the change in KE in SI units. *[2]*
2. (a) What is the work done by a force when the force is
   (i) normal to the displacement produced.
   (ii) in the same direction as the displacement produced? *[2]*

Section B [40 Marks]

5. (a) Show how the energy of a freely falling object remains conserved. *[3]*
   (b) A uniform metre rod is balanced at the 70 cm mark by suspending a weight of 50 gf at the 40 cm mark and 200 gf at the 95 cm mark. Draw a diagram of the arrangement and calculate the weight of the metre rod. *[3]*
   (c) Draw a diagram of a pulley system of velocity ratio 4. Calculate its mechanical advantage if its efficiency is 90%. *[4]*
6. (a) What is understood by lateral displacement? State two factors on which it depends. *[3]*
   (b) An object is kept at a distance of 15 cm from a convex lens of focal length 10 cm. Calculate the image distance and state the characteristics of the image formed. *[3]*

CHALLENGERS

It includes some special questions based on the pattern of olympiad and other competitions to give the students a taste of the questions asked in competitions. These are not meant for school examinations.

SAMPLE QUESTION PAPERS and SPECIMEN PAPER

To make the students practice in the real sense, we have provided 5 Sample Question Papers, exactly based on the latest pattern, Latest Specimen Question Paper & Solved Paper.

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- Turning Force
- Torque or Moment of a Force
- Moment of Couple
- Equilibrium of an Object
- Principle of Moment
- Centre of Gravity
- Uniform Circular Motion

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COURSE STRUCTURE

*There will be **one** paper of **two hours** duration carrying 80 marks and Internal Assessment of practical work carrying 20 marks.*

*The paper will be divided into two sections, **Section I** (40 marks) and **Section II** (40 marks).*

***Section I** (compulsory) will contain short answer questions on the entire syllabus.*

***Section II** will contain six questions. Candidates will be required to answer any four of these six questions.*

***Note:** Unless otherwise specified, only S I. Units are to be used while teaching and learning, as well as for answering questions.*

Force, Work, Power and Energy

(i) Turning forces concept; moment of a force; forces in equilibrium; centre of gravity; [discussions using simple examples and simple numerical problems].

Elementary introduction of translational and rotational motions; moment (turning effect) of a force, also called torque and its cgs and SI units; common examples - door, steering wheel, bicycle pedal, etc.; clockwise and anti-clockwise moments; conditions for a body to be in equilibrium (translational and rotational); principle of moment and its verification using a metre rule suspended by two spring balances with slotted weights hanging from it; simple numerical problems; Centre of gravity (qualitative only) with examples of some regular bodies and irregular lamina.

(ii) Uniform circular motion

As an example of constant speed, though acceleration (force) is present. Differences between centrifugal and centripetal force.

(iii) Work, energy, power and their relation with force.

Definition of work. $W = FS \cos\theta$; special cases of $\theta = 0^0$, 90^0. W= mgh. Definition of energy, energy as work done. Various units of work and energy and their relation with SI units.[erg, calorie, kW h and eV]. Definition of Power, P = W/t; SI and cgs units; other units; kilowatt (kW), megawatt (MW) and gigawatt (GW); and horse power (1hp=746W) [Simple numerical problems on work, power and energy].

(iv) Different types of energy (e.g. chemical energy, Mechanical energy, heat energy, electrical energy, nuclear energy, sound energy, light energy).

Mechanical energy: potential energy U = mgh (derivation included) gravitational PE, examples; kinetic energy $K= ½ mv^2$ (derivation included); forms of kinetic energy: translational, rotational and vibrational - only simple examples. [Numerical problems on K and U only in case of translational motion]; qualitative discussions of electrical, chemical, heat, nuclear, light and sound energy, conversion from one form to another; common examples.

(v) Machines as force multipliers; load, effort, mechanical advantage, velocity ratio and efficiency; simple treatment of levers, pulley systems showing the utility of each type of machine.

Functions and uses of simple machines: Terms- effort E, load L, mechanical advantage MA = L/E, velocity ratio VR = VE/VL = dE / dL, input (Wi), output (Wo), efficiency (η), relation between η and MA,VR (derivation included); for all practical machines η <1; MA < VR.

Lever: principle. First, second and third class of levers; examples: MA and VR in each case. Examples of each of these classes of levers as also found in the human body.

Pulley system: single fixed, single movable, block and tackle; MA, VR and η in each case.

(vi) Principle of Conservation of energy.

Statement of the principle of conservation of energy; theoretical verification that U + K = constant for a freely falling body. Application of this law to simple pendulum (qualitative only); [simple numerical problems].

Light

(i) Refraction of light through a glass block and a triangular prism - qualitative treatment of simple applications such as real and apparent depth of objects in water and apparent bending of sticks in water. Applications of refraction of light.

Partial reflection and refraction due to change in medium. Laws of refraction; the effect on speed (V), wavelength (λ) and frequency (f) due to refraction of light; conditions for a light ray to pass undeviated. Values of speed of light (c) in vacuum, air, water and glass; refractive index $\mu = c/V$, $V = f\lambda$. Values of μ for common substances such as water, glass and diamond; experimental verification; refraction through glass block; lateral displacement; multiple images in thick glass plate/mirror; refraction through a glass prism simple applications: real and apparent depth of objects in water; apparent bending of a stick under water. (Simple numerical problems and approximate ray diagrams required).

(ii) Total internal reflection: Critical angle; examples in triangular glass prisms; comparison with reflection from a plane mirror (qualitative only). Applications of total internal reflection.

Transmission of light from a denser medium (glass/water) to a rarer medium (air) at different angles of incidence; critical angle (C) $\mu = 1/\sin C$. Essential conditions for total internal reflection. Total internal reflection in a triangular glass prism; ray diagram, different cases - angles of prism (60°60°60°, (60°30°90°, (45°45°90°; use of right angle prism to obtain $\delta = 90°$ and 180°(ray diagram); comparison of total internal reflection from a prism and reflection from a plane mirror.

(iii) Lenses (converging and diverging) including characteristics of the images formed (using ray diagrams only); magnifying glass; location of images using ray diagrams and thereby determining magnification.

Types of lenses (converging and diverging), convex and concave, action of a lens as a set of prisms; technical terms; centre of curvature, radii of curvature, principal axis, foci, focal plane and focal length,; detailed study of refraction of light in spherical lenses through ray diagrams; formation of images - principal rays or construction rays; location of images from ray diagram for various positions of a small linear object on the principal axis; characteristics of images. Sign convention and direct numerical problems using the lens formula are included.(derivation of formula not required).

Scale drawing or graphical representation of ray diagrams not required.

Power of a lens (concave and convex) – [simple direct numerical problems]: magnifying glass or simple microscope: location of image and magnification from ray diagram only [formula and numerical problems not included]. Applications of lenses.

(iv) Using a triangular prism to produce a visible spectrum from white light; Electromagnetic spectrum. Scattering of light.

Deviation produced by a triangular prism; dependence on colour (wavelength) of light; dispersion and spectrum; electromagnetic spectrum: broad classification (names only arranged in order of increasing wavelength); properties common to all electromagnetic radiations; properties and uses of infrared and ultraviolet radiation. Simple application of scattering of light e.g. blue colour of the sky.

Sound

(i) Reflection of Sound Waves; echoes: their use; simple numerical problems on echoes.

Production of echoes, condition for formation of echoes; simple numerical problems; use of echoes by bats, dolphins, fishermen, medical field. SONAR.

(ii) Natural vibrations, Damped vibrations, Forced vibrations and Resonance - a special case of forced vibrations.

Meaning and simple applications of natural, damped, forced vibrations and resonance.

(iii) Loudness, pitch and quality of sound:

Characteristics of sound: loudness and intensity; subjective and objective nature of these properties; sound level in dB (as unit only); noise pollution; interdependence of: pitch and frequency; quality and waveforms (with examples).

Electricity and Magnetism

(i) Ohm's Law; concepts of emf, potential difference, resistance; resistances in series and parallel, internal resistance.

Concepts of pd (V), current (I), resistance (R) and charge (Q). Ohm's law: statement, V=IR; SI units;

experimental verification; graph of V vs I and resistance from slope; ohmic and non-ohmic resistors, factors affecting resistance (including specific resistance) and internal resistance; super conductors, electromotive force (emf); combination of resistances in series and parallel and derivation of expressions for equivalent resistance. Simple numerical problems using the above relations. [Simple network of resistors].

(ii) Electrical power and energy.

Electrical energy; examples of heater, motor, lamp, loudspeaker, etc. Electrical power; measurement of electrical energy, $W = QV = VIt$ from the definition of pd. Combining with Ohm's law $W = VIt = I^2 Rt = (V^2/R)t$ and electrical power $P = (W/t) = VI = I^2R = V^2/R$. Units: SI and commercial; Power rating of common appliances, household consumption of electric energy; calculation of total energy consumed by electrical appliances; $W = Pt$ (kilowatt $\times$ hour = kW h), [simple numerical problems].

(iii) Household circuits – main circuit; switches; fuses; earthing; safety precautions; three-pin plugs; colour coding of wires.

House wiring (ring system), power distribution; main circuit (3 wires-live, neutral, earth) with fuse / MCB, main switch and its advantages - circuit diagram; twoway switch, staircase wiring, need for earthing, fuse, 3-pin plug and socket; Conventional location of live, neutral and earth points in 3 pin plugs and sockets. Safety precautions, colour coding of wires.

(iv) Magnetic effect of a current (principles only, laws not required); electromagnetic induction (elementary); transformer.

Oersted's experiment on the magnetic effect of electric current; magnetic field (B) and field lines due to current in a straight wire (qualitative only), right hand thumb rule – magnetic field due to a current in a loop; Electromagnets: their uses; comparisons with a permanent magnet; Fleming's Left Hand Rule, the DC electric motor- simple sketch of main parts (coil, magnet, split ring commutators and brushes); brief description and type of energy transfer(working not required): Simple introduction to electromagnetic induction; frequency of AC in house hold supplies , Fleming's Right Hand Rule, AC Generator - Simple sketch of main parts, brief description and type of energy transfer(working not required). Advantage of AC over DC. Transformer- its types, characteristics of primary and secondary coils in each type (simple labelled diagram and its uses).

Heat

(i) Calorimetry: meaning, specific heat capacity; principle of method of mixtures; Numerical Problems on specific heat capacity using heat loss and gain and the method of mixtures.

Heat and its units (calorie, joule), temperature and its units (°C, K); thermal (heat) capacity $C' = Q/\Delta T$... (SI unit of C): Specific heat Capacity $C = Q/m\Delta T$ (SI unit of C) Mutual relation between Heat Capacity and Specific Heat capacity, values of C for some common substances (ice, water and copper). Principle of method of mixtures including mathematical statement. Natural phenomenon involving specific heat. Consequences of high sp. heat of water. [Simple numerical problem].

(ii) Latent heat; loss and gain of heat involving change of state for fusion only.

Change of phase (state); heating curve for water; latent heat; sp latent heat of fusion (SI unit). Simple numerical problems. Common physical phenomena involving latent heat of fusion.

Modern Physics

(i) Radioactivity and changes in the nucleus; background radiation and safety precautions.

Brief introduction (qualitative only) of the nucleus, nuclear structure, atomic number (Z), mass number (A).Radioactivity as spontaneous disintegration. α, β and γ - their nature and properties; changes within the nucleus. One example each of α and β decay with equations showing changes in Z and A. Uses of radioactivity - radio isotopes. Harmful effects. Safety precautions. Background radiation.

Radiation: X-rays; radioactive fallout from nuclear plants and other sources.

Nuclear Energy: working on safe disposal of waste. Safety measures to be strictly reinforced.

(ii) *Nuclear fission and fusion; basic introduction and equations.*

CHAPTER 1

Force

Force may be defined as an external agency or cause (a push or a pull), which changes or tends to change the state of rest or of uniform motion or the direction of motion of a body.

In mathematical form, it is defined as the rate of change of linear momentum,

$$\text{Force, } F \propto \frac{\text{Change in momentum}}{\text{Time}}$$

$$F \propto \frac{p_1 - p_2}{t} \Rightarrow F \propto \frac{m(v-u)}{t} \Rightarrow F \propto ma \qquad \left[\because \frac{v-u}{t} = a\right]$$

$$\therefore \quad F = kma$$

The quantity k is a constant of proportionality. One unit of force is defined as the amount that produce an acceleration of 1 m/s^2 on an object of 1 kg-mass.

i.e. 1 unit of force $= k \times 1\,\text{kg} \times 1\,\text{m/s}^2 \Rightarrow k = 1$

Thus, the force can be written as $\boxed{F = ma}$

SI unit is newton (N) or kilogram-force (kgf), where 1 kgf $= g$N. If g is the acceleration due to gravity $= 9.8\ \text{ms}^{-2}$.

A force applied on an object can produce four types of effects such as

(i) Force can start a stationary object and can stop a moving object.
(ii) Force can change speed of a moving object making it to move slower or faster.
(iii) Force can change the direction of motion of an object.
(iv) Force can change the shape of an object.

Rigid Body

Every material object is made up of a large number of particles. A rigid body is one whose size and shape remains the same whatever force be applied to different parts of it.

A rigid body has two types of motion

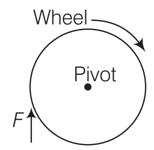
(i) **Translational Motion** When a force is applied on a stationary rigid body, the body starts moving in a straight path in the direction of applied force, this type of motion is called translational motion.

e.g., On pushing a ball lying on a floor it starts moving.

Chapter Objectives

- Rigid Body
- Turning Force
- Torque or Moment of a Force
- Moment of Couple
- Equilibrium of an Object
- Principle of Moment
- Centre of Gravity
- Uniform Circular Motion

(ii) **Rotational Motion** When a force is applied on fixed point of a body which is pivoted at a point, then body starts rotating about that point. This is called a rotational motion. e.g., If a wheel is pivoted at its centre and a force is applied tangentially on its rim as shown in figure, the wheel rotates about its centre.



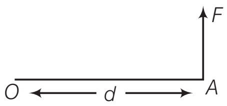
Rotational motion of a wheel

Turning Force

A force which provides rotational effect is called **turning force**. e.g., To open or close a door, we apply a normal force on the handle of the door. A door is a rigid body, which can rotates about a fixed vertical axis passing through the hinges.

Torque or Moment of a Force

The turning effect produced by a force on a rigid body fixed about a point (pivot or fulcrum) is called **moment of a force** or **torque.** Torque is equal to the product of the magnitude of the force and the perpendicular distance of the line of action of force from the axis of rotation. It is represented by τ.



i.e., Torque (moment of force)

= Force $\times$ Perpendicular distance of line of action of force from axis of rotation

$$\boxed{\tau = F \times d}$$

where, d is the perpendicular distance of line of action of force from the axis of rotation (O).

It is a vector quantity. Its SI unit is newton-metre (N-m) and CGS unit is dyne-cm.

But, if force is measured in gravitational unit, then the unit of moment of force in SI system is kgf $\times$ m and in CGS system, the unit is gf $\times$ cm.

These units are related as follows

$$1\,\text{N-m} = 10^7\ \text{dyne-cm}$$

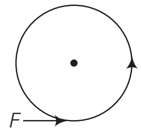
$$1\ \text{kgf} \times \text{m} = 9.8\,\text{N-m}$$

$$1\ \text{gf} \times \text{cm} = 980\,\text{dyne-cm}$$

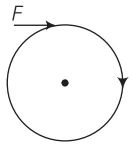
Note
- The torque acting on a body is zero, if F = 0 or d = 0. It may be remembered that internal forces acting on the body do not contribute anything to the torque.
- Torque is maximum when the force is perpendicular to the axis of rotation but the two do not intersect.

Clockwise and Anti-clockwise Moments

The direction of turning (sense of rotation) produced on the body depends on the point of application of force and the direction of force. If the turning effect on the body is anti-clockwise or positive, then the moment of force is called anti-clockwise moment.



Anti-clockwise (positive)



Clockwise (negative)

On the other hand, if the turning effect on the body is clockwise or negative, then the moment of force is called clockwise moment.

Common Examples of Moment of Force

Some common examples of moment of force are given as below

(i) It is easier to open the door by applying force near the outer edge, away from the hinges or axis of rotation.

(ii) For turning a steering wheel, a force is applied tangentially on the rim of the wheel.

(iii) In a bicycle, the toothed wheel is rotated by applying less force on the foot pedal which is at a large distance from the axle of rear wheel.

Example 1. A body is pivoted at a point. A force of 20 N is applied at a distance of 20 cm from the pivot. Find the moment of force about the pivot.

Sol. Given, $F = 20$ N, $d = 20$ cm $= 0.2$ m

$\therefore$ Moment of force $= F \times d = 20 \times 0.2 = 4$ N-m

Example 2. The moment of a force of 10 N about a point X is 4 N-m. Find the distance of point of application of the force from the point X.

Sol. Given, moment of force = 4 N-m, $F = 10$ N

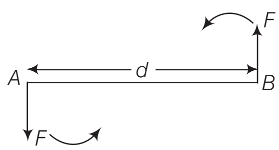
If the distance of point of application of force from the point X is d metre, then

moment of force = force $\times$ distance

$$4 = 10d \Rightarrow d = \frac{4}{10} = \frac{2}{5} = 0.4\,\text{m}$$

Moment of Couple

The pair of equal and opposite forces acting along parallel lines (not on the same line) forms a couple and the moment of couple is defined as the product of either force and the perpendicular distance between the lines of action of forces (or couple arm).



Moment of couple

i.e., Moment of couple

= Either force × Perpendicular distance between the line of action of forces

$= F \times d$

A couple always produces a rotational motion in a rigid body. Its SI unit is also newton-metre (N-m).

Some common examples of moment of couple are

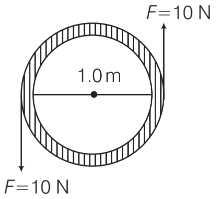
(i) opening a tap

(ii) tightening a screw with a screw driver

(iii) steering of a four wheeler.

Example 3. **A steering wheel of diameter 1 m is rotated anti-clockwise by applying forces each of magnitude 10 N. Draw a diagram to show the application of forces and calculate the moment of the couple applied.**

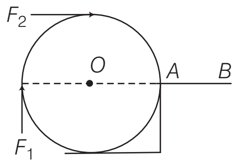
Sol. As the rotation is anti-clockwise, the moments must be anti-clockwise. The direction of the two forces will be as shown in figure. The two forces are forming a couple whose moments are



= One of the force × Arm of the couple

$= 10 \times 1.0 = 10$N-m

Example 4. **In figure, a roller of diameter 0.2 m is raised on the pavement AB by the forces F_1 and F_2 each of magnitude 20 N. Compare the torques produced by the two forces.**



Sol. Given, $F_1 = F_2 = 20\,\text{N}$

Perpendicular distance of point of rotation A from the force F_1 is $d_1 = 0.2\,\text{m}$

while that of force F_2 is $d_2 = \frac{1}{2} \times 0.2\,\text{m} = 0.1\,\text{m}$

$$\therefore \frac{\text{Torque produced by force } F_1}{\text{Torque produced by force } F_2} = \frac{F_1 \times d_1}{F_2 \times d_2} = \frac{20 \times 0.2}{20 \times 0.1} = \frac{2}{1}$$

Equilibrium of an Object

An object is said to be in equilibrium, if a number of forces acting on it produce no change in its state of rest or of uniform motion. Its motion may be rotational or translational.

Types of Equilibrium

There are three types of equilibrium as given below

(i) **Static Equilibrium** A body is said to be in static (or stable) equilibrium, if it has a tendency to return to its original position, after being slightly disturbed from its equilibrium position.
e.g., We consider the beam balance, if the beam is balanced in the horizontal position, the clockwise moment is balanced by anti-clockwise moment and beam has no rotational motion. After disturbing from this balance, the beam will regain its position and hence beam is said to be in static or stable equilibrium.

(ii) **Dynamic Equilibrium** A body is said to be in dynamic (unstable) equilibrium, if it has no tendency to come to its original position after being disturbed from its equilibrium position.
e.g., When a body provided once in motion, then it moves on a smooth surface with a constant velocity and zero acceleration and hence the body is said to be in dynamic or unstable equilibrium.

(iii) **Neutral Equilibrium** A body is said to be in neutral equilibrium, if on being disturbed from its initial position, it stays in equilibrium in new position also.
e.g., When a cone lying on a horizontal surface along a slant height, then it is said that the cone is disturbed from its equilibrium position and it will acquire the equilibrium whenever it is released.

Conditions for Equilibrium

From the above types of equilibrium, we find that the following two conditions must be satisfied for a body to be in equilibrium.

(i) Vector sum of the forces acting on the body should be zero for translational equilibrium.
i.e., $\Sigma F_i = 0$

(ii) Vector sum of moment of forces acting on the body should be zero for rotational equilibrium.
i.e., $\Sigma \tau_i = 0$

Principle of Moment

According to the principle of moment in equilibrium, if different forces act on a body capable to rotate about an axis, but no rotation takes place, then algebraic sum of moments of all the forces is zero.

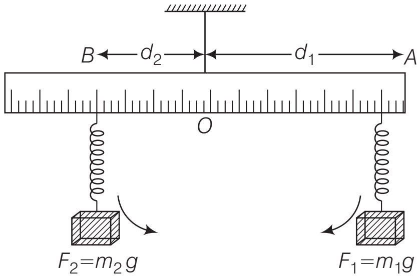
Sum of the anti-clockwise moments

= Sum of the clockwise moments

Note The clockwise torques are taken negative and anti-clockwise torques are taken positive.

Verification of the Principle of Moments

Let us consider a meter rule suspended horizontally from a rigid support by a strong inextensible thread at O. Now, suspend some slotted weights, say $m_1 g$ and $m_2 g$ by two spring balances A and B on either side of the thread, so the meter rule may tilt to one side.



Verification of principle of moments

Now, adjust either the slotted weights on the spring balance or the position of the spring balance on either side of thread in such a way that the meter rule again becomes horizontal.

Let d_1 = distance of weight $m_1 g$ on RHS from O

d_2 = distance of weight $m_2 g$ on LHS from O

$m_1 g \times l_1$ = clockwise moment of first weight about the point O

and $m_2 g \times l_2$ = anti-clockwise moment of second weight about the point O.

Here, first weight tend to turn the meter rule clockwise, while the second weight turn the meter rule anti-clockwise.

In equilibrium, when the meter rule is horizontal, it is found that $m_1 g \times d_1 = m_2 g \times d_2$

or $$f_1 d_1 = f_2 d_2 \quad \left(\because \begin{array}{l} f_1 = m_1 g \\ \text{and } f_2 = m_2 g \end{array}\right)$$

i.e., clockwise moment = anti-clockwise moment

This verifies the principle of moments.

Similarly, **in case of fulcrum** (i.e., level system)

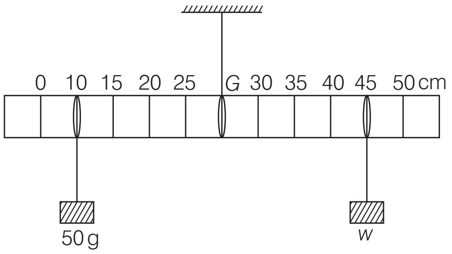
load × load arm = effort × effort arm

i.e., $$f_1 d_2 = f_2 d_2$$

This is called principle of moment of a lever.

Example 5. **A half meter ruler is suspended by a thread from the mid-point of the ruler as shown in the figure. It balances horizontally when a 50 g and an unknown weight was suspended respectively, from 10 cm and the 45 cm mark.**

Calculate the magnitude of weight w.



Sol. Since, the ruler is in equilibrium.

∴ According to the principle of moments,

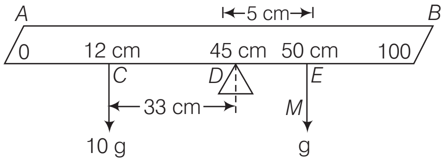
clockwise moment = anti-clockwise moment

$$w \times 20 \text{ cm} = 50 \text{ gf} \times 15 \text{ cm}$$

$$w = \frac{50\text{gf} \times 15 \text{ cm}}{20 \text{ cm}} = 37.5 \text{ gf}$$

Example 6. **A meter scale is balanced on a knife-edge at its centre. 10 g weight is put one on top of the other at the 12 cm mark, the scale is found to be balanced at 45.0 cm. What is the mass of the meter scale?**

Sol. Let total mass of the meter scale be Mg.



Distance between mid-point E and new centre of gravity (DE)

$$= 50 - 45 = 5 \text{ cm}$$

Distance between 12 cm mark and new centre of gravity (CD),

$$= 45 - 12 = 33 \text{ cm}$$

From principle of moments in equilibrium,

$$Mg \times DE = 10 \times CD$$

$$M \times 5 = 10 \times 33$$

or $$M = 66 \text{ g}$$

∴ Mass of the meter scale is 66 g.

CHECK POINT 01

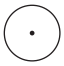
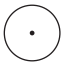
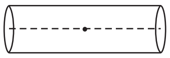
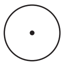
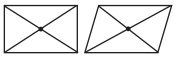
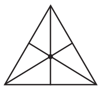
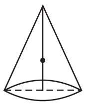
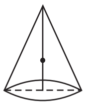
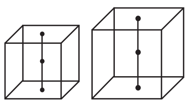
1. What is the basic difference between pure translational motion and pure rotational motion?
2. A door is hinged at one end and is free to rotate about a vertical axis. Does its weight cause any torque about its axis? Give reason for your answer.
3. The stone of a hand flour grinder is provided with a handle near its rim. Give reason.
4. A faulty balance with unequal arms has its beam horizontal. Are the weights of the two pans equal?
5. What is the principle of moment?

Centre of Gravity

Centre of gravity of a rigid body is the point at which its whole weight can be supposed to act. Its position depends upon the distribution of mass of the body. It may be inside or outside the body. If the body is of symmetrical shape whose weight is distributed uniformly, then the centre of gravity of the body lies at its geometrical centre.

e.g., The centre of gravity of a uniform straight wire is at its mid-point. But, if this wire is bent into the form of a circle, then its centre of gravity will be at the centre of circle.

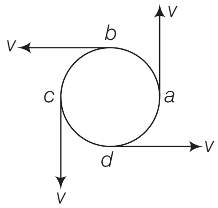
The following table shows the position of centre of gravity of different objects

Object	Figure of the Object	Centre of Gravity
Uniform rod		Mid-point of rod
Circular disc		Geometric centre
Sphere (solid or hollow)		Geometric centre of the sphere
Cylinder		Mid-point on the axis of the cylinder
Circular ring		Centre of the ring
Rectangle parallelogram		The point of intersection of the diagonals
Triangular lamina		The point of intersection of medians (centroid)
Hollow cone		At a height $\left(\frac{h}{3}\right)$ from the base on its axis
Solid cone		At a height $\left(\frac{h}{4}\right)$ from the base on its axis
Cube/Cuboid		At the point of intersection of diagonals

Note Centre of gravity is the point about which the algebraic sum of moment of weights of constituent particles of the body is zero. For the stable equilibrium of a body, its centre of gravity must be as low as possible and it must be above the base and near the geometric centre of the body.

Uniform Circular Motion

When a body moves with a constant speed in a circular path, then its motion is known as **uniform circular motion**. However, the direction of motion of the body changes at every point of the circular path. Due to this continuous change in direction of motion, the velocity is no longer uniform because it direction changes continuously (only magnitude remains same) i.e. the motion is an accelerated motion.

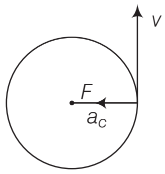


Speed in a circular path

Centripetal Force

The force which keeps a body moving with a uniform speed along a circular path and directed along the radius towards the centre is called centripetal force.

The magnitude of the centripetal force on an object of mass m moving at tangential speed v along a path with radius of curvature r is given by

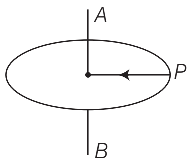


Centripetal force

$$F = ma_c = \frac{mv^2}{r}$$

where, a_c is centripetal acceleration.

The torque of the centripetal force about the axis of rotation AB is zero as it intersects the axis.



Torque of the centripetal force

Centrifugal Force

It is the apparent force that draws a rotating body away from the centre of rotation. It is caused by the inertia of the body as the body's path is continually redirected.

The centrifugal force is in the opposite direction to the direction of centripetal force, but it is not the force of reaction of centripetal force.

CHECK POINT 02

1 Can it be possible that the centre of gravity be situated outside the material of the body?
2 Why is the motion of a circulating fan non-uniform?
3 Draw a neat diagram for a particle moving in a circular path with a constant speed and show the direction of velocity at any instant.
4 Is it possible to have an accelerated motion with a constant speed? Explain.
5 Is centrifugal force, the force of reaction of centripetal force?

SUMMARY

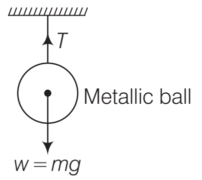
- A push or pull which changes the state of rest or of uniform motion or the direction of motion of a body is called force.
- A force that can rotate an object is called turning force.
- A rigid body is the one whose size and shape remains same whatever force be applied to different parts of it.
- Torque or moment of force is given by
  torque (τ) = force $(F) \times$ perpendicular distance (d)
- Torque is a vector quantity and its SI unit is newton-metre (N-m).
- A pair of equal and opposite forces acting on an object is called couple.
  Moment of couple = Either force × Perpendicular distance between the forces
- Principle of moment is given by
  sum of anti-clockwise moment = sum of clockwise moment
- Centre of gravity of a body is the point at which the algebraic sum of moments of weights of all the particles of the body is zero.
- When a body moves with a constant speed in a circular path, then its motion is known as uniform circular motion.
- The force that maintains the uniform circular motion of an object is called centripetal force and it is directed towards the centre of the circle.
- The apparent force that draws a rotating body away from the centre of rotation is called centrifugal force. It is a pseudo force.

EXAM PRACTICE

a 2 Marks Questions

1. A metallic ball is hanging by a string from a fixed support. Draw a neat labelled diagram showing the forces acting on the ball and the string. ***[2014]***

Sol.



where, T is tension in the string and w is weight of the ball, $T = mg$ or $T = w$ ***[2]***

2. (i) Define one newton.

(ii) Write the relation between SI unit and CGS unit of force.

Sol. (i) One newton is the amount of force required to produce an acceleration of 1 m/s^2 in a body of mass 1 kg. ***[1]***

(ii) *The relation between SI unit and CGS unit of force is*

$$1\,N = kg \times 1\,m/s^2 = 10^3\,g \times 10^3\ cm/s^2$$

$$(\because 1\ kg = 10^3\ g, 1\,m = 10^2 cm)$$

$\therefore\ 1\,N = 10^5$ dyne ***[1]***

3. (i) Define 1 kgf.

(ii) How is it related to the SI unit of force?

Sol. (i) 1 kgf is the force with which the earth pulls an object of mass 1 kg towards itself. ***[1]***

(ii) It is related by, 1 kgf $= mg = 9.8$ N

$$(\because m = 1\,kg,\ g = 9.8\ m/s^2)$$ ***[1]***

4. A force is applied on

(i) a rigid body and

(ii) a non-rigid body.

How does the effect of the force differ in the above two cases? ***[2014]***

Sol. When a force applied on a rigid body does not change the inter-spacing between its constituent particles and therefore it does not change the dimensions of the object, but causes motion in it. ***[1]***

On the other hand, when a force applied on a non-rigid body, it changes the inter-spacing between its constituent particles and therefore causes a change in its dimensions. ***[1]***

5. Give any two effects of a force on a non-rigid body. ***[2013]***

Sol. *The two main effects of a force on a non-rigid body are*

(i) It can change the state of rest or of motion of the body.

(ii) It can change the size or shape of the body. ***[1+1]***

6. In which condition, the following are produced by a force?

(i) Translational motion

(ii) Rotational motion

Sol. *The conditions are as follows*

(i) **For Translational Motion** When the body is free to move in a straight path. ***[1]***

(ii) **For Rotational Motion** When the body is pivoted at a point. ***[1]***

7. (i) Give one example of pure rotational motion.

(ii) Comment on the movement of particles on the axis of rotation in pure rotational motion.

Sol. (i) Rotation of a potter's wheel. ***[1]***

(ii) The particles on the axis of rotation are stationary in pure rotational motion. ***[1]***

8. (i) What is meant by the term moment of force?

(ii) If the moment of force is assigned a negative sign, then will the turning tendency of the force be clockwise or anti-clockwise? ***[2012]***

Sol. (i) The turning effect produced by a force on a rigid body about a point, pivot or fulcrum is called the moment of force. ***[1]***

(ii) If moment of the force is negative, then turning tendency of the force is clockwise. ***[1]***

9. What do you mean by the terms

(i) Static equilibrium and

(ii) Dynamic equilibrium?

Sol. Refer to theory (Page 3).

10. Where does the position of centre of gravity lie for

(i) a circular lamina?

(ii) a triangular lamina?

Sol. (i) The position of centre of gravity for a circular lamina lie at the centre of the circle. ***[1]***

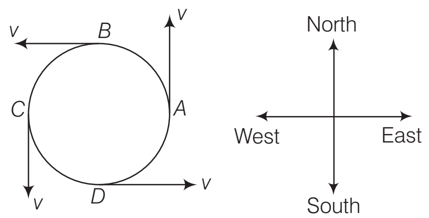
(ii) The position of centre of gravity for a triangular lamina is lie at the centroid or the point of intersection of the medians. ***[1]***

11. (i) On what factor does the position of the centre of gravity of a body depend?
(ii) What is the SI unit of the moment of force?

Sol. (i) The position of centre of gravity of a body depends upon the shape and size of the body. ***[1]***
(ii) The SI unit of moment of force or torque is N-m, i.e., newton-metre. ***[1]***

12. Draw a neat labelled diagram for a particle moving in a circular path with a constant speed. In your diagram, show the direction of velocity at any instant.

Sol. *The labelled diagram for a particle moving in a circular path is shown as below*



Constant speed in circular path ***[2]***

13. Read each statement carefully and state with reasons, if it is true or false.
(i) For a body moving in a circular path with a constant speed, the acceleration is centripetal in nature.
(ii) The net acceleration of a particle in circular motion is always along the radius of the circle towards the centre.

Sol. (i) True, for a body moving in a circular path, the direction of acceleration is perpendicular to the direction of motion at every point. Its acts along the radius of the circle and is directed towards the centre. ***[1]***
(ii) False, because the net acceleration is directed towards the centre only in case of uniform circular motion. ***[1]***

14. (i) For a particle in uniform circular motion, what is the direction of its velocity at any point in its path?
(ii) A stone tied at the end of string is whirled in a circle. If the string breaks, then the stone flies away tangentially. Why?

Sol. (i) Along the tangent to the circle at that point. ***[1]***
(ii) When a stone is going around a circular path, then the instantaneous velocity of stone is along the tangent to the circle.
When the string breaks, then the centripetal force stops to act. Due to inertia, the stone continues to move along the tangent to circular path. So, the stone flies off tangentially to the circular path. ***[1]***

15. (i) Explain the motion of a planet around the sun in a circular path. ***[2015]***
(ii) What is the nature of centripetal force on the planet?

Sol. (i) A planet moves around the sun in a circular path for which the force of attraction on planet by the sun provides the necessary centripetal force. ***[1]***
(ii) The centripetal force on the planet is gravitational which is attractive in nature. ***[1]***

16. Explain the fictitious force and also explain how does it play an important role in a uniform circular motion?

Sol. A force which is not real is called fictitious force. ***[1]***
Centrifugal force is a fictitious force. It is the apparent force that draws a rotating body away from the centre of rotation. ***[1]***

17. Write the differences between centripetal and centrifugal force.

Sol. *Differences between centripetal force and centrifugal force are*

Centripetal Force	Centrifugal Force
A force which acts on an object towards the centre of a circle to produce centripetal acceleration, so that the object moves in a circle is known as centripetal force.	A force which does not act on the object moving in the circle but it is equal and opposite force to centripetal force called centrifugal force.
It is a real force.	It is a fictitious force.

[2]

b 3 Marks Questions

18. What do you meant by clockwise and anti-clockwise moments of force. Explain with the diagram.

Sol. Refer to theory (Page 2).

19. (i) Why does a rope walker hold a long pole in his hands?
(ii) The passengers in a boat are not allowed to stand while crossing a river. Why?
(iii) The screw drivers have long handles. Why?

Sol. (i) The rope walker holds a long pole in his hands to adjust the centre of gravity. When he feels that he is falling towards right, he shifts the pole towards left so that his centre of gravity is not disturbed and he can balance himself. ***[1]***

(ii) This is because, if the passengers stand, then the centre of gravity of the boat is raised. This may cause the boat to overturn as well as producing imbalance. ***[1]***

(iii) Torque = Force × Perpendicular distance = $F \times d$.

If the handle is long, the value is d is more, hence more torque is produced. ***[1]***

20. Explain the following

(i) You always keep your feet wide apart when receiving the charge from an opponent at football.

(ii) It is easier to knock over a person who is standing on one foot than one who is standing on two.

(iii) Why do the wine glasses have a heavy and broad base?

Sol. (i) While receiving the charge from an opponent at football, we keep our feet wide apart to adjust the centre of gravity as low as possible to maintain ourselves in stable equilibrium. Thus, on hitting we do not fall. Similarly, players do the same while playing cock-fighting. ***[1]***

(ii) It is easier to knock over a person who is standing on one foot than one who is standing on both because the person standing on one foot has a smaller base area than the person standing on both the feet. Thus, the person standing on one foot is in a less stable equilibrium and can easily knocked down. ***[1]***

(iii) Wine glass has a broad and heavy base because heavy base lowers its centre of gravity and broad base will adjust the line joining the centre of gravity and centre of the earth fall within the base and keep the glass in stable equilibrium.

Due to similar reason, base of bunsen burner, table lamp, flask and bottle, etc., have a heavy and broad base. ***[1]***

21. (i) Where is the centre of gravity of a uniform ring situated?

(ii) "The position of the centre of gravity of a body remains unchanged even when the body is deformed". State whether the statement is true or false.

Sol. (i) The centre of gravity of a uniform ring is situated at the centre of ring which is not part of the body. i.e., it is outside the body. ***[1½]***

(ii) The statement is false, because it changes its position when the body is deformed. ***[1½]***

22. A very small stone is placed near the periphery of a circular disc which is rotating about an axis passing through its centre.

(i) What will be your observation when you are standing outside the disc? Explain.

(ii) What will be your observation when you are standing at the centre of the disc? Explain.

Sol. (i) When we stand outside the circular disc which is rotating on its axis, then the stone seems to move in a circular path. ***[1½]***

(ii) When we are standing at the centre of disc, then it seems that the stone is moving away from us and falls down. ***[1½]***

C 4 Marks Questions

23. Explain briefly, how can you verify the principle of moment?

Sol. Refer to theory (Page 4).

24. Explain the moment of a force with diagram and formula for

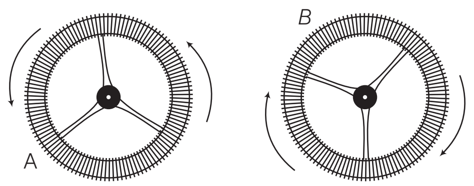
(i) the steering wheel of a car

(ii) the pedal and the rear wheel of a bicycle.

Sol. For turning a steering wheel, a force is applied tangentially on rim of the wheel.

The sense of rotation of wheel is changed by changing the point of application of force without changing the direction of force.

In Fig. (a), when force F is applied at the point A of the wheel, the wheel rotates anti-clockwise; while in Fig. (b), the wheel rotates clockwise when the force F in same direction is applied at the point B of the wheel.

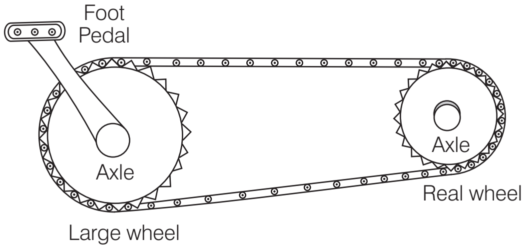


(a) Anti-clockwise rotation (b) Clockwise rotation

[2]

In the case of a bicycle wheel, a small force is applied at the pedal which is at large distance from the axle. Since, in one revolution, the pedal moves through a large distance than the links of the chain. Thus, the applied force gets multiplied and is passed on the rear wheel.

The two pedals provide two such forces and form a torque i.e., moment of force which rotates the wheel.



[2]

25. Draw sketch diagram and indicate the position of the centre of gravity of
 (i) sphere (solid or hollow)
 (ii) triangular lamina
 (iii) parallelogram
 (iv) cylinder

Sol. Refer to table (Page 5).

26. (i) Centre of gravity of a body on the earth coincides with its centre of mass for a small object and for a large object, it may not. What is qualitative meaning of small and large in this regard.
For which of the following two of them coincides, a building, a pond, a lake, a mountain.
 (ii) The bottom of a ship is made heavy. Why?

Sol. (i) Centre of mass and centre of gravity are two different concepts. But, if g does not vary from one part of body to other than CG and CM will coincides.
So, when vertical height of the object is very small compared to radius of earth, we call object small, otherwise we call it extended.
In above context, building and pond are small objects and a deep lake and a mountain are large extended objects. **[2]**

(ii) The bottom of a ship is made heavy, so that its centre of gravity remains low. This ensures the stability of its equilibrium. **[2]**

27. (i) Which of the following remains constant in a uniform circular motion, speed or velocity or both?
 (ii) Name the force required for a uniform circular motion. State its direction.
 (iii) Explain the motion of a planet around the sun in a circular path.

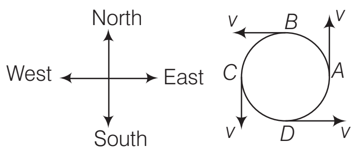
Sol. (i) Speed remains constant in a uniform circular motion. **[1]**

(ii) Centripetal force is required for a uniform circular motion. Centripetal force is always directed towards the centre. **[1]**

(iii) For a planet moving around the sun in a circular path, the gravitational force of attraction between the planet and the sun provides the necessary centripetal force. **[2]**

28. A uniform circular motion is an accelerated motion, explain using diagram.

Sol. A particle is moving in a circular path with uniform speed x in the anti-clockwise direction. The particle travels in each quarter path of the circle AB, BC, CD and DA in same time interval $t = \frac{T}{4}$. Thus, speed of the particle is constant. But the direction of motion of the particle is different at different points on the circular path. **[2]**



Velocity at point A is in North direction, at point B it is in West direction, at C it is in South direction and at point D it is in East direction. As velocity is changing at each point, hence the motion is said to be accelerated. **[2]**

Numerical Based Questions

29. A body of mass 1.5 kg is dropped from second floor of a building which is at a height of 12 m. What is the force acting on it during its fall? (Take, $g = 9.8\ \text{m/s}^2$)

Sol. Given, mass, $m = 1.5$ kg, height, $h = 12$ m

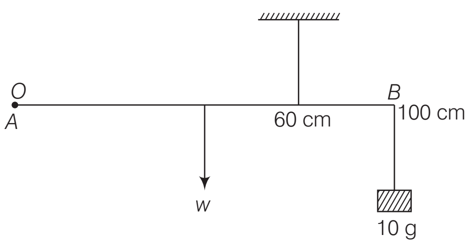
$\therefore$ Force acting on the body during its fall

$$= mg = 1.5 \times 9.8 = 14.7\ \text{N}$$

[2]

30. A uniform meter scale rests horizontally with a hard massless string at the 60 cm mark when a mass of 10 g is suspended from one end. From which end this mass be suspended? What is the mass of the meter scale?

Sol. It is clear from the figure, the weight w of the meter scale acts at the 50 cm mark. The mass of 10 g must be suspended from the other end i.e., from B. **[1]**



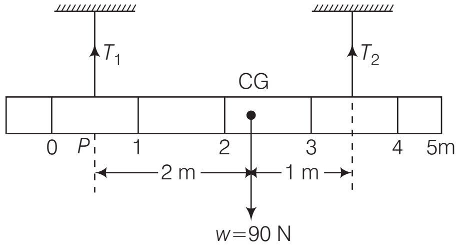
Since, the meter scale is in equilibrium.

$\therefore$ According to the principle of moment,

$$w \times (60-50) = 10 \times (100-60)$$
$$w \times 10 = 10 \times 40$$
$$w = 40 \text{ g}$$ **[1]**

31. A uniform metal rod of 5m in length and weight 90 N is suspended horizontally by two vertical wires attached at 50 cm and 3.5 m respectively, from one end of the rod. Find the tension in each wire.

Sol. Let tension in the wires be T_1 and T_2. As the rod is uniform its weight act as the centre of gravity of the rod i.e., at 25 m from one end. **[1]**



[1]

Now, according to the principle of moment,

sum of upward forces = sum of downward forces

i.e., $T_1 + T_2 = 90\text{ N}$ ...(i)

Taking moment about Q_1,

clockwise moment = anti-clockwise moment

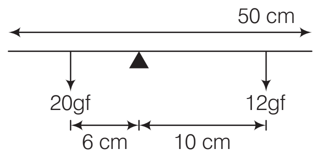
$T_1 \times 2\text{ m} = T_2 \times 1\text{ m}$ ...(ii) **[1]**

On solving Eqs. (i) and (ii), we get

$T_1 = 30\text{ N}$

and $T_2 = 60\text{ N}$ **[1]**

32. A half- metre rod is pivoted at the centre with two weights of 20 gf and 12 gf suspended at a perpendicular distance of 6 cm and 10 cm from the pivot respectively as shown below.



(i) Which of the two forces acting on the rigid rod causes clockwise moment?

(ii) Is the rod in equilibrium?

(iii) The direction of 20 kgf force is reversed. What is the magnitude of the resultant moment of the forces on the rod? **[2018]**

Sol. (i) Force due to 12 gf the rigid rod causes clockwise movement. **[1]**

(ii) Clockwise movement $= 12 \text{ gf} \times 10 \text{ cm}$
$= 120 \text{ gf cm}$

Anti-clockwise movement $= 20 \text{ gf} \times 6 \text{cm}$
$= 120 \text{ gf cm}$

$\therefore$ Clockwise movement = Anti-clockwise movement

Hence, the rod is in equilibrium. **[1]**

(iii) According to question, the direction of 20 gf force is reversed. Hence, the total thing will be move in clockwise direction.

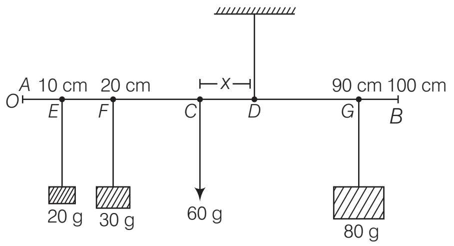
$\therefore$ Clockwise movement
= Resultant movement of force

Resultant movement of force

$= (12 \times 10) + (20 \times 6) = 120 + 120 = 240 \text{ gf cm}$ **[1]**

33. A uniform meter scale of mass 60 g, carrier masses of 20 g, 30 g and 80 g from points 10 cm, 20 cm and 90 cm marks. Where must be the scale hanged with string to balance the scale.

Sol. Let D is the position of tied hanged string, so that the meter scale and various masses are balanced.



Since, the meter scale is balanced.

$\therefore$ Sum of the clockwise moments must be equal to the sum of anti-clockwise moments. **[1]**

Taking moments about D, we get

$$80 \times GD = 20 \times ED + 30 \times FD + 60 \times CD$$

or $80 \times (40 - x) = 20 \times (40 + x) + 30 \times (30 + x)$

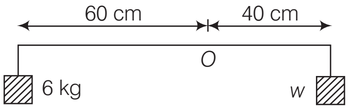
$\Rightarrow$ $3200 - 80x = 800 + 20x + 900 + 30x + 60x$

$\Rightarrow$ $1500 = 190x$

$\Rightarrow$ $x = \dfrac{1500}{190} = 7.9\text{ cm}$ **[2]**

Hence, the string must be tied at $50 + 7.9 = 57.9$ cm to maintain balance of meter scale. **[1]**

34. A meter scale is balanced in horizontal position as shown in figure given below. Find the value of w.



Sol. Given, load, $F_1 = 6$ kg

Load arm, $d_1 = 60$ cm

Effort, $F_2 = w$

Effort arm, $d_2 = 40$ cm **[1]**

According to the principle of moments in equilibrium,

$$F_1 d_1 = F_2 d_2$$

$$\Rightarrow \quad 6 \times 60 = w \times 40 \Rightarrow w = \frac{6 \times 60}{40} = 9 \text{ kg}$$ **[1]**

35. A man can open a nut by applying a force of 150 N by using a lever handle of length 0.4 m. What should be the length of the handle, if he is able to open it by applying a force of 60 N?

Sol. Given, load, $F_1 = 150$ N, load arm, $d_1 = 0.4$ m

Effort, $F_2 = 60$ N, effort arm, $d_2 = ?$

By principle of moments,

$$F_1 \times d_1 = F_2 \times d_2$$ **[1]**

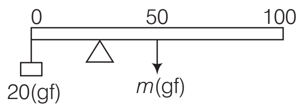
$$\Rightarrow \quad d_2 = \frac{F_1 \times d_1}{F_2} = \frac{150 \times 0.4}{60} = 1 \text{ m}$$ **[1]**

36. A uniform half meter rule balances horizontally on a knife-edge at 29 cm mark when a weight of 20 gf is suspended from one end.

(i) Draw a diagram of the arrangement.

(ii) What is the weight of the half meter rule? ***(2017)***

Sol. (i) *Diagram of the arrangement is shown below*



[1½]

(ii) $20(29 - 0) = m(50 - 29)$ ($\because$ principle of moments)

$$\Rightarrow \quad m = 27.6 \text{ gf}$$ **[1½]**

37. A boy of mass 30 kg is sitting at a distance of 2 m from the middle of a see-saw. Where should a boy of mass 40 kg sit, so as to balance the see-saw? ***[2012]***

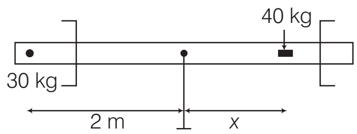
Sol. Let the distance of boy of mass 40 kg from the mean position be x metre. Using principle of moments,

load $\times$ load arm = effort $\times$ effort arm **[1]**

$$30 \times 2 = 40 \times x$$

$$\Rightarrow \quad x = 1.5 \text{ m}$$

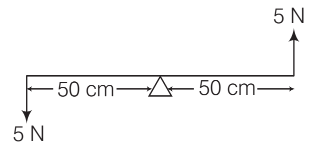
So, the boy of mass 40 kg should sit at a distance 1.5 m from the middle of see-saw



[1]

38. Two forces each of 5 N act vertically upwards and downwards, respectively. On the two ends of a uniform meter rule which is placed at its mid-point as shown in the diagram.

Determine the magnitude of the resultant moment of these forces about the mid-point.



Sol. Given, forces, $F_1 = F_2 = 5$ N **[1]**

Distances, $d_1 = d_2 = 50$ cm $= 0.5$ m

Resultant moment = torque, $\tau = ?$ **[1]**

$\therefore \quad \tau_1 = F_1 \times d_1 = 5 \times 0.5 = 2.5$ N-m

and $\quad \tau_2 = F_2 \times d_2 = 5 \times 0.5 = 2.5$ N-m

$\therefore$ Resultant moment,

$$\tau = \tau_1 + \tau_2 = 2.5 + 2.5 = 5 \text{ N-m}$$ **[1]**

39. Figure shows a uniform meter rule weighing 100 gf pivoted at its centre O. Two weights 150 gf and 250 gf hang from the meter rod as shown in the figure.

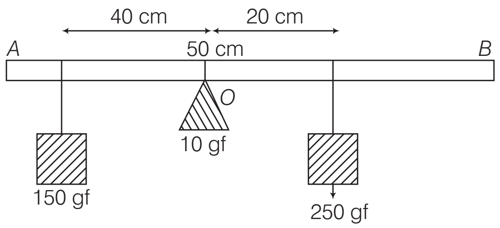
Calculate

(i) the total anti-clockwise moments about O.

(ii) the total clockwise moments about O.

(iii) the difference of anti-clockwise and clockwise moments about O.

(iv) the distance O, where a 100 gf weight should be placed to balanced the meter rule.



Sol. According to the figure, given in question, we get

(i) The moments of the weight of 150 gf

$$= 150 \text{ gf} \times 40 \text{ cm} = 6000 \text{ gfcm}$$ **[1]**

(ii) The moments of the weight of 250 gf

$$= -250 \times 20 = -5000 \text{ gfcm i.e., clockwise}$$ **[1]**

(iii) The difference of moments $= 6000$ gfcm

$$-5000 \text{ gfcm} = 1000 \text{ gfcm}$$ **[1]**

(iv) To balance these 1000 gfcm anti-clockwise moments, 100 gf weight must be at a distance

$$x = \frac{1000 \text{ gfcm}}{100 \text{ gf}} = 10 \text{ cm on the right side of } O.$$ **[1]**

40. A car is of weight 1800 kg. The distance between its front and back axles is 1.8 m. Its centre of gravity is 1.05 m behind the front axle. Determine the force exerted by the level ground on each front wheel and each back wheel.

Sol. Total mass of the car $= 1800$ kg

Let m and $(900 - m)$ kg be the masses of each front wheel and each back wheel, respectively.

Distance of centre of gravity from the front axle $= 1.05$ m

$\therefore$ Distance of centre of gravity from the back axle

$$= 1.80 - 1.05 = 0.75 \text{ m}$$ **[1]**

Taking torque about centre of gravity,

$$m \times 1.05 = (900 - m) \times 0.75$$

or $\quad 1.05\, m + 0.75\, m = 900 \times 0.75$

or $\quad 1.80\, m = 900 \times 0.75$

or $\quad m = \dfrac{900 \times 0.75}{1.80} = 375$ kg

$\therefore \quad (900 - m) = 900 - 375 = 525$ kg **[1]**

$\therefore$ Weight of each front wheel $(w_1) = m_1 g$

$= 375 \times 9.8$

$= 3675$ N **[1]**

Force exerted by the level ground on each front wheel = Force exerted by each front wheel on the level ground $(w_1) = 3675$ N

Weight of each back wheel $(w_2) = m_2 g$

$$w_2 = 525 \times 9.8 = 5145 \text{ N}$$

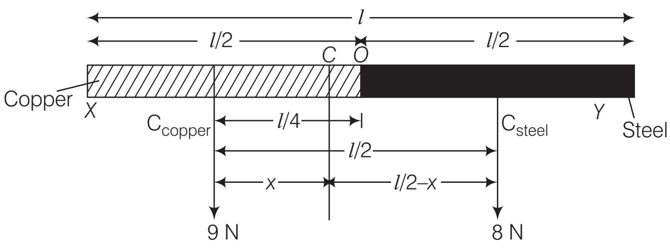
$\therefore$ Force exerted by the level ground on each back wheel = Force exerted by each back wheel on level ground (w_2)

$= 5145$ N **[1]**

41. In a meter rod, half of it is made of copper and rest half of steel. Weights of copper and steel are 9 N and 8 N, respectively. Is the centre of gravity of the rod at its geometric centre? If not, where is it?

Sol. Since, the rod is not uniform, half portion of the rod is made up of copper is heavier.

So, its centre of gravity is not at the geometrical centre. **[1]**



Let l is the length of rod XY, and C_{copper} and C_{steel} be the centre of gravity of copper and steel part, respectively. If C is the centre of gravity of the combination, then by making moment about C

$$9 \times x = 8 \times \left(\frac{l}{2} - x\right)$$

$$\Rightarrow \quad 9x = 8 \times \frac{l}{2} - 8x \quad \Rightarrow 17x = 4l$$

$$\therefore \quad x = \frac{4}{17} l \quad \text{and} \quad OC = \frac{l}{4} - \frac{4}{17} l = \frac{1}{68} l$$

Hence, the centre of gravity of the combined rod is at point C at a distance of $\frac{1}{68} l$ from the geometrical centre O of the rod towards the copper half. **[3]**

CHAPTER EXERCISE

2 Marks Questions

1. Give any two effects of a force on a rigid body.

2. (i) What do you understand by negative and positive moments of a force?
(ii) If the moment of force is assigned a positive sign, then will the turning tendency of the force be clockwise or anti-clockwise?

3. A body is acted upon by two forces each of magnitude F but in opposite directions. State the effect of the force, if
(i) the two forces act at two different points of the body at a separation.
(ii) both forces act at the same point of the body.

4. (i) When a knife is sharpened with the help of a rotating grinding stone, then the spark always travel tangentially to it, why?
(ii) Can a body move on a curved path without having acceleration?

5. (i) Justify that a uniform circular motion is an accelerated motion.
(ii) A women rides in a carnival ferris wheel. What is the direction of her centripetal acceleration at the lowest point?

3 Marks Questions

6. What is uniform circular motion? Draw a diagram to explain it.

7. With reference to their direction of action, how does a centripetal force differ from a centrifugal force? ***[2013]***

4 Marks Questions

8. Define couple, prove that

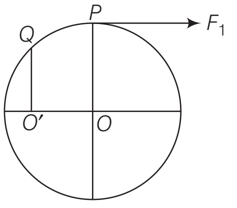
moment of couple = force × couple arm.

9. How an object is said to be in equilibrium. Explain the types of equilibrium.

Numerical Based Questions

10. Two forces each of magnitude 20 N acting at the point A and B at a separation of 100 cm, in opposite directions, calculate the resultant moment of two forces about the point (i) A (ii) B and (iii) O, situated exactly at the middle of the two forces.
(i) 2 N-m (clockwise) (ii) 2 N-m (clockwise)
(iii) 2 N-m (clockwise) ***Ans.*** 20 N-m

11. In the given diagram, wheel shown has a fixed axle passing through O. The wheel is kept stationary under the action of two forces F_1 and F_2 such that (i) a horizontal force F_1 at P and diagram (ii) a vertical force F_2 at Q. Show that the direction of F_2 in the diagram. Which is the greater force? Find the ratio between the forces.



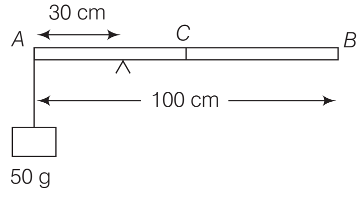
(Given, $PO = 2.5$ cm, $OQ' = 1.5$ cm and $OO' = 2.0$ cm)

Ans. $\frac{F_2}{F_1} = \frac{4}{5}$

12. A uniform half meter rule is suspended from its mid-point. A weight of 50 gf is suspended at one end of it. Where should a weight of 100 gf be suspended to keep the rule horizontal.
Ans. At distance 25 cm from the other end

13. A uniform meter scale balances horizontally with a string attached at 55 cm mark when a mass of 25 g is suspended from one end. Draw a diagram of this arrangement. Calculate the mass of the scale.
Ans. 225 gf

14. A one meter scale AB is balanced horizontally across a knife-edge as shown in the figure.



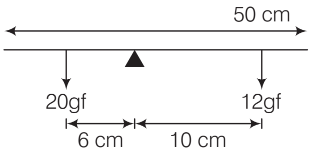
Calculate
(i) the mass of the scale,
(ii) the force on the knife-edge and
Ans. (i) 75 g, (ii) 125 g

ARCHIVES* *(Last 8 Years)*

Collection of Questions Asked in Last 8 Years' (2018-2011) ICSE Class 10th Examinations

2018

1. A half- metre rod is pivoted at the centre with two weights of 20 gf and 12 gf suspended at a perpendicular distance of 6 cm and 10 cm from the pivot respectively as shown alongside.



(i) Which of the two forces acting on the rigid rod causes clockwise moment?

(ii) Is the rod in equilibrium?

(iii) The direction of 20 kgf force is reversed. What is the magnitude of the resultant moment of the forces on the rod? ***[3]***

2017

2. A uniform half meter rule balances horizontally on a knife-edge at 29 cm mark when a weight of 20 gf is suspended from one end.

(i) Draw a diagram of the arrangement.

(ii) What is the weight of the half meter rule? ***[3]***

3. Why is a jack screw provided with a long arm? ***[2]***

4. How does uniform circular motion differ from uniform linear motion? ***[1]***

2016

5. A stone of mass *m* is rotated in a circular path with a uniform speed by tying a strong string with the help of your hand. Answer the following question.

(i) Is the stone moving with a uniform or variable speed? ***[1]***

(ii) Is the stone moving with a uniform acceleration? In which direction does the acceleration act? ***[1]***

(iii) What kind of force acts on the hand and state its direction? ***[1]***

2015

6. Name the factors affecting the turning effect of a body. ***[2]***

7. (i) Define equilibrium. ***[1]***

(ii) In a beam balance, when the beam is balanced horizontal position, then it is in .... equilibrium. ***[1]***

8. Explain the motion of a planet around the sun in a circular path. ***[3]***

2014

9. A force is applied on

(i) a rigid body

(ii) a non-rigid body.

How does the effect of the force differ in the above two cases? ***[2]***

2013

10. (i) Where is the centre of gravity of a uniform ring situated? ***[2]***

(ii) The position of the centre of gravity of a body remains unchanged even when the body is deformed. State whether the statement is true or false. ***[2]***

11. Give any two effects of a force on a non-rigid body. ***[2]***

2012

12. A boy of mass 30 kg is sitting at a distance of 2 m from the middle of a see-saw. Where should a boy of mass 40 kg sit so as to balance the see-saw? ***[2]***

13. (i) What is meant by the term moment of force?

(ii) If the moment of force is assigned a negative sign, then will the turning tendency of the force be clockwise or anti-clockwise? ***[2]***

2011

14. A man can open a nut by applying a force of 150 N by using a lever handle of length 0.4 m. What should be the length of the handle, if he is able to open it by applying a force of 60 N? ***[2]***

15. Where does a position of centre of gravity lie for

(i) a circular lamina?

(ii) a triangular lamina? ***[2]***

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 A particle of mass m is executing a uniform circular motion on a path of radius r. If p is the magnitude of its linear momentum, then what is the radial force acting on the particle?

(a) $\frac{p^2}{mr}$ (b) $\frac{r}{p}$ (c) $\frac{r_m}{p^2}$ (d) $\frac{p}{m}$

2 When a car of mass M passes through a convex bridge of radius r with velocity v, then it exerts a force on it. What is the magnitude of the force?

(a) Mg (b) $Mg + \frac{Mv^2}{r}$ (c) $\frac{Mv^2}{r}$ (d) $Mg - \frac{Mv^2}{r}$

3 What type of motions are exhibited by a vehicle and its wheels?

(a) Translatory (b) Translatory and rotatory
(c) Rotatory (d) None of these

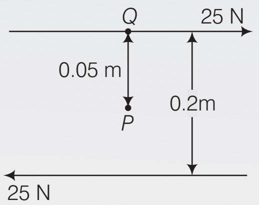
4 A mechanic can open a nut by applying 120 N force while using a lever of 50 cm length. How long should the handle be, if he wishes to open, it by applying a force of only 40N?

(a) 1 m (b) 2 m (c) 1.5 m (d) 2.5 m

5 The gate of a building is 3 m broad. It can be opened by applying 100 N force at the middle of the gate. Calculate the least force required to open this gate, (at a point 6m)

(a) 10 N (b) 30 N (c) 20 N (d) 50 N

6 From the given figure, calculate moment of force about (i) P and (ii) Q.



(a) 5 N-m clockwise, 10 N-m anti-clockwise (b) 10 N-m clockwise, 10 N-m anti-clockwise
(c) 5 N-m clockwise, 5 N-m clockwise (d) 10 N-m clockwise, 5 N-m anti-clockwise

7 Force in linear motion has its analogue in rotational motion?

(a) Moment of inertia (b) Torque
(c) Angular momentum (d) Weight

8 Two particles of equal masses are revolving in circular paths of radii r_1 and r_2 respectively, with the same speed. The ratio of their centripetal forces is

(a) $\frac{r_2}{r_1}$ (b) $\left(\frac{r_1}{r_2}\right)^2$ (c) $\sqrt{\frac{r_2}{r_1}}$ (d) $(r_2 / r_1)^2$

9 Essential characteristic of equilibrium is

(a) momentum equals to zero (b) acceleration equals to zero
(c) KE equals to zero (d) velocity equals to zero

10 The length of seconds hand of a clock is 10 cm. The angular speed of the tip of the hand is

(a) $\frac{\pi}{3}$ rad s^{-1} (b) $\frac{\pi}{30}$ rad s^{-1} (c) $\frac{\pi}{300}$ rad s^{-1} (d) $\frac{\pi}{3000}$ rad s^{-1}

Answers

1. (a) **2.** (d) **3.** (b) **4.** (c) **5.** (d) **6.** (c) **7.** (b) **8.** (a) **9.** (b) **10.** (b)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 237.

CHAPTER

2

Work, Power and Energy

In our daily life, we generally use the terms work, energy and power. Work is done by a force, when the force produces a displacement in the body on which it acts, in any direction other than the direction perpendicular to the applied force.

Work and energy both are equivalent to each other. In physics, energy is the **capacity** to do work. The power is the rate of work done, the machine or men who does more work in lesser time has more power. The aim of this chapter is to understand the concepts of these three physical quantities, i.e., **work, power** and **energy.**

Chapter Objectives

- Work
- Power: Rate of Doing Work
- Energy
- Mechanical Energy
- Potential Energy
- Transformation of Energy
- Principle of Conservation of Energy

Work

Work is said to be done, if on applying a force on an object, it is displaced from its position in direction of force.

After spending lot of time in studies, reading books, drawing diagrams, attending classes, performing experiments, you may get completely exhausted, but have not done any work in terms of science as there is no displacement.

Scientific Conception of Work

From the point of view of science, following two conditions need to be satisfied for work to be done

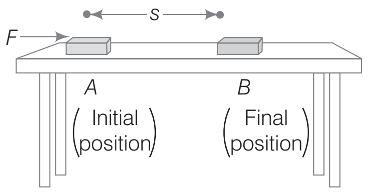
(i) a force should act on an object (ii) the object must be displaced.

If any one of the above conditions does not exist, work is not said to be done.

e.g., A girl pulls a trolley and the trolley moves through a distance. In this way, she has exerted a force on the trolley and as a result it is displaced. Hence, work is said to be done.

Work Done by a Constant Force

"Work done by a force on an object is equal to the magnitude of the force multiplied by the displacement moved in the any direction of applied force."



Work done by a force when the body moves in the direction of force

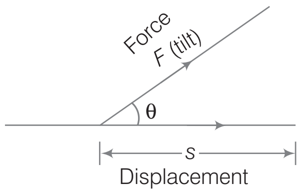
Let us assume, if a constant force F acts on an object at point A (shown in the figure), due to which the object gets displaced through a distance s in the direction of the force and reach at point B, then the work done (W) by force (F) on that object will be equal to the product of the force and displacement.

$\therefore$ Work done = force × displacement in the direction of force

or $\boxed{W = F \times s}$ ...(i)

When force F on an object acts in such a direction that it makes an angle θ with the direction of displacement s, then the work done by the force is

$$\boxed{W = Fs\cos\theta}$$



Angle subtended between the direction of force and the direction of displacement

SI Unit of Work

In Eq. (i), if $F = 1$ N and $s = 1$ m, then the work done by the force will be 1 N-m.

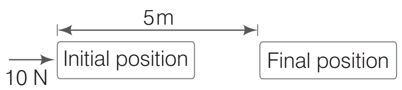
The SI unit of work is **newton-metre** (N-m) or **joule** (J)**.**

Thus, **1 J is the amount of work done on an object when a force of 1 N displaces it by 1 m along the line of action of the force.**

$$\boxed{1\text{ joule} = 1\text{ newton} \times 1\text{ metre} \Rightarrow 1\text{ J} = 1\text{N-m}}$$

Work is a scalar quantity, it has only magnitude and no direction.

Example 1. A force of 10 N is acting on an object. The object is displaced through 5 m in the direction of force. What is the work done in this case?



Sol. Given, force, $F = 10$N, displacement, $s = 5$m

$\therefore$ Work done, $W = F \times s = 10\text{ N} \times 5\text{m} = 50\text{ N-m or }50\text{J}$

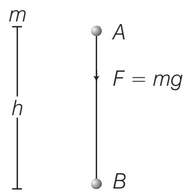
Positive, Negative and Zero Work

When the force F and displacement s are in the same directions (i.e., angle between direction of force and displacement is 0°), work done is said to be **positive**.

e.g., A boy pulls an object towards himself. Here, the direction of force and direction of displacement are same.

$$\boxed{W = +F \times s}$$

Similarly, in free fall of a body of mass m under gravity through a height h from A to B, then the force of gravity ($F = mg$) is in the direction of displacement ($s = h$), then the work done by the force of gravity is $W = Fs = mgh$.



When the force F and displacement s are in opposite directions (i.e., angle between direction of force and displacement is 180°), work done is said to be **negative**.

e.g., Frictional force acts in the direction opposite to the direction of displacement, so work done by friction will be negative.

$$\boxed{W = -F \times s}$$

When the force and displacement are in perpendicular directions (i.e., angle between direction of force and displacement is 90°), work done is said to be **zero.**

e.g., A coolie carrying load on his head. In this case, force is acting vertically downward (i.e., weight of load) and displacement is along horizontal direction, i.e., force and displacement are perpendicular to each other.

$$\boxed{W = 0}$$

Absolute Units of Work

Work done is said to be one absolute unit if an absolute unit of force displaces a body through a unit distance in the direction of the force.

(i) **Joule** It is an absolute unit of work in SI system, named after British physicist James Prescott Joule (1811-1869).

One joule of work is said to be done when a force of one newton displaces a body through a distance of one metre in its own direction.

From work done (W) = $Fs\cos\theta$,

$$1\text{ J} = 1\text{ N} \times 1\text{ m} \times \cos 0° = 1\text{ N-m}$$

(ii) **Erg** It is an absolute unit of work in CGS system. One erg of work is said to be done if a force of one dyne displaces a body through a distance of one centimetre in its own direction.

From work done (W) = $Fs\cos\theta$

$$1\text{ erg} = 1\text{ dyne} \times 1\text{ cm} \times \cos 0° = 1\text{ dyne-cm}$$

Relation between Joule and Erg

$$1\text{ J} = 1\text{ N} \times 1\text{ m}$$
$$= 10^5\text{dyne} \times 10^2\text{ cm}$$
$$= 10^7\text{ dyne-cm}$$
$$1\text{ J} = 10^7\text{ erg}$$

Gravitational Units of Work

Work done is said to be one gravitational unit if a gravitational unit of force displaces a body through a unit distance in the direction of the force.

(i) **Kilogram-metre** (kg-m) It is the gravitational unit of work in SI system. One kilogram-metre of work is said to be done when a force of a one kilogram weight displaces a body through a distance of one metre in its own direction.

We know, work done $(W) = Fs\cos\theta$

$1 \text{ kg-m} = 1 \text{ kgf} \times 1 \text{ m} \times \cos 0° = 9.8 \text{ N} \times 1 \text{ m} \times 1 = 9.8 \text{ J}$

i.e., 1 kg-m = 9.8 J

(ii) **Gram-centimetre** (g-cm) It is the gravitational unit of work in CGS system. One gram-centimetre of work is said to be done when a force of one gram weight displaces a body through one centimetre in its own direction.

$\therefore \quad 1 \text{ g-cm} = 1 \text{ g-wt} \times 1 \text{cm} = 980 \text{ dyne} \times 1 \text{ cm}$

or $\quad 1 \text{ g-cm} = 980 \text{ erg}$

Larger Units of Work

There are some larger units of work, which are very important to be remembered.

They are as follows

1 kilojoule (kJ) $= 10^3$ J ; 1 Megajoule (MJ) $= 10^6$ J ;

1 Gigajoule (GJ) $= 10^9$ J

Example 1. **A lawn roller has been pushed by a gardener through a distance of 30 m. What will be the work done by him if he applies a force of 30 kg-wt in the direction inclined at 60° to the ground? (Take, $g = 10 \text{ m/s}^2$).**

Sol. Displacement, $s = 30$ m

Force, $F = 30 \text{ kg-wt} = 30 \times 10 = 300 \text{ N}$

$\theta = 60°$

The work done by the gardener,

$$W = \mathbf{F} \cdot \mathbf{s} = Fs\cos\theta = 300 \times 30 \times \cos 60° = 300 \times 30 \times \frac{1}{2}$$

$$= 4500 \text{ J} \qquad \left(\because \cos 60° = \frac{1}{2}\right)$$

Example 2. **A person is holding a bag by applying a force of 15 N. He moves forward and covers the horizontal distance of 8 m and then he climbs up and covers the vertical distance of 10 m. What will be the work done by him?**

Sol. The net work done by the person is the sum of work done to cover the horizontal distance and the work done to climb up in the vertical distance.

$F = 15 \text{ N}, s_1 = 8 \text{ m and } s_2 = 10 \text{ m}$

As person is walking horizontally, therefore the angle between the bag and distance covered is 90°.

Thus, $\theta = 90°$

The work done, $W_1 = Fs_1 \cos\theta = 15 \times 8 \cos 90° = 0$ J

Now, the person climbs up and covers the distance of 10 m vertically. Therefore, the angle between the bag and the vertical plane is 0°.

Thus, $\theta = 0°$

The work done, $W_2 = Fs_2 \cos\theta = 15 \times 10 \times \cos 0° = 150$ J

The net work done by him, $W = W_1 + W_2 = 0 + 150 = 150$ J

Example 3. **A cyclist comes to a skidding stop in 10 m. During this process, the force on the cycle due to the road is 200 N and is directly opposed to the motion.**

(i) How much work does the road do on the cycle?

(ii) How much work does the cycle do on the road?

Sol. (i) The stopping force and the displacement make an angle of 180° with each other. Thus, work done by the road or the work done by the stopping force is

$$W_r = Fs\cos\theta = 200 \times 10 \times \cos 180° = -2000 \text{ J}$$

It is thus negative work that brings the cycle to a halt.

(ii) According to Newton's third law, an equal and opposite force acts on the road due to the cycle. Its magnitude is 200 N. However, the road undergoes no displacement. So, work done by the cycle on the road is zero.

CHECK POINT 01

1. State whether the work done by an applied force on a body moving on through horizontal plane with uniform velocity is positive or negative.
2. What should be the angle between force and displacement to get the work (i) maximum (ii) minimum?
3. A coolie carrying a load on his head and moving on a frictionless horizontal platform does no work. Explain the reason, why?
4. A person continues to push a rock for sometimes but fails to move it. What is the work done by it?
5. What is the work done when you apply a 10 N force on a wall? ***Ans.*** zero
6. If a 5 kg mass is raised to a height of 2 m, calculate the work done against the force of gravity. (Take, $g = 9.8 \text{ ms}^{-2}$) ***Ans.*** 98 J

Power: Rate of Doing Work

The rate of doing work or the rate at which energy is transferred or used or transformed to other form is called **power.**

If work W is done in time t, then

$$\text{Power, } P = \frac{\text{Work}}{\text{Time}} \Rightarrow \boxed{P = \frac{W}{t}}$$

The SI unit of power is **watt** in honour of James Watt having the symbol W. i.e., $1 \text{ W} = 1 \text{ Js}^{-1}$

Other Units of Power

Apart form the units of power in SI and CGS systems, there are some of its major units which are required to be discussed.

1 kilo Watt (kW) $= 10^3$ W

1 Mega Watt (MW) $= 10^6$ W

1 Giga Watt (GW) $= 10^9$ W

1 Horse Power (HP) = 746 W $\simeq$ 750 W.

Average Power

Average power is defined as the ratio of total work done by the total time taken. A power or machine may perform work at different rates at different intervals of time. In such situation, average power is considered by dividing the total energy consumed by the total time taken.

$$\therefore \quad \boxed{\text{Average power} = \frac{\text{Total energy consumed}}{\text{Total time taken}}}$$

Example 4. Calculate the power of an electric engine which can lift 20 tonne of coal per hour from a mine 180 m depth.

Sol. Given, $m = 20$ tonne

or $m = 20 \times 1000 = 20000$ kg $\quad (\because 1 \text{ tonne} = 1000 \text{ kg})$

$h = 180$ m

$t = 1\text{h} = 3600$s

$g = 9.8$ m/s^2

We know that, power $(P) = \dfrac{\text{Work } (W)}{\text{Time } (t)} = \dfrac{mgh}{t}$

$$= \frac{20000 \times 9.8 \times 180}{3600}$$

$\Rightarrow \quad P = 9800$ W

Example 5. A car of mass 2000 kg is lifted up a distance of 30 m by a crane in 1 min. A second crane does the same job in 2 min. Do the cranes consume the same or different amounts of fuel? What is the power supplied by each crane? Neglect power dissipation against friction.

Sol. Here, $m = 2000$ kg, $s = 30$ m

$t_1 = 1 \text{ min} = 60\text{s}, \; t_2 = 2 \text{ min} = 120\text{s}$

Work done by each crane,

$W = Fs = mgs \quad (\because F = mg)$

$= 2000 \times 9.8 \times 30 = 5.88 \times 10^5$ J

As, both the cranes do same amount of work, so both consume same amount of fuel.

Power supplied by first crane,

$$P_1 = \frac{W}{t_1} = \frac{5.88 \times 10^5}{60} = 9800 \text{ W}$$

Power supplied by second crane,

$$P_2 = \frac{W}{t_2} = \frac{5.88 \times 10^5}{120} = 4900 \text{ W}$$

Energy

It is the ability to do work. It is always essential for performing any mechanical work. An object having a capability to do work is said to possess **energy.** The object which does the work, losses energy and the object on which work is done, gains energy.

Units of Energy

Energy has the same units as that of work. The SI unit of energy is joule (J) and in CGS system of units, unit of energy is erg.

Other Important Units of Energy

(i) **Units of Electrical Energy** Watt hour (Wh) and kilowatt hour (kWh) are the two bigger units of energy.

(a) The energy consumed by a source of power I W in 1 h, is said to be one Watt hour.

$$1 \text{ watt hour (Wh)} = 1\text{W} \times 1\text{h}$$
$$= 1 \text{ Js}^{-1} \times 3600 \text{ s}$$
$$= 3600 \text{ J} = 3.6 \text{ kJ}$$

(b) The energy consumed by a source of power of 1 kW in 1h, is known as one kilowatt hour.

$$1 \text{ kilowatt hour (kWh)} = 1\text{kw} \times 1 \text{ h}$$
$$= 1000 \text{ Js}^{-1} \times 3600 \text{ s}$$
$$= 3.6 \text{ MJ}$$

$\therefore$ 1 kilowatt hour (kWh) = 3.6 MJ

Note 1 kWh is also known as the commercial unit, i.e. board of trade unit.

(ii) **Units of Heat Energy** Calorie and kilocalorie are the two units in which the heat energy is measured.

(a) The quantity of energy which is required to raise the temperature of l g of water through 1°C, is known as 1 calorie.

$$1 \text{ calorie} = 4.2 \text{ J}$$

(b) The quantity of energy which is required to raise the temperature of 1 kilogram of water through 1°C, is known as 1 kilocalorie.

$$1 \text{ kilocalorie} = 4.2 \text{ kJ}$$

(iii) **Unit of Nuclear Energy** (electron volt) 1 electron volt is the energy gained by an electron.
when it is accelerated through a potential difference of 1 volt.

i.e., $\quad 1 \text{ eV} = 1.6 \times 10^{-19}$ J

and $\quad 1 \text{ MeV} = 1.6 \times 10^{-13}$ J

Mechanical Energy

It is the form of energy, which is possessed by a body due to its state of rest or motion, position and configuration. Mechanical energy is of two types, i.e., kinetic energy and potential energy.

Kinetic Energy

It is a form of mechanical energy which is possessed by an object due to its motion. In other words, energy due to the motion of a body is called **kinetic energy**. Kinetic energy of a body moving with a certain velocity is equal to the work done on it to make it acquire that velocity. Kinetic energy of an object increases with its speed.
Due to kinetic energy, a bullet fired from a gun can pierce a target.

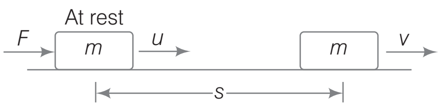
A moving hammer, drives a nail into the wood. Due to its motion, it has kinetic energy or ability to do work.

Calculation of Kinetic Energy

The kinetic energy of an object is measured by the amount of work it can do before coming to rest. Consider an object of mass m moving with a uniform velocity u. A force F is applied on it which displaces it through a distance s and it attains a velocity v.

Then, work done to increase its velocity from u to v.

$$W = Fs \quad \text{...(i)}$$



According to the equation of motion,

$$v^2 - u^2 = 2as \quad \Rightarrow \quad s = \frac{v^2 - u^2}{2a}$$

where, a is uniform acceleration.

Also, from $\quad F = ma$

Substituting the values of F and s in Eq. (i), we have

$$W = ma \cdot \frac{v^2 - u^2}{2a}$$

or $$W = \frac{1}{2} m(v^2 - u^2)$$

This is known as **work-energy theorem**.

If initial velocity, $\quad u = 0$

Then, $$W = \frac{1}{2} mv^2$$

It is clear that the work done is equal to the change in the kinetic energy of an object.

Thus, kinetic energy possessed by an object of mass m, moving with a uniform velocity v is

$$\text{KE (or } E_K) = \frac{1}{2} mv^2$$

Some important results can be derived from the formula,

$$\text{KE} = \frac{1}{2} mv^2$$

These are given below

(i) If the mass of an object is doubled, its kinetic energy also gets doubled.

(ii) If the mass of an object is halved, its kinetic energy also gets halved.

(iii) If the speed of an object is doubled, its kinetic energy becomes four times.

(iv) If the speed of an object is halved, its kinetic energy becomes one-fourth.

(v) Heavy objects moving with high speed have more kinetic energy than small objects moving with less speed.

Example 6. Determine the kinetic energy of a body of mass 5 kg moving with a velocity 2 ms^{-1}.

Sol. Given, mass of the body, $m = 5$kg

Velocity of the body, $v = 2\,\text{ms}^{-1}$.

Since, kinetic energy is given by,

$$\text{KE} = \frac{1}{2} mv^2$$

$$\therefore \quad = \frac{1}{2} \times 5 \times (2)^2 = \frac{1}{2} \times 5 \times 4 = 10 \text{ J}$$

Example 7. A bullet of mass 8 g is fired with a velocity of 80 m/s. Calculate its kinetic energy.

Sol. Given, mass, $m = 8\,\text{g} = \frac{8}{1000}$ kg

Velocity, $v = 80$ m/s

$$\text{KE of the bullet} = \frac{1}{2} mv^2 = \frac{1}{2} \times \frac{8}{1000} \times (80)^2$$

$$= \frac{1}{2} \times \frac{8}{1000} \times 80 \times 80 = 25.6 \text{ J}$$

Example 8. A van of mass 2000 kg is travelling at 10 ms^{-1} . Calculate its kinetic energy. If its speed increases to 20 ms^{-1}, by how much amount does its kinetic energy increases?

Sol. Given, $m = 2000$ kg, $v_1 = 10$ ms^{-1}, $v_2 = 20$ ms^{-1}

Kinetic energy of van at 10 ms^{-1},

$$\text{KE}_1 = \frac{1}{2} mv_1^2 \qquad \left(\because \text{KE} = \frac{1}{2} mv^2\right)$$

$$= \frac{1}{2} \times 2000 \text{ kg} \times (10 \text{ ms}^{-1})^2$$

$$= 100000 \text{ J} = 100 \text{ kJ}$$

Kinetic energy of van at 20 ms^{-1},

$$\text{KE}_2 = \frac{1}{2} mv_2^2 = \frac{1}{2} \times 2000 \text{ kg} \times (20 \text{ ms}^{-1})^2$$

$$= 400000 \text{ J} = 400 \text{ kJ}$$

The change in kinetic energy $= \text{KE}_2 - \text{KE}_1$

$$= 400 \text{ kJ} - 100 \text{ kJ} = 300 \text{ kJ}$$

So, the kinetic energy of van increases by 300 kJ when it speeds up from 10 ms^{-1} to 20 ms^{-1}.

Relation between Kinetic Energy (KE) and Momentum (p) of a Body

$$\text{As, KE} = \frac{1}{2}mv^2 = \frac{1}{2}(mv)^2\frac{m}{m}$$
$$= \frac{m^2v^2}{2m} = \frac{(mv)^2}{2m} = \frac{p^2}{2m}$$

Example 9. A body of mass 50 kg has a momentum of 2000 kg ms^{-1}. Calculate (i) KE of the body (ii) the velocity of the body.

Sol. (i) $\text{KE} = \frac{p^2}{2m} = \frac{(2000)^2}{2\times 50} = 40{,}000\,\text{J}$

(ii) Velocity of the body,
$$v = \frac{p}{m} = \frac{2000}{50} = 40\,\text{m/s}$$

Different Forms of Kinetic Energy

There are three different forms of kinetic energy

(i) **Translational Kinetic Energy** Translational motion is the motion of a body in a straight line path. So, the kinetic energy of the body due to motion in a straight line is known as translational kinetic energy. e.g., A truck moving on a road covering straight path, a freely falling body, etc.

(ii) **Rotational Kinetic Energy** Rotational motion comes in to play when a body rotates about an axis. So, the kinetic energy of body due to rotational motion known as rotational kinetic energy. e.g., Rotation of earth on its own axis, spinning top, etc.

(iii) **Vibrational Kinetic Energy** Vibrational motion comes in to existence, when a body moves to and fro about its mean position. So, the kinetic energy of the body due to its vibrational motion is called vibrational kinetic energy.

e.g. A polyatomic molecule has the vibrational motion in addition to rotational and translational energies.

CHECK POINT 02

1. How can you define the term 'power'? State its SI unit.
2. What is the necessity of using term 'Average Power' instead of power?
3. Why it is required to use kilowatt hour or board of trade as commercial unit of energy?
4. What amount of energy is kWh is consumed in 10 h by a machine of power 500 W? ***Ans.*** 5 kWh
5. Compute the speed of 2 kg ball having kinetic energy of 4 J. ***Ans.*** 2 ms^{-1}
6. Calculate the kinetic energy of a body of mass 0.1 kg and momentum 40 kg ms^{-1}. ***Ans.*** 8000 J

Potential Energy

The energy possessed by a body due to the change in its position or shape, is called potential energy or we can say that, the potential energy possessed by a body is the energy present in it by virtue of its position or configuration.

e.g., A stretched rubber band, spring, string of the bow, etc. Now, we can say that a body mass possesses energy even when it is not in motion.

Examples of potential energy are given below

(i) Water stored in dam has potential energy due to its position at the height.

(ii) A stone lying on the roof of the building has potential energy due to its height.

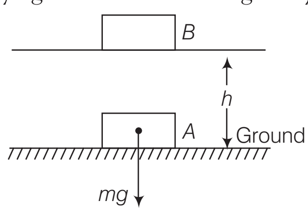
(iii) A wound spring of a watch has potential energy due to its shape.

Potential Energy of an Object at a Height

When an object is raised through a certain height above the ground, its energy increases. This is because work is done on it against gravity while it is being raised. The energy present in such an object is the **gravitational potential energy.** The gravitational potential energy of an object at a point above the ground is defined as the work done in raising it from the ground to that point against gravity.

Expression for (Gravitational) Potential Energy

Consider a body of mass m, lying at a point A on the earth's surface. Here, its potential energy is zero and its weight mg acts vertically downwards. To lift the object to another position B at a height h, we have to apply a minimum force which is equal to mg in the upward direction. So, work is done on the body against the force of gravity.



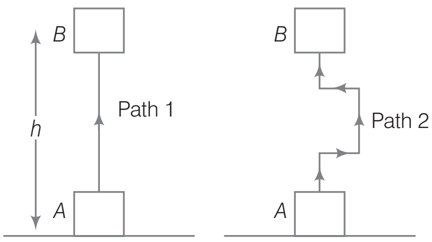
Therefore, work done = force × displacement
$$W = F \times s$$
But, $F = mg$ (weight of the body)
$$s = h,$$
Therefore, $W = mg \times h = mgh$

i.e., $\text{PE} = mgh$

This work done is equal to the gain in energy of the body. This is called the potential energy of the body.

The potential energy of an object at a height depends on the ground level or the zero level you choose. An object in a given position can have a certain potential energy with respect to one level and a different value of potential energy with respect to another level.

The work done by gravity depends on the difference in vertical heights of the initial and final positions of the objects and not on the path along which the object is moved. It is clear from the figure given below.



In both the above situations, the work done on the object is *mgh*.

The another type of potential energy is elastic potential energy which is described below.

Elastic Potential Energy

As elasticity is the property by virtue of which a body regains original configuration on the removal of external force. So, elastic potential energy is the energy possessed by the body in the deformed state due to change in its configuration. For example, energy possessed by a compressed or elongated spring is elastic potential energy.

Example 10. On falling from a height of 12 m, a ball hits the ground. Find out of the velocity with which the ball hits the ground.

Sol. Given, $h = 20\text{m}$, $v = ?$

When the ball hits the ground its kinetic energy is converted into potential energy.

When it hits the ground KE = PE

$$\frac{1}{2}mv^2 = mgh$$

$$\therefore \quad v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 20}$$

$$= \sqrt{392} = 19.798 \text{ m/s}$$

Example 11. Suppose two bodies A and B having equal masses are kept at heights of h and 3 h, respectively. Find the ratio of their potential energies.

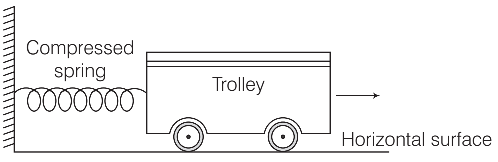
Sol. Let the mass of each body be m.

$$\text{PE of body} A = mgh$$

$$\text{PE of body } B = mg \times 3h$$

$$\therefore \text{ Ratio of their potential energies} = \frac{mgh}{mg \times 3h} = \frac{1}{3} = 1:3$$

Example 12. A spring is kept compressed by a small trolley of mass 1 kg lying on a smooth horizontal surface as shown in the figure given below:



When the trolley is released, it is found to move at a speed of 4 ms^{-1}. What potential energy did the spring possess when compressed ?

Sol. The potential energy of the spring when compressed

$$= \text{Kinetic energy of the trolley}$$

$$= \frac{1}{2} \times 1 \times (4 \text{ ms}^{-1})^2 = \frac{1}{2} \times 4 \times 4 = 8 \text{ J}$$

Various Forms of Energy

There are six various forms of energy

(i) **Heat Energy** A body possesses heat energy due to the disorderly motion of its molecules. Heat energy is also related to the internal energy of the body. In winter, we generate heat by rubbing our hands against each other.

(ii) **Chemical Energy** A stable chemical compound has lesser energy than its constituent atoms, the difference being in the arrangement and motion of electron in the compound. This difference is called chemical energy. If the total energy of the reactant is more than the product of the reaction, then heat is released and the reaction is said to be an exothermic reaction. If the reverse is true, then heat is absorbed and the reaction is called endothermic.

(iii) **Electrical Energy** Work is said to be done when electric charge moves from one point to another in an electric field or motion of a current carrying conductor inside a magnetic field. This energy is associated with an electric charge. The flow of electric charge causes bulbs to glow, motor to run and electric heater to produce heat.

(iv) **Nuclear Energy** When U^{235} nucleus breaks up into lighter nuclei on being bombarded by a slow neutron, a tremendous amount of energy is released. Thus, the energy so released is called nuclear energy and this phenomenon is known as nuclear fission. Nuclear reactors and nuclear bombs are the sources of nuclear energy.

(v) **Light Energy** It is a form of energy due to which we can see the objects around us. We can experience our surroundings, e.g., If we burn a candle, we will notice that this source of heat energy will provide a light energy. The light coming from sun is a natural source of light.

(vi) **Sound Energy** It is a form of mechanical energy which causes the sensation of hearing in us, e.g., A vibrating body possesses the sound energy, which is sensed by our ears.

Principle of Conservation of Energy

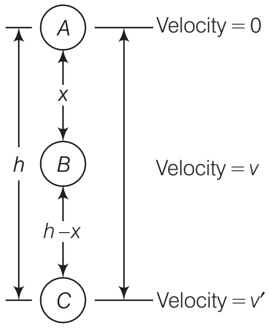
It states that, the energy can neither be created nor be destroyed but can only be converted from one form to another.

It is one of the fundamental laws and is applied in all the processes taking place in the universe.

Whenever energy in one form disappears, then equivalent amount of energy appears in some other form. Thus, the total energy remains constant.

Conservation of Mechanical Energy in a Freely Falling Body

Consider a body of mass m lying at position A at a height h above the ground. As the body falls, its kinetic energy increases at the expense of potential energy as shown in figure.



Conservation of energy in a freely falling body

At point A, The body is at rest,

KE of the body, $K_A = 0$

PE of the body, $U_A = mgh$

Total mechanical energy,

$$E_A = K_A + U_A = 0 + mgh$$

$\Rightarrow$ **Mechanical energy at position** A, $E_A = mgh$

At point B Suppose the body falls freely through height x and reaches the point B with velocity v. Then,

$$v^2 - 0^2 = 2as \qquad \text{(using } v^2 - u^2 = 2as\text{)}$$

$$\Rightarrow \quad v^2 = 2gx$$

$$\therefore \quad K_B = \frac{1}{2}m(v')^2 = \frac{1}{2} \times m \times 2gx = mgx$$

$$\text{PE,} \quad U_B = mg(h - x)$$

$$\Rightarrow \quad E_B = K_B + U_B = mgx + mg(h - x) = mgh$$

Mechanical energy at position B, $E_B = mgh$

At point C Suppose the body finally reached at point C on the ground with velocity v'. Then, considering motion from A to C.

$$v'^2 - 0^2 = 2gh \quad \text{or} \quad v'^2 = 2gh$$

$$K_C = \frac{1}{2}m(v')^2 = \frac{1}{2} \times m \times 2gh = mgh$$

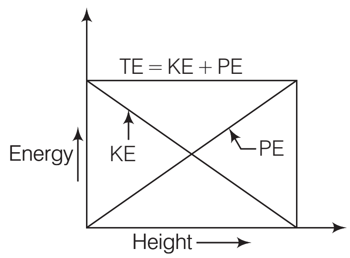
$$U_C = mg \times 0 = 0$$

$$\therefore \quad E_C = U_C + K_C = 0 + mgh = mgh$$

Mechanical energy at position C, $E_C = mgh$

Clearly, as the body falls as PE decreases and KE increases by an equal amount. Thus, its total mechanical energy remains constant at all points.

Hence, total mechanical energy is conserved during free fall of the body as shown in figure.

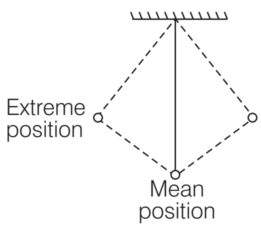


Plot of PE and KE during free fall of a body

Conservation of Mechanical Energy in Simple Pendulum

In an isolated system, the mechanical energy E of the system cannot change which means for isolated system mechanical energy of the system is conserved.

The oscillatory motion of a simple pendulum is another example of conversion of PE into KE and *vice-versa* and hence conservation of mechanical energy.



Simple Pendulum

At the mean position, bob of the simple pendulum has maximum KE. The PE at this position is zero.

At the two extreme positions, the bob of the simple pendulum has maximum PE. The KE at these two point is zero.

Example 13. The bob of a pendulum is released from a horizontal position. If the length of the pendulum is 1.5 m, what is the speed with which the bob arrives at the lowermost point?

Sol. On releasing the bob of pendulum from horizontal position, it falls vertically downward by a distance equal to length of pendulum, i.e., $h = l = 1.5$ m.

According to conservation of mechanical energy,

$$\frac{1}{2}mv^2 = mgh$$

$$\Rightarrow \quad v = \sqrt{2 \times gh}$$

$$= \sqrt{2 \times 9.8 \times 1.5}$$

$$= 5.42 \text{ ms}^{-1}$$

Example 14.

(i) A body of mass 1 kg is allowed to fall freely under gravity, what is the momentum of the body after 5 s?

(ii) What is the height of the freely falling body?

Sol. (i) Here, mass $(m) = 1$ kg, $u = 0$, $t = 5$ s, $p = ?$

$$v = u + at$$

$$= 0 + 10 \times 5 = 50 \text{ m/s}$$

Linear momentum $(\mathbf{p}) = m \cdot (\mathbf{v}) = 1 \times 50 = 50$ kg-m/s

(ii) Kinetic energy of a body

$$= \frac{1}{2}mv^2 = \frac{1}{2} \times 1 \times (50)^2$$

$$= 1250 \text{ J}$$

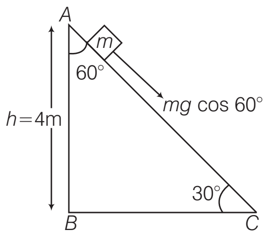
So, for a freely falling of the body from height h,

we get, $mgh = \frac{1}{2}mv^2$

$\Rightarrow \quad 1 \times 10 \times h = 1250, \; h = 125\,\text{m}$

Example 15. If a body slides on an inclined plane making an angle of 60°. Find its kinetic energy at the bottom as given in the figure and also find work done (by gravity) on the body.

(Take, initial velocity, $u = 0$, $g = 10 \text{ ms}^{-2}$)



Sol. As from the figure,

potential energy at the top = mgh

So, according to conservation of energy, kinetic energy at the bottom will be equal to the potential energy at the top.

So, KE at bottom = $mgh = 4mg$

Now, work done

$$(W) = \text{force } (F) \times \text{displacement } (s)$$

$$= mg \times (AB)$$

$$= mg \times (AC \cos 60°)$$

$$= mg \times (AB) = mg \times (4) = 4mg$$

Transformation of Energy

Energy can be converted into its one form to another. This phenomenon is called transformation of energy when an object is dropped from a height, its potential energy continuously converts into kinetic energy. When an object is thrown upwards, its kinetic energy continuously converts into potential energy.

e.g.,

(i) Green plants prepare their own food (stored in the form of chemical energy) using solar energy through the process of photosynthesis.

(ii) When we throw a ball, the muscular energy which is stored in our body, gets converted into kinetic energy of the ball.

(iii) The wound spring in the toy car possesses potential energy. As the spring is released, its potential energy changes into kinetic energy due to which, toy car moves.

(iv) In a stretched bow, potential energy is stored. As it is released, the potential energy of the stretched bow gets converted into the kinetic energy of arrow which moves in the forward direction with large velocity.

Some Energy Transformations

S.No.	Instrument	Transformation
(i)	Electric motor	Electrical energy into mechanical energy.
(ii)	Electric generator	Mechanical energy into electrical energy.
(iii)	Steam engine	Heat energy into kinetic energy.
(iv)	Electric bulb	Electrical energy into light energy.
(v)	Dry cell	Chemical energy into electrical energy.
(vi)	Solar cell	Light energy into electrical energy.
(vii)	Atomic bomb	Atomic energy into heat and light energy.

CHECK POINT 03

1. Does work done by the gravity depends on the path covered by object?
2. If an engine supplies 100 J of energy to a weight of 200 g, how high it can be lifted? ***Ans.*** 51.02 m
3. How total energy of the universe is remains conserved?
4. How does the total mechanical energy remain constant in a simple pendulum during the oscillations?
5. In dry cell which type of energy transformation takes place?

SUMMARY

- Work is said to be done by a force, when a body is displaced through some distance in the direction of the force.
- Work done by a force is the dot product of force and displacement.

$$W = F \cdot s = F\, s \cos\theta$$

  where θ is the angle between the direction of force (F) and displacement (s).
- Work done is zero if direction of 'F' is perpendicular to direction of 's'.
- Work done is positive if F and s are in the same direction and negative if they are in opposite directions.
- The capacity to do work is called energy.
- The units of work and energy are same. The SI unit of work and energy is joule (J).
- The rate at which work is done is called power.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

  The SI unit of power is watt (W).
- Mechanical energy is the sum of kinetic energy and potential energy.
- The energy possessed by a body by virtue of its motion is called kinetic energy.
- The kinetic energy of a body of mass m moving with a velocity v is given by

$$= \frac{1}{2} mv^2$$

- The energy possessed by a body due to the change in its position or shape is called its potential energy.
- Potential energy possessed by an object of mass m at a height h is given by $=$ mgh. This is called gravitational potential energy.
- Energy can be transformed from one form to another, but the total energy of an isolated system remains constant. Energy can be neither created nor destroyed. This is called principle of conservation of energy.

EXAM PRACTICE

a 2 Marks Questions

1. Define work. State its SI unit.

Sol. Work is said to be done when the force applied on a body displaces it in the direction of force applied on the body. The SI unit of work is joule (J). ***[1+1]***

2. Define Joule. SI unit of work and establish a relationship between the SI and CGS units of work. ***[2008]***

Sol. When a force of one newton displaces a body through one metre in its own direction, the work done is said to be 1 Joule.

$$1\text{ J} = 1\text{ N} \times 1\text{ m} = 10^5\text{dyne} \times 100\text{ cm}$$
$$= 10^7\text{ dyne cm} = 10^7\text{ erg}$$
$$\therefore \quad 1\text{ J} = 10^7\text{ erg}$$ ***[1]***

This is a required relation between the SI unit and CGS unit of work. ***[1]***

3. A man having a box on his head, climbs up a slope and another man having an identical box walks the same distance on a levelled road. Who does more work against the force of gravity and why? ***[2014]***

Sol. A man having a box on his head climbs up a slope does more work, because the work done by the man walking on a levelled road is zero as the angle between displacement and force is 90°, as ***[1]***

$$w = mgs\cos 90° = mgs \times 0 = 0$$ ***[1]***

4. A man holding bucket of water on his head stands stationary. Is he doing any work? Give reason.

Sol. No, he is not doing any work. It is because, there is zero displacement occur.

$$\therefore \quad W = F \times s = F \times 0 = 0$$ ***[1+1]***

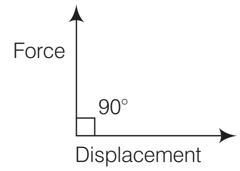
5. "If a satellite revolves around the earth in a circular orbit, the amount of work done by the satellite is zero". Justify the statement.

Sol. If a satellite revolves around the earth in a circular orbit, the amount of work done by the satellite is zero. It is due to the fact that the force of gravity is directed towards the centre of circular path of the satellite, i.e., the earth and the displacement at all instant is along the tangent to the circular path or normal to the direction of force on the satellite. ***[1]***

$$\because \quad W = F \times s\cos 90°$$
$$\Rightarrow \quad W = F \times s \times 0 = 0$$ ***[1]***

6. Is it possible that an object is in the state of accelerated motion due to external force acting on it, but no work is being done by the force? Explain it with an example.

Sol. Yes, when force acts in a direction perpendicular to the direction of displacement.



e.g., Earth revolves around the Sun under gravitational force of Sun on Earth, but no work is done by the Sun, though Earth has centripetal acceleration. ***[2]***

7. (i) State and define the SI unit of power.

(ii) How is the unit horse power related to the SI unit of power? ***[2018]***

Sol. (i) The rate of doing work is called the power and the SI unit of power is watt(W). ***[1]***

(ii) $1\text{HP} = 746\text{ W}$. ***[1]***

8. An object of mass m is moving with a constant velocity v. How much work should be done on the object in order to bring the object to rest?

Sol. Change in kinetic energy (KE) = Work done

Given, mass $= m$, initial velocity, $u = v$

Final velocity, $v = 0$

$$\text{So,} \quad W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$\Rightarrow \quad W = \frac{1}{2}m(0)^2 - \frac{1}{2}mv^2 \Rightarrow W = -\frac{1}{2}mv^2$$ ***[1]***

Hence, the work that should be done in order to bring the object to rest is $\frac{1}{2}mv^2$. ***[1]***

9. If a speed of a particle is doubled, what will be the ratio of its kinetic energy to its momentum?

Sol. $\therefore$ Kinetic energy, $KE' = \frac{1}{2}m(v')^2 \qquad (\because v' = 2v)$

$$= \frac{1}{2}m(2v)^2 = 4\text{ KE}$$ ***[1]***

and momentum, $p' = mv' \qquad (\because v' = 2v)$

$$= m(2v) = 2p$$

$$\therefore \quad \frac{KE'}{p'} = \frac{4KE}{2p} = 2 \times \left(\frac{KE}{p}\right)$$

Hence, ratio gets doubled. ***[1]***

10. Two bodies of masses m_1 and m_2 have equal kinetic energies. What will be the ratio of their linear moment?

Sol. Given, $K_1 = K_2$

$$\Rightarrow \quad \frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2 \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$$

$$\Rightarrow \quad \frac{m_1 v_1}{m_2 v_2} = \frac{m_1}{m_2}\sqrt{\frac{m_2}{m_1}} \Rightarrow \frac{p_1}{p_2} = \sqrt{\frac{m_1}{m_2}}$$ **[2]**

11. (i) Why is the motion of a body moving with a constant speed around a circular path said to be accelerated?

(ii) Name the unit of physical quantity obtained by the formula $\frac{2K}{v^2}$, where K is kinetic energy and v is linear velocity. **[2018]**

Sol. (i) In a circular motion with constant speed, linear velocity changes in terms of direction therefore it is said to be accelerated motion. **[1]**

(ii) We know that,

$$\text{kinetic energy } (K) = \frac{1}{2} mv^2 \quad \ldots\text{(i)}$$

Given, $$m = \frac{2K}{v^2}$$

From Eq. (i), we get,

$$= \frac{2}{v^2} \times \left(\frac{1}{2} mv^2\right) = m \text{ (mass)}$$

Hence, the physical quantity is mass. **[1]**

12. (i) Is it possible a body possesses energy without having momentum?

(ii) Is it possible a body possesses momentum without having energy?

Sol. (i) Yes it is possible, it is because a body at rest can possesses the potential energy or energy stored due to position or shape as elastic potential energy even when there is zero momentum. **[1]**

(ii) No, it is not possible, if a body possesses some momentum, then it must be in motion, it must have some kinetic energy. **[1]**

13. Define potential energy. Write an expression for potential energy. Write the SI unit of potential energy.

Sol. The energy possessed by a body due to its configuration is known as potential energy.

The potential energy of a body is given by

$$\text{PE} = mg$$

The SI unit of potential energy is joule (J). **[2]**

14. Derive an expression for the gravitational potential energy.

Sol. Let us consider that, m = mass of the object, h = height at which object is placed and F = force required to lift the object against the force of gravity.

$$F = mg$$

Now, work done on lifting the object to height h is **[1]**

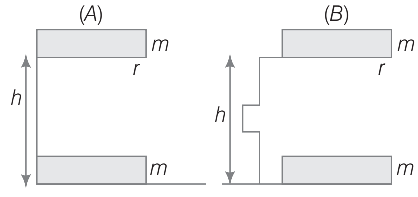
$$W = \text{Force} \times \text{Displacement}$$
$$= mg \times h = mgh$$

This work done on the body is stored in it in the form of gravitational potential energy, i.e., U.

$$\therefore \quad U = mgh$$ **[1]**

15. (i) What is meant by potential energy of a body?

(ii) A body of mass m is raised to a vertical height h through two different paths A and B.



What will be the potential energy of the body in the two cases? Give reason for your answer.

Sol. (i) Energy possessed due to the position of a body is called potential energy. **[1]**

(ii) The work done against gravity in both the cases is *mgh*. It is independent of the path along which the body is moved and it depends only on the initial and final positions of the body. **[1]**

16. A ball is placed on a compressed spring. When the spring is released, the ball is observed to fly away.

(i) What form of energy does the compressed spring possess?

(ii) Why does the ball fly away? **[2012]**

Sol. (i) The compressed spring possesses elastic potential energy. **[1]**

(ii) The ball flies away, because potential energy is converted into kinetic energy and it is also transferred to the ball. **[1]**

17. What is meant by transformation of energy? Explain with the help of two suitable examples.

Sol. Refer to theory (Page 25).

18. State the energy changes in the following cases while in use

(i) An electric iron.

(ii) A ceiling fan. **[2018]**

Sol. (i) An electric iron converts electrical energy into heat energy. ***[1]***

(ii) A ceiling fan converts electrical energy into mechanical energy. ***[1]***

19. Write the statement of law of conservation of mechanical energy.

Sol. Refer to theory (Page 24). ***[2]***

20. Mention any two examples in which the mechanical energy of the system remains constant?

Sol. (i) Mechanical energy of the vibrating body of simple pendulum remains constant. ***[1]***

(ii) Mechanical energy of a freely falling body remains constant. ***[1]***

21. At the bottom of the waterfall, water is warmer than at the top. Give reason.

Sol. When water falls on the ground, its mechanical energy (KE + PE) is converted into heat energy, due to which the temperature of water at the bottom of the waterfall increases. ***[2]***

22. The moment, an arrow is shoot from its bow, it has some kinetic energy. From where does it get the kinetic energy?

Sol. On the account of a change in the shape of stretched bow, it possesses potential energy. In order to shoot an arrow, the bow is released. So, the potential energy of the bow changes into kinetic energy. ***[2]***

b *3 Marks Questions*

23. (i) Derive a relationship between SI and CGS unit of work.

(ii) A force acts on a body and displaces it by a distance S in a direction at an angle θ with the direction of force. What should be the value of θ to get the maximum positive work? ***[2018]***

Sol. (i) The SI unit of work is joule

$$1\,\text{J} = 1\,\text{N} \times 1\,\text{m} = 10^5\ \text{dyne} \times 100\ \text{cm}$$
$$= 10^7\ \text{dyne cm}$$
$$= 10^7\ \text{erg}$$ ***[1½]***

(ii) For maximum work done, the angle should be 0°.

i.e. $W_{max} = \mathbf{F} \cdot \mathbf{s}$

$$= |\mathbf{F}||\mathbf{s}|\cos 0° = Fs \qquad (\because \cos 0° = 1)$$ ***[1½]***

24. Read the following statements and state whether the work done in the following cases is positive or negative.

(i) Work done by friction on a body sliding down an inclined plane. ***[1]***

(ii) Work done by a man in lifting a bucket out of the well by means of rope tied to the bucket. ***[1]***

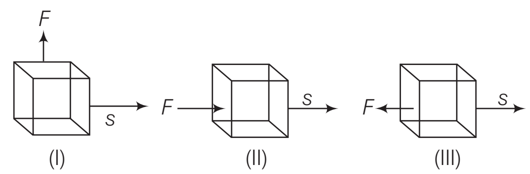
(iii) Work done by a resistive force of air on a vibrating pendulum in bringing it to a rest. ***[1]***

Sol. (i) In this case, the frictional force acts opposite to the direction of motion of body, so the work done by the friction on a body sliding down an inclined plane will be negative. ***[1]***

(ii) In this case, the bucket moves in the direction of the applied force by the man, so the work done will be positive. ***[1]***

(iii) The resistive force of air always acts opposite to the direction of motion of the oscillating pendulum due to which the work done will be negative. ***[1]***

25. In each of the following, a force F is acting on an object of mass m. The direction of displacement is from West to East shown by the longer arrow. Observe the figure carefully and state whether the work done by the force is negative, positive or zero.



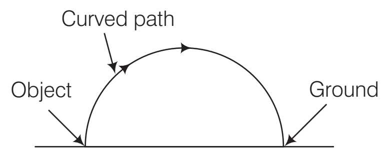
Sol. (i) In Fig. (I), angle between F and s is 90°, so work done is zero. ***[1]***

(ii) In Fig. (II), angle between F and s is 0°, so work done is positive. ***[1]***

(iii) In Fig. (III), angle between F and s is 180°, so work done is negative. ***[1]***

26. An object thrown at a certain angle to the ground moves in a curved path and falls back to the ground. The initial and the final points of the object lie on the same horizontal line. What is the work done by the force of gravity on the object?

Sol. *The path can be traced as shown below*



Thus, the work done by the force of gravity,

$$W = mgh$$

where, h = difference in height of initial and final positions of the object.

According to question, the initial and final positions of the object lie in same horizontal line, so $h = 0$.

$\therefore$ Work done, $W = mg \times 0 = 0$ **[3]**

27. A boy weighing 40 kgf in 4 minute and a girl weighing climbs up a stair of 30 steps each 20 cm high 30 kgf does the same in 3 minutes. Compare

(i) the work done by them

(ii) the power developed by them.

Sol. (i) Both of them climbs up the same number of stairs, so work done by them will be equal. **[1]**

(ii) Power developed by the girl is more, because

$$\text{power of boy} = \frac{40 \times 10 \times 30 \times 20}{4 \times 100 \times 60} = \frac{600}{60} \text{ W} = 10 \text{ W}$$

$$\text{power of Girl} = \frac{30 \times 10 \times 30 \times 20}{3 \times 60 \times 100} = 10 \text{ W}$$

Power developed is same but girl takes lesser time. **[2]**

28. Differentiate between the potential energy (U) and the kinetic energy (K).

Sol.

Potential Energy	Kinetic Energy
The energy possessed by a body by virtue of its state of position is known as potential energy.	It is the energy possessed by a body by the virtue of state of motion.
Potential energy of a body is equal to the work done on the body to lift it to a height h.	Kinetic energy of a body is equal to the amount of work done by the body before it comes to rest.
A body mass possess this energy, when it is not in motion.	Kinetic energy of the body increases by increasing the motion of the body.

[1 × 3]

29. A car is moving on a levelled road and gets its velocity doubled. In this process,

(i) how would the potential energy of the car change?

(ii) how would the kinetic energy of the car change?

(iii) how will its momentum change? Give reasons for your answer.

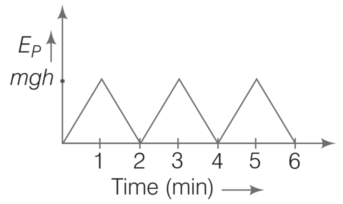
Sol. (i) The potential energy of the car remains same, since PE $(= mgh)$ is independent of velocity.

(ii) The kinetic energy of the car becomes four times, since KE$\left(= \frac{1}{2} mv^2\right)$ is proportional to square of velocity.

(iii) The momentum of the car will also get doubled, since momentum $(p = mv)$ is proportional to velocity. **[1+1+1]**

30. A girl sits and stands repeatedly for 6 min. Draw a graph to show the variation of potential energy of her body with time.

Sol. *The path can be traced as shown below*



[1]

From the graph shown above, we can take the sitting position of the girl as the position of zero potential energy. Let m be the mass of the girl and h be the position of centre of gravity while standing above the sitting position.

The PE while standing is + mgh and while sitting is zero. We can assume that there is no acceleration or deceleration while standing and sitting, this is repeated after every minute. **[2]**

31. Write transformation of energy in

(i) solar cell

(ii) electric iron

(iii) induction cooker

Sol. (i) Light energy to electrical energy. **[1]**

(ii) Electrical energy to heat energy. **[1]**

(iii) Electrical energy to heat energy. **[1]**

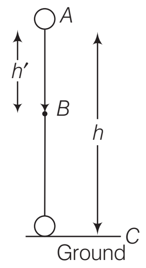
32. A battery lights a bulb. Describe the energy changes involved in the process.

Sol. A battery contains chemical and supplies electrical energy. So, a battery converts chemical energy into electrical energy. In an electrical bulb, the electrical energy is first converted into heat energy. This heat energy causes the filament of bulb to become white-hot and produce light energy. **[2]**

Thus, the energy changes are

Chemical energy $\Rightarrow$ Electrical energy $\Rightarrow$ Heat energy $\Rightarrow$ Light energy **[1]**

33. The potential energy of a freely falling object decreases progressively.
Does this violate law of conservation of energy? If no/yes, then why?



Sol. It is true that the potential energy of freely falling object decreases progressively. But as the object falls down, its speed increases, i.e., the kinetic energy of the object increases progressively (kinetic energy will increase with the increase in speed). ***[2]***

Now, we can say that the law of conservation of energy is not violated, because the decrease in potential energy results in the increase of kinetic energy. ***[1]***

34. If a body falls from a height bounces from ground and again goes upwards with loss of a part of its energy.
(i) How will its potential energy change?
(ii) What are various energy conversions taking place?
(iii) What will be its ultimate energy?

Sol. (i) When it strikes ground, its PE is zero and after bouncing, its potential energy increases gradually. ***[1]***
(ii) At the time it strikes the ground, it has maximum KE and after it bounces, its KE starts changing into potential energy. ***[1]***
(iii) The ultimate or total energy remains constant at any point of time during the motion. ***[1]***

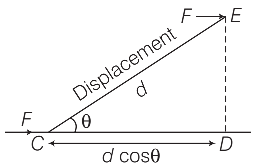
C 4 Marks Questions

35. Given below are a few situations, study them and state in which of the given cases work is said to be done. Give reason for your answer.
(i) A person pushing hard a huge rock but the rock does not move.
(ii) A bullock pulling a cart up to 1 km on road.
(iii) A girl pulling a trolley for about 2 m distance.
(iv) A person standing with a heavy bag on his head.

Sol. (i) As the displacement is zero in first case. So, work done = zero. ***[1]***
(ii) The work done in pulling a cart by the bullock will be positive. As F and s are in same direction. ***[1]***
(iii) Work done in case of pulling a trolley by the girl will be positive. As force and displacement are in same direction. ***[1]***
(iv) As there is no displacement, so work done by a person standing with a heavy bag on his head is zero. ***[1]***

36. Explain, how do the work is related to direction of force and displacement.

Sol. When the displacement of the body is not in the direction of the force, so in order to calculate the amount of work done, we should find the component of the displacement in the direction of force. e.g.,
Let us assume that the force F is acting along CD and it displaces the point of application of force from C to E such that the displacement $CE(=d)$ is at an angle θ to the direction of force. ***[1]***
The component of the displacement in the direction of force is CD.



$\therefore$ Work done, $W = F \times CD$ ...(i)
In right angled ΔCDE, ***[2]***

$$\cos\theta = \frac{CD}{CE} = \frac{CD}{d} \Rightarrow CD = d\cos\theta$$

Substituting this value in Eq. (i), we get

$$W = F \times d\cos\theta$$

which is a required relationship between work, force and the displacement. ***[1]***

37. If a body of mass m is moving with velocity v, then derive an expression for its kinetic energy.

Sol. Consider a body of mass m is moving with velocity v. It is brought to rest by an opposing force F. Let it travels a distance s before coming to rest and a be the uniform retardation produced by the force. ***[1]***
Kinetic energy of the body = Work done by the retarding force in stopping it.

Kinetic energy = force × displacement ...(i)
Retarding force, $F = ma$ ...(ii)
Initial velocity, $u = v$, final velocity, $v = 0$ ***[1]***

From the relation, $v^2 = u^2 + 2as$

$$0 = v^2 - 2as$$

$\therefore$ Displacement, $s = \dfrac{v^2}{2a}$ ...(iii) ***[1]***

Put the values of F and s from Eqs. (ii) and (iii) in Eq. (i), we get

Kinetic energy, $K = F \times s = ma \times \dfrac{v^2}{2a} = \dfrac{1}{2}mv^2$

Kinetic energy $= \dfrac{1}{2} \times \text{mass} \times (\text{velocity})^2$ ***[1]***

38. Two protons are brought towards each other. Will the potential energy energy of the system decrease or increase? What happens if a proton and an electron are brought nearer?

Sol. The potential energy will increase, because in bringing two protons closer, work has to be done against the force of repulsion. This work done gets stored up in the form of potential energy. However, the potential energy will decrease when a proton and an electron are brought nearer to each other.

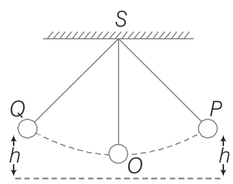
The work done gets stored up in the from of potential energy. However, the potential energy will decrease when a proton and an electron are brought nearer to each other. The work will be done by the force of attraction between them. ***[2 + 2]***

39. State the energy changes in each of the following cases given below

(i) Explosion of crackers
(ii) Burning of match stick
(iii) Respiration
(iv) Charging of a battery

Sol. (i) Chemical energy into heat, light and sound energy.
(ii) Chemical energy into light and heat energy.
(iii) Chemical energy into heat energy.
(iv) Electrical energy into chemical energy. ***[1 × 4]***

40. Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?



Sol. Let a simple pendulum be suspended from a rigid support S and OS be the equilibrium position of the pendulum. Let the pendulum be displaced to a position P, where it is at rest. At position P, the pendulum has potential energy (mgh). When the pendulum is released from position P, it begins to move towards position O.

The speed of the pendulum increases and its height decreases that means the potential energy is converting into kinetic energy. ***[1]***

At position O, whole of the potential energy of the pendulum is converted into its kinetic energy.

Then, the pendulum swings to other side due to inertia of motion.

As the pendulum begins to move towards position Q, the speed of pendulum decreases and height increases that means kinetic energy is converting into potential energy. At point Q, whole of the kinetic energy is converted into potential energy. ***[1]***

Thus, we find that the potential energy is converted into kinetic energy and *vice-versa* during the motion of the pendulum. But the total energy remains constant.

When the pendulum oscillates in air, the air friction opposes its motion.

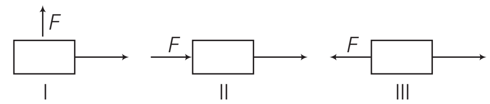
So, some part of kinetic energy of pendulum is used to overcome this friction. ***[1]***

With the passage of time, energy of the pendulum goes on decreasing and finally becomes zero.

The energy of the pendulum is transferred to the atmosphere. So, energy is being transferred, i.e., is converted from one form to another. So, no violation of law of conservation of energy takes place. ***[1]***

Numerical Based Questions

41. In each of the following a force, F is acting on an object of mass m. The direction of displacement is from West to East shown by the longer arrow. Observe the diagrams carefully and state whether the work done by the force is negative, positive or zero.



Sol. *Case* I The force and displacement are perpendicular to each other, so $\theta = 90°$.

Work done, $W = Fs\cos\theta$

$= Fs\cos 90°$

$= Fs \times 0 = 0 \quad (\because \cos 90° = 0)$

i.e., the work done is zero. ***[1]***

Case II The force and displacement are in the same directions, so $\theta = 0°$

$\therefore$ Work done, $W = Fs\cos\theta = Fs\cos 0°$

$= Fs \times 1 = Fs \quad (\because \cos 0° = 1)$

i.e., the work done is positive. ***[1]***

Case III The force and displacement are in opposite directions, so $\theta = 180°$.

$\therefore$ Work done, $W = Fs\cos\theta = Fs\cos 180°$

$= Fs \times -1 = -Fs$

$(\because \cos 180° = -1)$

i.e., the work done is negative. ***[1]***

42. If a force of 10 kg is applied on a body and the body gets displaced by 0.5 m. Determine the work done by the force when the displacement
(i) is in the direction of force.
(ii) at an angle of $60°$ with the force.
(iii) normal to the force (Take, $g = 10\ \text{Nkg}^{-1}$).

Sol. Given, force $F = 10$ kg, $F = 100$ N.
Displacement, $s = 0.5$ m.
(i) When displacement is in the direction of force, $\theta = 0°$

$W = Fs\cos 0°$ $\quad(\because \cos 0° = 1)$

$\Rightarrow \quad W = 100 \times 0.5 = 50\ \text{J}$ **[1]**

(ii) When displacement is at an angle of $60°$,

$\Rightarrow \quad W = Fs\cos 60°$

$\Rightarrow \quad W = 100 \times 0.5 \times \frac{1}{2}$ $\quad\left(\because \cos 60° = \frac{1}{2}\right)$

$\Rightarrow \quad W = 25\ \text{J}$ **[1]**

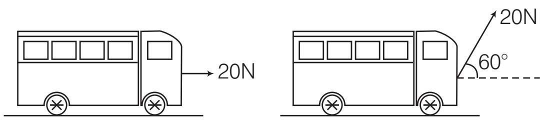
(iii) When displacement is normal to the direction of force,

$W = Fs\cos 90°$

$\Rightarrow \quad W = 100 \times 0.5 \times 0$ $\quad(\because \cos 90° = 0)$

$\Rightarrow \quad W = 0$ **[1]**

43. When a 20N force acts in two different ways to displace a trolley in the same displacement. Find the ratio of the work done as determined in both the cases.



Sol. In case (i), work done, $W_1 = 20 \times d\cos 0° = 20d$ **[1/2]**

In case (ii), work done, $W_2 = 20 \times d\cos 60° = 20d \times \frac{1}{2}$

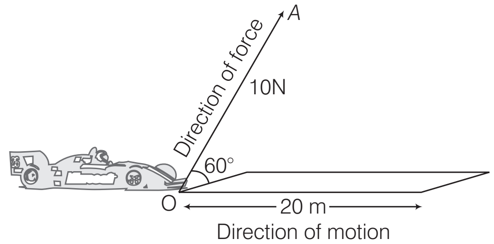
$= 10d$ **[1/2]**

$\therefore$ The required ratio, $\frac{W_1}{W_2} = \frac{20d}{10d}$

$\Rightarrow \quad \frac{W_1}{W_2} = 2$ **[1]**

44. A child pulls a toy car through a distance of 20 m on smooth and horizontal floor. The string held in child's hand makes an angle of $60°$ with horizontal surface. If the force applied by the child be 10 N, calculate the work done by the child in pulling the car.

Sol. We know that, work done when a body moves at an angle to the direction of force is



[1]

$$W = Fs\cos\theta$$ **[1]**

Here, force, $F = 10$ N
Angle, $\theta = 60°$
and distance, $s = 20$ m
So, on putting values in above formula, we get
Work done, $W = 10 \times 20 \times \cos 60°$
As, the value of $\cos 60° = 0.5$
So, $W = 10 \times 20 \times 0.5 = 100\ \text{J}$ **[1]**

45. Determine the power of the motor in terms of HP of an elevator, which can carry 10 persons of average mass 60 kg through a vertical height of 20 m in 30s.

Sol. Given, mass = 60 kg, time = 30 s, $h = 20$ m
Mass to be lifted $= 10 \times 60 = 600$ kg

Power, $P = \frac{mgh}{t}$ **[1]**

$= \frac{600 \times 10 \times 20}{30}$

$= \frac{120000}{30}$

$\Rightarrow \quad P = 4000\ \text{W}$ **[1]**

In HP $= \frac{P}{750} = \frac{4000}{750} = 5.33$ HP

$(\because 1\ \text{HP} \approx 750\ \text{W})$ **[1]**

46. A girl of mass 40 kg runs up stairs and reaches the 8 m high first floor in 5s. Determine
(i) the force of gravity acting on the body.
(ii) the work done by her against the gravity.
(iii) the power spent by the girl.

Sol. Given, $m = 40$ kg, $h = 8$ m,
$t = 5$ s, $g = 10\ \text{ms}^{-1}$
(i) Let the force of gravity on the girl be F.

$\therefore \quad F = mg = 40 \times 10 = 400\ \text{N}$ **[1]**

(ii) Work done by the girl against the gravity,

$$W = mgh = 4 \times 10 \times 8 = 3200\ \text{J} \quad \textit{[1]}$$

(iii) Power spent, $P = \frac{W}{t} = \frac{3200}{5}$

$$= 640\ \text{Js}^{-1}$$
$$= 640\ \text{W} \quad \textit{[1]}$$

47. Determine the horse power of an engine, which lifts 4000 m^3 of water from a depth of 50 m in 40 min.

Sol. Mass of water $= V \times D = 4000 \times 10^3$

$$= 4 \times 10^6\ \text{kg}$$

$$(\because \text{density of water} = 10^3\ \text{kg/m}^3) \quad \textit{[1]}$$

Work done in lifting water $= mgh$

$$= 4 \times 10^6 \times 10 \times 50$$
$$= 2 \times 10^9\ \text{J} \quad \textit{[1]}$$

Power of engine $= \frac{W}{t} = \frac{2 \times 10^9}{2400} = \frac{10^9}{1200}$ W

$\therefore$ Power in horse power $= \frac{1 \times 10^9}{1200 \times 750}$

$$= 1111.1\ \text{HP} \quad \textit{[1]}$$

48. The human heart does 1.5 J of work in every beat. How many times per minute does it beat, if its power is 2 W?

Sol. Given, power, $P = 2$ W, time, $t = 1\ \text{min} = 60$ s

Total work, $W = Pt \quad \left(\because P = \frac{W}{t}\right)$

$$= 2 \times 60\ \text{s} = 120\ \text{J} \quad \textit{[1]}$$

$\because$ 1.5 J work is done in 1 beat.

$\therefore$ 120 J work will be done in $\frac{1 \times 120}{1.5} = 80$ beats

Therefore, number of beats per min = 80 *[1]*

49. For an experiment to measure his power, a student records the time taken by him in running up a flight of steps on a staircase.
Use the following data to calculate the power of the student.
(Take, number of steps = 28, height of each step = 20 cm, time taken = 5.4 s, mass of student = 55 kg and acceleration due to gravity = 9.8 ms^{-2})

Sol. Given, $n = 28, h = 20\ \text{cm} = 0.2\ \text{m}, t = 5.4$ s

$$m = 55\ \text{kg}, g = 9.8\ \text{m s}^{-2}$$

We know that the power of student is given by

$$P = n \times \frac{W}{t} = n \times \frac{mgh}{t} \quad (\because W = mgh)$$
$$= \frac{28 \times 55 \times 9.8 \times 0.2}{5.4}$$
$$= 559\ \text{W} \quad \textit{[2]}$$

50. If a man raises a box of 50 kg mass to a height of 2 m, while the other man raises the same box to a same height in 5 min. Compare

(i) the work done.

(ii) the power developed by them.

Sol. (i) For the first man, $m = 50$ kg

Height, $h = 2$ m

Time, $t_1 = 2\ \text{min} = 2 \times 60\ \text{s} = 120$ s

For the second mass, $m = 50$ kg

Height, $h = 2$ m

Time, $t = 5\ \text{min} = 5 \times 60 = 300$ s

Let work done by the first man be W.

Since, $W = mgh$

Therefore, the work done by the second man is the same.

$\therefore \quad W_1 : W_2 = 1:1$ *[2]*

(ii) Let power developed by the first man $= P_1$.

$\because \quad W = mgh = 50 \times 10 \times 2 = 1000$ J

$$P_1 = \frac{W}{t_1} = \frac{1000}{120}\ \text{W} = \frac{25}{3}\ \text{W} \quad \textit{[1]}$$

Now, assume that the power developed by the second man $= P_2$.

Therefore, power,

$$P_2 = \frac{W}{t} = \frac{1000}{300}\ \text{W} = \frac{10}{3}\ \text{W}$$

$$\therefore \quad \frac{P_1}{P_2} = \frac{25}{3} : \frac{10}{3}$$

$$\therefore \quad \frac{P_1}{P_2} = \frac{5}{2}$$

$$\Rightarrow \quad P_1 : P_2 = 5:2 \quad (\because t_2 = 5\ \text{min}) \quad \textit{[1]}$$

51. A boy X can run with a speed of 8 ms^{-1} against the frictional force of 10 N and another Y can move with a speed of 3 ms^{-1} against the frictional force of 20 N. Find the ratio of powers of X and Y.

Sol. Given, distance travelled by the boy X in 1 s = 8 m

Distance travelled by the boy Y in 1 s = 3 m

As we know, work done by the boy X to run against the frictional force of 10 N = 10 N × 8 m = 80 J

So, power of 80 J of work done by $X = \frac{W}{t} = \frac{80\text{ J}}{1\text{s}}$

$= 80$ W **[1]**

Similarly, work done by the boy Y to run against the frictional force of 20 N = 20 N × 3 m = 60 J

$$\text{Power of } Y = \frac{60\text{ J}}{1\text{ s}} = 60\text{ W}$$

So, ratio of two values of powers is given by

$$\frac{\text{Power of } X}{\text{Power of } Y} = \frac{80}{60} = \frac{4}{3} = 4:3$$ **[1]**

52. Calculate the total energy consumed in the month of November in a household in which four devices of power 500 W each are used daily for 10 h.

Sol. Given, power, $P = 500$ W, time, $t = (4 \times 10 \times 30)$ h

Energy consumed in the month of November

$= 500 \text{ W} \times 4 \times 10 \text{ h} \times 30$

$= 600000$ Wh $= 600$ kWh

$= 600$ units **[2]**

53. In a house 3 bulbs of 25 W each are used for 5 h a day. Calculate the units of electricity consumed in a month of 31 days. Also, find the total expenditure, if 1 unit of electricity costs ₹ 2.50.

Sol. Given, power of each bulb = 25 W, time = 5 h

Cost of 1 unit of electricity = ₹ 2.50

Electric energy consumed by 3 bulbs in a day

$= \text{power} \times \text{time} = 3 \times 25 \times 5 = 375$ Wh **[1/2]**

∴ Electricity consumed in 31 days

$= 375 \times 31 = 11625$ Wh

$= 11.625$ kWh $= 11.625$ units

∴ Cost of electricity consumed $= 11.625 \times 2.50$

$=$ ₹ 29.06 **[1½]**

54. When a body of mass m moves with a uniform velocity, a force is applied on the body due to which its velocity changes. State how much work is being done by the force?

Sol. Let us suppose that force acts on the body through a distances, which changes its velocity from u to v.

Let the force acts for a time t.

∴ Work done by the force $= F \times s$

$= ma \times s$ $\quad (\because F = ma)$

$= m\left(\frac{v-u}{t}\right) \times s$ **[1]**

Since, $\frac{s}{t} = \text{average velocity} = \frac{u+v}{2}$

Therefore, work done by the force

$$= \frac{m(v-u)(u+v)}{2} = \frac{1}{2}m(v^2 - u^2)$$

$$W = \frac{1}{2}m(v^2 - u^2)$$ **[1]**

= change in kinetic energy.

It is also called work-energy theorem.

55. A force is applied on a body of mass 20 kg moving with a velocity of 40 ms^{-1}. The body attains a velocity of 50 ms^{-1} in 2s . Determine the work done by the body. **[2013]**

Sol. Given, $m = 20$ kg, $u = 40$ ms^{-1}, $v = 50$ ms^{-1}, $t = 2$ s

According to work-energy theorem,

work done $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ **[1]**

$$= \frac{1}{2} \times 20 \times (50)^2 - \frac{1}{2} \times 20 \times (40)^2$$

$$= \frac{1}{2} \times 20 \times 2500 - \frac{1}{2} \times 20 \times 1600 = 25000 - 16000$$

$\Rightarrow \quad W = 9 \times 10^3$ J **[1]**

56. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity to 60 kmh^{-1}.

Sol. Change in kinetic energy is equal to the work done W.

Given, initial velocity, $u = 60$ kmh^{-1}

$$= 60 \times \frac{5}{18} = \frac{50}{3}\text{ ms}^{-1}$$

$(\because 1 \text{ kmh}^{-1} = 5/18 \text{ ms}^{-1})$

Final velocity, $v = 0$

So, magnitude of change in kinetic energy $= W$ **[1]**

$$= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$\Rightarrow \quad W = \frac{1}{2}m(v^2 - u^2)$$

$$= \frac{1}{2} \times 1500 \times \left(\frac{-50 \times 50}{9}\right)$$

$$= -\frac{1}{2} \times \frac{1500 \times 50 \times 50}{9}$$

$$W = -\frac{625000}{3}$$

$= -208333.3$ J **[1]**

Hence, the work required to be done to stop a car is 208333.3 J.

57. 6.4 kJ of energy causes a displacement of 64 m in a body in the direction of force in 2.5 s. Calculate
(i) the force applied.
(ii) power in Horse Power (HP). (Take, 1 HP = 746 W) **[2009]**

Sol. As change in kinetic energy is equal to the total work done by work energy theorem, so by applying work energy, then you can get net force.
Given, energy, $E = 6.4 \text{ kJ} = 6400 \text{ J}$, time, $t = 2.5 \text{ s}$
Displacement, $s = 64 \text{ m}$, force, $F = ?$,
Power in HP = ?
(i) Energy = Work done = Fs

$$\therefore \quad E = Fs$$
$$\therefore \quad F = \frac{E}{s}$$
$$\Rightarrow \quad F = \frac{6400}{64} = 100 \text{ N}$$ **[1]**

(ii) Power, $P = \frac{E}{t} = \frac{6400}{2.5} = 2560 \text{ W}$

$$= \frac{2560}{746} = 3.43 \text{ HP} \quad (\because 1 \text{HP} = 746 \text{ W})$$ **[1]**

58. A child drops a stone of 1 kg from the top of a tower. Find its kinetic energy, 5 s after it starts falling. (Take, $g = 10 \text{ m s}^{-2}$)

Sol. Given, mass of stone, $m = 1$ kg
Initial velocity, $u = 0$, time, $t = 5$ s
Acceleration due to gravity, $g = 10 \text{ m s}^{-2}$
As from equation of motion,

$$v = u + gt \qquad \text{(for downward motion)}$$
$$\Rightarrow \quad v = 0 + 10 \times 5 \quad \Rightarrow \quad v = 50 \text{ ms}^{-1}$$ **[1]**

$\therefore$ Kinetic energy of the stone is given by

$$\frac{1}{2} mv^2 = \frac{1}{2} \times 1 \times (50)^2 = 1250 \text{ J}$$ **[1]**

59. A mass of 20 kg is dropped from a height of 0.5 m. Find its
(i) velocity and
(ii) KE as it just reaches the ground.

Sol. Given, height, $h = 0.5$ m, mass, $m = 20$ kg
(i) $\therefore \; v^2 = 2gh = 2 \times 10 \times 0.5 = 10 \qquad (\because g = 10 \text{ ms}^{-2})$

$$v = \sqrt{10} = 3.16 \text{ ms}^{-1}$$ **[1]**

(ii) We know that, $\text{KE} = \frac{1}{2} mv^2 = \frac{1}{2} \times 20 \times 10 = 100 \text{ J}$ **[1]**

60. How fast should a man weighing 60 kg run so that, his kinetic energy is becomes 750 J ?

Sol. Given, mass, $m = 60$ kg, KE = 750 J **[1]**

$$\because \quad \text{KE} = \frac{1}{2} mv^2$$
$$\therefore \quad v = \sqrt{\frac{2\text{KE}}{m}} = \sqrt{\frac{2 \times 750}{60}} = \sqrt{25} = 5 \text{ ms}^{-1}$$ **[1]**

61. A moving body weighing 400 N possesses 500 J of KE. Calculate the velocity with which the body is moving (Take, $g = 10 \text{ m/s}^2$). **[2012]**

Sol. Calculate mass of the body from the given weight and then calculate velocity from KE.
Given, weight, $w = 400 \text{ N} = mg \Rightarrow m = \frac{w}{g}$
Kinetic energy, KE = 500 J
Velocity, $v = ?$ and $g = 10 \text{ m/s}^2$ **[1]**

$$\text{KE} = \frac{1}{2} mv^2 = \frac{1}{2} \frac{w}{g} v^2 \qquad \left(\because m = \frac{w}{g}\right)$$
$$500 = \frac{1}{2} \times \frac{400}{10} \times v^2$$
$$\Rightarrow \quad v = \sqrt{\frac{500 \times 20}{400}} = 5 \text{ m/s}$$ **[1]**

62. Determine the decrease in the kinetic energy of a moving body, if its velocity reduces to 1/3 rd of the initial velocity.

Sol. Let us assume that original kinetic energy,

$$K = \frac{1}{2} mv^2$$

When velocity reduces to 1/3rd of the initial velocity.

$$v' = \frac{1}{3} v$$
$$\therefore \quad \text{New kinetic energy, } K' = \frac{1}{2} m\left(\frac{1}{3} v\right)^2$$
$$= \frac{1}{9}\left(\frac{1}{2} mv^2\right) = \frac{K}{9}$$ **[1]**
$$\therefore \quad \text{Decrease in KE} = K - K' = K - \frac{K}{9} = \frac{8K}{9}$$ **[1]**

63. If two bodies have masses in the ratio 1 : 8, have their speed in the ratio 4 : 5, find the ratio of their KE.

Sol. Given, $m_1/m_2 = 1:8$, and $v_1/v_2 = 4:5$

$$\Rightarrow \quad \frac{\text{KE}_1}{\text{KE}_2} = \frac{1/2\; m_1 v_1^2}{1/2\; m_2 v_2^2} = \frac{m_1}{m_2}\left(\frac{v_1}{v_2}\right)^2 = \frac{1}{8} \times \left(\frac{4}{5}\right)^2$$
$$= \frac{1}{8} \times \frac{16}{25} = \frac{2}{25} = 2:25$$
$$\therefore \quad \text{KE}_1 : \text{KE}_2$$ **[2]**

64. A rocket is moving up with a velocity v. If the velocity of this rocket is suddenly tripled, what will be the ratio of two kinetic energies?

Sol. Given, $v_1 = v$ and $v_2 = 3v$

$\therefore$ Kinetic energy of rocket, $K = \frac{1}{2} mv^2$

The ratio of two kinetic energies, $\frac{K_1}{K_2} = \frac{\frac{1}{2} mv_1^2}{\frac{1}{2} mv_2^2}$

$$\frac{K_1}{K_2} = \frac{v_1^2}{v_2^2} \qquad (\text{put } v_2 = 3v \text{ and } v_1 = v)$$

$\therefore$ We get $= \frac{v^2}{(3v)^2} = \frac{v^2}{9v^2} = \frac{1}{9} \Rightarrow \frac{K_1}{K_2} = \frac{1}{9}$

Thus, the ratio of two kinetic energies $K_1 : K_2 = 1 : 9$. ***[2]***

65. The kinetic energy of an object of mass m moving with a velocity of 5 ms^{-1} is 25 J. What will be its kinetic energy when its velocity is increased three times?

Sol. Kinetic energy, KE $= \frac{1}{2} mv^2$

where, m = mass of object and

and v = velocity of the object.

Here, mass (m) is same in both the cases

$$\therefore \quad \frac{K_1}{K_2} = \left(\frac{v_1}{v_2}\right)^2$$

Initial kinetic energy, $K_1 = 25$ J

Initial velocity, $v_1 = 5 \text{ ms}^{-1}$ ***[1½]***

New kinetic energy, $K_2 = ?$

Final velocity, $v_2 = 3v_1 = 3 \times 5 = 15 \text{ ms}^{-1}$

$$\therefore \quad \frac{25}{K_2} = \left(\frac{5}{15}\right)^2$$

$$\Rightarrow \quad \frac{25}{K_2} = \frac{1}{9}$$

$$\Rightarrow \quad K_2 = 225 \text{ J}$$ ***[1½]***

66. A body of mass 50 kg has a momentum of 3000 kg-ms^{-1}. Determine

(i) the kinetic energy of the body.

(ii) the velocity of the body. ***[2010]***

Sol. (i) Kinetic energy, $E_K = \frac{p^2}{2m} = \frac{(3000)^2}{2 \times 50} = 90000$ J ***[1]***

(ii) Velocity of the body, $v = \frac{p}{m} = \frac{3000}{50} = 60 \text{ ms}^{-1}$ ***[1]***

67. A body of mass 0.2 kg falls from a height of 10 m to a height of 6 m above the ground. Find the loss in potential energy taking place in the body (Take, $g = 10 \text{ ms}^{-2}$).

Sol. Given, mass $m = 0.2$ kg,

height, $h_2 = 10$ m, height, $h_1 = 6$ m

Loss in PE = ? and $g = 10 \text{ m/s}^2$

Loss in PE = $mg(h_2 - h_1)$

$= 0.2 \times 10 (10 - 6) = 8$ J ***[2]***

68. The power of a motor pump is 5 kW. How much water per minute the pump can raise to a height of 20 m? (Take, $g = 10 \text{ ms}^{-2}$)

Sol. Given, power, $P = 5$ kW

Time, $t = 60$ s, height, $h = 20$ m

Energy supplied to the pump = Power × Time

$= 5 \text{ kW} \times 1 \text{ min} = 5000 \text{ W} \times 60 \text{ s} = 3 \times 10^5$ J

$\therefore$ Energy, $E = mgh$

$$\Rightarrow \quad m = \frac{E}{gh} = \frac{3 \times 10^5}{10 \times 20} = 1.5 \times 10^3 \text{ kg}$$

So, volume of water lifted per minute $= \frac{\text{mass}}{\text{density}}$

$$= \frac{1.5 \times 10^3}{10^3} \quad (\because \text{density of water, } \rho = 1000 \text{ kgm}^{-3})$$

$= 1.5 \text{ m}^3$ ***[2]***

69. A shotput player throws a shotput of mass 3 kg. If it crosses the top of wall 2 m high at a speed of 4 ms^{-1}. Compute the total mechanical energy gained by the shotput when it crosses the wall. (Take, $g = 9.8 \text{ ms}^{-2}$)

Sol. Given, $m = 3$ kg, $h = 2$ m, $v = 4 \text{ ms}^{-1}$, $g = 9.8 \text{ ms}^{-2}$

Total mechanical energy = KE + PE $= \frac{1}{2} mv^2 + mgh$

$$= \frac{1}{2} \times 3 \times 16 + 3 \times 9.8 \times 2$$

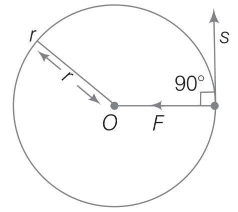
$= 24 + 58.8 = 82.8$ J ***[2]***

70. What is the amount of work done in the following cases? Justify your answer by giving the appropriate reason.

(i) By an electron revolving in a circular orbit of radius r around a nucleus.

(ii) By the force of gravity, when a stone of mass m is dropped from the top of a multi-storeyed building of height h.

Sol. (i) Work done is zero as shown in the figure. When electron revolves around the nucleus, a centripetal force F acts along the radius towards the centre O. The displacement (s) acts tangentially, therefore the angle between the force and the displacement is 90°. Therefore,



$$W = Fs\cos 90° = 0 \quad (\because \cos 90° = 0)$$ **[1]**

(ii) We know that, $W = mgh$

As the stone is dropped, its PE starts to convert into KE.

Let its speed be v, then from $v^2 = 2gh$

(when stone reaches the ground)

$$\Rightarrow \quad \text{KE} = \frac{1}{2}mv^2 = \frac{1}{2} \times m \times 2gh = mgh$$

$$\Rightarrow \quad W = mgh$$ **[1]**

71. At a height of 20 m above the ground, an object of mass 4 kg is released from rest. It is travelling at a speed of 20 ms^{-1} when it hits the ground. The object does not rebound and the gravitational field strength is 10 Nkg^{-1}.

How much energy is converted into heat and sound on impact?

Sol. Given, height above the ground, $h = 20$ m

Mass of the ball, $m = 4$ kg

Speed of the ball while striking the ground,

$$v = 20\ \text{ms}^{-1}$$

Acceleration due to gravity, $g = 10$ Nkg^{-1}

According to law of conservation of energy, all the energy of the ball will be converted into sound and heat energy because the ball does not rebound. **[1]**

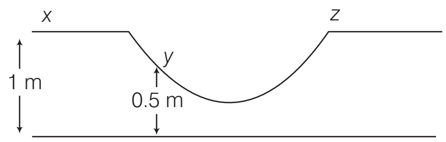
$$\therefore \text{ Energy of the ball} = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 4 \times (20)^2$$

$$= 800\ \text{J}$$

Hence, 800 J of energy will be converted into heat and sound. **[2]**

72. A particle is placed at the point A of a frictionless track xyz as shown in figure. It is pushed slightly towards right. Find its speed when it reaches the point y. (Take, $g = 10$ m/s^2)



Sol. Let us take the gravitational potential energy to be aero at the horizontal surface shown in the figure. The potential energies of the particle at x and y are

$$U_x = Mg\,(1\,\text{m}) \quad \text{and} \quad U_y = Mg\,(0.5\,\text{m})$$ **[1]**

The kinetic energy at the point X is zero. As the track is frictionless,no energy is lost. The normal force on the particle does no work. Applying the principle of conservation of energy,

$$U_x + K_x = U_y + K_y$$

or, $$Mg(1\,\text{m}) = Mg(0.5\,\text{m}) + \frac{1}{2}Mv_y^2$$

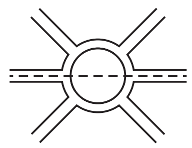
or, $$\frac{1}{2}v_y^2 = g(1\,\text{m} - 0.5\,\text{m})$$

$$= (10\,\text{m/s}^2) \times 0.5\,\text{m}$$

$$= 5\,\text{m}^2/\text{s}^2$$

$$v_y = \sqrt{10}\,\text{m/s}.$$ **[2]**

73. A boy is moving on a straight road against a frictional force of 5 N. After travelling a distance of 1.5 km, he forgot the correct path at a round about of radius 100 m as shown in figure.



However, he moves on the circular path for one and half cycle and then he moves forward up to 2 km. Calculate the work done by him.

Sol. Given, force applied by boy against friction = 5 N

Displacement on the circular path

= one cycle + half cycle = 0 + half cycle

= 0 + diameter of circular path

($\because$ displacement depends on initial and final point)

$= 0 + 2r = 0 + 2 \times 100$ (given, $r = 100$ m)

$= 0 + 200 = 200$ m **[1/2]**

$\therefore$ Total displacement = 1.5 km + 200 m + 2 km

$= 1.5 \times 1000 + 200 + 2 \times 1000$ m ($\because$ 1km = 1000 m)

$= 3700$ m **[1/2]**

Work done by boy $= Fs\cos\theta$

$$= 5 \times 3700 \times \cos 0° = 18500\ \text{J} \quad \begin{pmatrix} \because & \theta° = 0° \\ \therefore & \cos 0° = 1 \end{pmatrix}$$ **[1]**

CHAPTER EXERCISE

2 Marks Questions

1. If a body of mass m falls through a height h. Establish an expression for the work done by the gravity.
2. Explain any two examples, when the work done is
   (i) positive and (ii) negative.
3. A body is acted upon by a force. State two conditions under which the work done could be zero.
4. State the two factors on which the power consumed or produced by a body depends. Explain the answer along with the example.
5. Differentiate between watt and watt hour.
6. If an electric heater of power P watt is used for time t hour, so how much energy does it consume? Give your for power consumed in expression (i) kWh and (ii) Joule.
7. What do you understand by electron volt and establish its relation with joule?
8. How does rain water possess kinetic energy?
9. State which would have greater effect on kinetic energy of an object doubling the mass or doubling the velocity?

3 Marks Questions

10. Define 1 erg of work and establish a relationship between erg and joule.
11. Assume that a boy of mass m climbs up a staircase of vertical height h. What is the work done by the boy against the force of gravity? What would have been the work done, if he uses a lift in climbing the same vertical height?
12. Mention the name of three forms of kinetic energy and give one example of each form.
13. Mention the type of energy (i.e., kinetic energy K or potential energy U) possessed in the following cases.
    (i) A moving bus
    (ii) A moving cricket ball
14. What do you mean by gravitational potential energy? Derive an expression for it.
15. Mention the form of energy that is possessed by a body in the following cases
    (i) A shooting arrow
    (ii) A called up spring and an air gun.
    (iii) A fish moving in water.

4 Marks Questions

16. Answer the given questions.
    (i) Determine the kinetic energy of a body of mass 1m moving with uniform velocity of 10 ms^{-1}.
    (ii) If the speed of the car is halved, how does the kinetic energy change?
        (a) Determine the workdone by the force F in moving the block X, 5 m along the slope?
        (b) By how much amount is the potential energy of block X increased?
        (c) Point out the difference in work done by the force and the increase in the potential energy of the block.
17. Named the energy transformation takes in following instruments.
    (i) Steam engine
    (ii) Atomic bomb
    (iii) Dry cell
    (iv) Electric generator

Numerical Based Questions

18. A boy pulls a toy car with force 50 N through a string which makes an angle of 30° with the horizontal, so as to move the toy by the distance of 1m in the horizontal direction. If the string were inclined at an angle of 45° with the horizontal.
    How much work would he apply along the string in order to moves it through the same distance of 1m? (Given, $\cos 30° = 0.8668$, $\cos 45° = 0.7071$)
    Ans. 43.34 J, 35.35 J
19. Find the power of an engine required to lift 10^5 kg of coal per hour from a mine 360 m deep. ***Ans.*** 10^5 W

20. Determine the velocity of a body of mass 100 g having a kinetic energy of 20 J. ***Ans.*** 20 m/s

21. How much energy is gained by a box of mass 20 kg when a man
(i) carrying the box waits for 5 min for a bus ?
(ii) runs carrying the box with a speed of 3 ms^{-1} to catch the bus ?
(iii) raise the box by 0.5 m in order to place it inside the bus ? ***Ans.*** (i) 0, (ii) 90J, (iii) 100J

22. A force is applied on a body of mass 20 kg moving with a velocity of 40 ms^{-1}. The body attains a velocity of 50 ms^{-1} in 2 s. Calculate the work done by the body. ***Ans.*** 9000 J

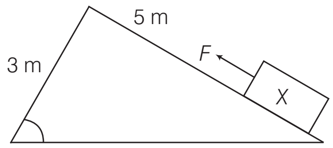
23. How much work is required to be done on a ball of mass 50 g to give it a momentum of 600g cms^{-1}? ***Ans.*** 3600 erg

24. When a boy of mass 40 kg runs up height of 50 steps each 10 cm high in 5 s. Determine ***Ans.*** (i) 2000 J, (ii) 400 W
(i) the work done by the boy.
(ii) the power developed.

25. A rocket of 3×10^6 kg mass takes off from a launching pad and acquires a vertical velocity of 1 Km s^{-1} at an altitude of 25 Km. Calculate (i) PE (ii) KE. (Take, $g = 10$ ms^{-2}). ***Ans.*** (i) 7.5×10^{11} J, (ii) 1.5×10^{12} J

26. A metal ball of mass 2 kg is allowed to fall freely from rest from a height of 5 m above the ground.
(i) Determine the potential energy possessed by the ball when initially at rest.
(ii) What is the kinetic energy of the ball just before hitting the ground ?
(iii) What happens to the mechanical energy after the ball hits the ground and comes to rest? ***Ans.*** (i) 100 J, (ii) 100 J, (iii) 1000 J

27. There is a block X, whose weight is 100 N, is pulled up a slope of length 5 m by a constant force F (=150 N) as given in the figure.



(i) Determine the workdone by the force F in moving the block X, 5 m along the slope?
(ii) By how much amount is the potential energy of block X increased?
(iii) Point out the difference in work done by the force and the increase in the potential energy of the block. ***Ans.*** (i) 500 J, (ii) 300 J, (iii) The difference, i.e., 200 J energy is used in doing work against frictional force

28. A stone of mass 500 g is thrown vertically upwards with a velocity of 15 ms^{-1}. Calculate
(i) the PE at the greatest height
(ii) KE on reaching the ground
(iii) the total energy at its half way point. ***Ans.*** (i) 56. 25 J, (ii) 56. 25 J, (iii) 56.25 J

ARCHIVES* *(Last 7 Years)*

Collection of Questions Asked in Last 7 Years' (2018-2012) ICSE Class 10th Examinations

2018

1. (i) State and define the SI unit of power.

(ii) How is the unit horse power related to the SI unit of power? *[2]*

2. (i) Why is the motion of a body moving with a constant speed around a circular path said to be accelerated?

(ii) Name the unit of physical quantity obtained by the formula $\frac{2K}{v^2}$, where K is kinetic energy and v is linear velocity. *[2]*

3. State the energy changes in the following cases while in use

(i) An electric iron.

(ii) A ceiling fan. *[2]*

4. (i) Derive a relationship between SI and CGS unit of work.

(ii) A force acts on a body and displaces it by a distance S in a direction at an angle θ with the direction of force. What should be the value of θ to get the maximum positive work? *[3]*

2017

5. If the power of a motor be 100 kW, at what speed can it raise a load of 50,000 N? *[2]*

6. Name the process used for producing electricity using nuclear energy. *[1]*

2016

7. A boy weighing 40 kgf climbs up a stair of 30 steps each 20 cm high 4 min and a girl weighing 30 kgf does the same in 3 min. Compare

(i) the work done by them. *[1]*

(ii) the power developed by them. *[1]*

2015

8. How is work done by a force measured, when the force

(i) is in the direction of displacement ? *[1]*

(ii) is at an angle to the direction of displacement ? *[1]*

9. State the energy changes in the following while in use:

(i) Burning of a candle

(ii) A steam engine. *[2]*

10. Rajan exerts a force of 150 N in pulling a cart at a constant speed of 10 m/s. Calculate the power exerted. *[3]*

11. Explain briefly why the work done by a fielder, when he takes a catch in a cricket match is negative. *[3]*

2014

12. The conversion of part of energy in to an undesirable form is called .... *[2]*

13. A body is thrown vertically upwards. Its velocity keeps on decreasing. What happens to its KE as its velocity becomes zero? *[2]*

14. (i) When does a force do Work? *[1]*

(ii) What is work done by the moon when it revolves around the earth? *[1]*

15. Calculate the change in kinetic energy of a moving body, if its velocity reduced to 1/3rd of the initial velocity? *[2]*

2013

16. If girl of mass 3.5 kg climps up from the first floor of building at a height 4 m above the ground to the third floor at height of 12 m above the ground. What will be the increase in gravitational potential energy? (Take, $g = 10\ ms^2$) *[4]*

2012

17. A ball is placed on a compressed spring. When the spring is released, the ball is observed to fly away.

(i) What form of energy does the compressed spring possess?

(ii) Why does the ball fly away? *[2]*

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 A women pushes a trunk on railway platform which has a rough surface. She supplies a force of 100 N over a distance of 10 m. Thereafter, she gets progressively tired and her applied force reduces linearly with distance to 50 N. The total distance by which the trunk has been moved is 20 m. Calculate the net work done by the two forces over 20 m.

(a) 1000 J (b) 500 J (c) 1750 J (d) 1500 J

2 A body of mass 0.5 kg travels in a straight line with velocity $v = ax^{3/2}$, where $a = 5\,\text{ms}^{-2}$. What is the work done by the net force during its displacement from $x = 0$ to $x = 2$ m?

(a) 150 J (b) 100 J (c) 50 J (d) 200 J

3 A boy P has a mass of 20 kg and is moving with a velocity of 5 ms^{-1}. Another boy Q has a mass of 5 kg and is moving with a velocity of 20 ms^{-1}. Calculate the ratio of the momentum of P and Q.

(a) 2 : 1 (b) 1 : 1 (c) 1 : 2 (d) 3 : 2

4 A boy of mass 40 kg walks up a flight of stairs to a vertical distance of 12 m in a time interval of 40 s. Rate at which the boy is doing work against the force of gravity is

(a) 500 W (b) 400 W (c) 120 W (d) 100 W

5 An electron and proton are detected in a cosmic ray experiment, the first with kinetic energy 10 keV and the second the 100 keV. Obtain the ratio of their speeds. (Take, electron mass = 9.11×10^{-31}kg, proton mass $= 1.67 \times 10^{-27}$kg, and $1\,\text{eV} = 1.60 \times 10^{-19}$J)

(a) 12.81 (b) 6.16 V (c) 13.54 (d) 11.62 V

6. The total work done on a particle is equal to the change in its kinetic energy

(a) always, if force is conservative
(b) Only if gravitational force alone acts on it
(c) Only if elastic force alone acts on it
(d) None of the above

7 A body is moved along a straight road by a machine delivering constant power. The distance moved by the body in time t is proportional to

(a) $t^{1/2}$ (b) $t^{3/4}$ (c) $t^{3/2}$ (d) t^2

8 A pump of 200 W power is lifting 2 kg water per second from an average depth of 10 m. The velocity with which water comes out of the pump is (Take, $g = 9.8\,\text{ms}^{-2}$)

(a) 2 ms^{-1} (b) 2.5 ms^{-1} (c) 4 ms^{-1} (d) 10.2 ms^{-1}

9 If the force acting on a body is inversely proportional to its speed, then its kinetic energy is

(a) linearly related to time
(b) inversely proportional to time
(c) inversely proportional to the sequence of time
(d) a constant

10 A pump motor is used to deliver water at a certain rate from a given pipe. To obtain twice as much water from the same pipe in the same time, the power of the pump has to be increased to

(a) 2 times (b) 4 times (c) 8 times (d) 16 times

Answers

1. (c) **2.** (c) **3.** (b) **4.** (c) **5.** (c) **6.** (a) **7.** (c) **8.** (d) **9.** (a) **10.** (c)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 238.

CHAPTER 3

Machines

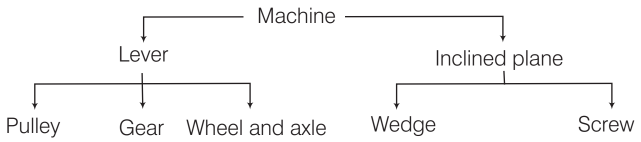
Chapter Objectives

- Ideal and Actual Machine
- Lever
- Pulley
- Gears

Machine is a device which helps us to do the work at one point and deliver it at another point with a view of accomplishing the work easily.

Basically, machines act as **force multiplier**, i.e., the net effort produced by the machine is much more than the effort applied. e.g., A jack is used to lift a bus or car, pulleys are used to lift heavy loads. In all such examples, the effort is much less than the load. So, we can say that machines act as a force multiplier.

Simple machines can be classified (or categorised) into two major classes, one is lever and other is inclined plane. Further it can be classified as shown below.



Classification of Machine

In this chapter, we will be exploring all the functions and terms related to machine, there after lever and inclined plane as important types of simple machine will be studied.

Terms Related to Machine

The terms related to machine are as follows

Load It is the resistive or opposing force against which the machine works. It is denoted by L.

Effort It is the force applied on the machine to overcome the load. It is denoted by E.

Mechanical Advantage (MA) It is the ratio of the load to the effort. It is denoted by MA.

It is expressed as, $\text{MA} = \dfrac{L}{E}$

(i) If MA > 1 (i.e., $L > E$), then machine works as force multiplier.

(ii) If MA < 1 (i.e., $L < E$), then machine gains speed, i.e., machine can help us to achieve greater movement of load by smaller movement of effort, e.g., The blades of a scissors more longer with smaller movement of handles.

(iii) If MA = 1 (i.e., $L = E$), then machine changes the direction of effort, i.e., machine can change the direction of effort to a more convenient direction, e.g., To lift the bucket from well, effort is applied on pulley in downward direction while bucket is pushed in upward direction.

Note Being a ratio of two like quantities (such as both load and effort are some types of forces) MA has no unit.

Velocity Ratio (VR) It is defined as the ratio of velocity of the effort to the velocity of the load. It is denoted by VR.
It is expressed as,

$$VR = \frac{\text{Velocity of effort } (v_E)}{\text{Velocity of load } (v_L)}$$

In terms of distance moved by a particular force, velocity ratio is the ratio of the distance moved by the effort to the corresponding distance moved by the load.

$$\because \quad VR = \frac{v_E}{v_L} = \frac{d_E/t}{d_L/t} = \frac{d_E}{d_L}$$

Here, d_L and d_E are the distances moved in same time t by the load and the effort, respectively.

Note Being a ratio of two like quantities, velocity ratio also has no unit.

Work Input The work done on the machine by the effort is called the work input (W_{input} or W_i). If an effort E causes a displacement d in its own direction, then

$$\text{Work input} = \text{Effort} \times \text{Displacement}$$
$$= E \times d$$

Work Output *The work output (W_{output} or W_o) can be classified into two ways*

(i) **Actual Output** The entire work done by the machine is known as actual output.

If L is the total load (load lifted by the machine and by resistance overcome) displaced through a distance d, then actual output will be treated as

$\Rightarrow$ total load $(L) \times$ distance (d)

i.e., Actual output $= L \times d$.

(ii) **Useful Output** The useful work done by the machine is termed as useful output.

If l is the useful load displaced through a distance d, then useful output will be treated as

$= \text{useful load } (l) \times \text{distance } (d)$

i.e., Useful output $= l \times d$.

Example 1. **If a machine is used to lift a load of 50 N such that resistance due to friction and movable part of machine is 15 N, then the total lifted load is 65 N, i.e., (50 + 15) N. If the displacement is caused through 2 m, then find actual and useful output.**

Sol. Actual output = total load × distance

$= 65\text{N} \times 2\text{m} = 130\text{J}$

and useful output = useful work × distance

$= 50\text{N} \times 2\text{m} = 100\text{J}$

Note In some problems or descriptions, only the term output is used. Hence, we will use this output as useful output not as actual output.

Efficiency (η) It is defined as the ratio of work done (W_{output}) by the machine to work done (W_{input}) on the machine. It is denoted by η. It is expressed as

$$\eta = \frac{\text{Work done on the load}}{\text{Work done by the effort}} = \frac{W_{output}}{W_{input}}$$

But efficiency is usually expressed in percentage, so we may write

$$\text{Efficiency, } \eta = \frac{W_{output}}{W_{input}} \times 100\%$$

Ideal and Actual Machine

Ideal Machine or Perfect Machine

Machine works on the principle of conservation of energy. The machine which converts are input work (effort) into output work (load) without any wastage of work is called ideal machine.

Work done (input) = Work done (output)

Thus, an ideal machine can be defined as follows

A machine whose parts are weightless and frictionless such that whatever the energy given to it, is same as the energy produced by it, is called as an ideal machine. The efficiency of an ideal machine is 100%. An ideal machine cannot be made practically because some part of the input is wasted in moving the parts of the machine and in overcoming the friction between the various parts of a machine.

Ideal Mechanical Advantage (IMA)

The ratio between total load moved to the effort (E) applied is called the ideal mechanical advantage. If L_0 is the total load such that L is the useful load and l is the load due to friction and movable parts of the machine, then

$$IMA = \frac{L_0}{E}, \text{ where } L_0 = L + l$$

Note For an ideal machine, IMA = VR.

Actual Machine

In an actual machine, the output energy is always less than the input energy indicating that there is some loss of energy during its operation, reasons of which are listed below

(i) The moving parts of the machine are neither weightless nor smooth or frictionless.

(ii) Different parts of the machine are not perfectly rigid.

(iii) The elastic materials (string) are not perfectly elastic.

Actual Mechanical Advantage (AMA)

The ratio of useful load (L) moved to the effort (E) applied is called the actual mechanical advantage.

$$\text{AMA} = \frac{L}{E}$$

Key Points

(i) For all practical or actual machines, efficiency is less than 1 (i.e., $\eta < 1$).

(ii) If mechanical advantage is mentioned in a question, it means only the actual mechanical advantage but not the ideal machine advantage.

(iii) A machine of η % efficient means η% of the total energy supplied to the machine and remaining $(100 - \eta)$% of the energy is lost to the surroundings.

(iv) The energy lost in overcoming the frictional force between the moving parts of a machine, is the most common type of loss of energy in it.

Relation between η, MA and VR

Consider a practical machine which overcomes a load L by the application of an effort E in time t. Suppose the displacement of effort be d_E and the displacement of load be d_L.

Now, we can write

Work input (W_{input})

$$= \text{Effort} \times \text{Displacement of effort} = E \times d_E$$

Work output (W_{output})

$$= \text{Load} \times \text{Displacement of load}$$

$$= L \times d_L$$

$$\text{Efficiency, } \eta = \frac{W_{\text{output}}}{W_{\text{input}}} = \frac{L \times d_L}{E \times d_E} = \frac{L}{E} \times \frac{d_L}{d_E} = \frac{L}{E} \times \frac{1}{\frac{d_E}{d_L}}$$

As, we know that

$$\text{MA} = \frac{L}{E} \quad \text{and} \quad \text{VR} = \frac{d_E}{d_L}$$

$$\therefore \qquad \eta = \frac{\text{MA}}{\text{VR}} \quad \text{or} \quad \boxed{\text{MA} = \eta \times \text{VR}}$$

For all practical machines, mechanical advantage is always less than velocity ratio,

i.e., $\text{MA} < \text{VR}$

Example 2. An effort of 10 kgf is applied on a machine through a distance of 100 cm, when a load of 100 kgf moves through a distance of 5 cm.

Calculate the

(i) velocity ratio

(ii) mechanical advantage

(iii) efficiency of the machine

Sol. Given, effort, $E = 10$ kgf, load, $L = 100$ kgf

Distance moved by effort, $d_E = 100$ cm

and distance moved by load, $d_L = 5$ cm

(i) Velocity Ratio (VR)

$$= \frac{\text{Distance through which the effort moves } (d_E)}{\text{Distance through which the load moves } (d_L)}$$

$$= \frac{100 \text{ cm}}{5 \text{ cm}} = 20$$

(ii) Mechanical Advantage (MA)

$$= \frac{\text{Load } (L)}{\text{Effort } (E)} = \frac{100 \text{ kgf}}{10 \text{ kgf}} = 10$$

(iii) Percentage efficiency, $\eta = \frac{\text{MA}}{\text{VR}} \times 100$

$$= \frac{10}{20} \times 100 = 50\%$$

Example 3. How is the mechanical advantage related with the velocity ratio for an actual machine? State whether the efficiency of such a machine is equal to 1, less than 1 or more than 1.

Sol. For a machine,

$$\frac{\text{work output}}{\text{work input}} = \frac{L \times d_L}{E \times d_E}$$

or
$$= \frac{\frac{L}{E}}{\frac{d_E}{d_L}} = \frac{\text{Mechanical Advantage (MA)}}{\text{Velocity Ratio (VR)}}$$

For an actual machine,

work output < work input

$$\therefore \qquad \frac{\text{MA}}{\text{VR}} < 1$$

or $\text{MA} < \text{VR}$

$$\therefore \quad \text{Efficiency, } \eta = \frac{\text{MA}}{\text{VR}} < 1$$

Thus, for an actual machine, efficiency will always be less than 1.

Example 4. A machine is operated by an effort of 80 N acting downward and moving through a downward displacement of 0.15 m. The load of mass 10 kg, is raised up by 10 cm. Calculate the MA, VR, work input, useful work output and efficiency (Take, $g = 10 \text{ ms}^{-2}$).

Sol. $\text{MA} = \dfrac{\text{Load }(L)}{\text{Effort }(E)}$ ($L = 10 \text{ kg} = 10 \times 10 = 100 \text{ N}$, $E = 80 \text{ N}$)

$= \dfrac{100}{80} = 1.25$

$\text{VR} = \dfrac{d_E}{d_L} = \dfrac{0.15}{0.1} = 1$

Work input $= E \times d_E = 80 \times 0.15 = 12 \text{ J}$

Useful work output $= L \times d_L = 100 \times \dfrac{10}{100} = 10 \text{ J}$

Efficiency, $\eta = \dfrac{\text{Output}}{\text{Input}} = \dfrac{10}{12} = 0.833 = 83.3\%$

CHECK POINT 01

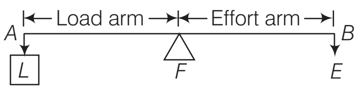
1. Name a device that helps us to do the work at one point and deliver it to the another point.
2. What happens when mechanical advantage (MA) becomes equal to one?
3. Write an expression for calculating the efficiency of a machine.
4. "An ideal machine cannot be made practically.'' Justify the statement.
5. Give one example each of a machine which is used to
   (i) multiply force
   (ii) change direction of application of force.
6. Can a simple machine act as a force multiplier and a speed multiplier at the same time ?
7. State whether in actual machines, the output energy is greater or lesser than input energy. Give reason.

Lever

A lever is a straight or bent rigid rod which can be turned or rotated about a fixed point called fulcrum. It is one of the most common and simple machine.

Principle of a Lever

Consider a lever (i.e., a straight rod) *AB* with balanced point at *F* (fulcrum for the lever). A load *L* acts at point *A* of the lever and effort *E* acts at point *B* as shown in the diagrams.



Lever

The perpendicular distance of the effort from the fulcrum is called the **effort arm** i.e., *BF*. The perpendicular distance of the load from the fulcrum is called the **load arm** i.e., *AF*. For an ideal lever, it is assumed that the lever is weightless and frictionless. A lever works on the principle of moment. In the equilibrium position of the lever, by the principle of moment,

moment of load about the fulcrum

= moment of effort about the fulcrum

The two moments are always in opposite directions.

In figure, the moment of load is anti-clockwise while the moment of effort is clockwise. Thus, we can write

$$\boxed{\text{Load} \times \text{Load arm} = \text{Effort} \times \text{Effort arm}}$$

This is also called principle of lever.

or $\quad L \times AF = E \times BF \quad$ or $\quad \dfrac{L}{E} = \dfrac{BF}{AF}$

$\therefore$ Mechanical Advantage (MA), $\dfrac{L}{E} = \dfrac{\text{Effort arm}}{\text{Load arm}} = \dfrac{BF}{AF}$

This relation is known as the **law of levers.**

From the above equation, it is clear that, if

(i) Effort arm = Load arm, MA = 1
(ii) Effort arm < Load arm, MA < 1
(iii) Effort arm > Load arm, MA > 1

Note Mechanical advantage of a lever can be increased either by increasing its effort arm or by decreasing its load arm.

Types of Levers

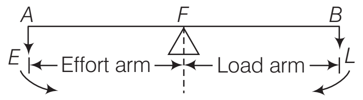
There are three types of levers

(i) Class I lever (ii) Class II lever (iii) Class III lever

Class I Lever

In this type of lever, the effort (*E*) and the load (*L*) are situated on either side of the fulcrum (*F*).

e.g., A pair of scissors, handle of water pump, a catapult and the nodding of the human head, etc.



Class I lever

MA of class I lever $= \dfrac{\text{Effort arm}}{\text{Load arm}}$

VR of class I lever $= \dfrac{d_E}{d_L}$

Characteristics of a Class I Lever

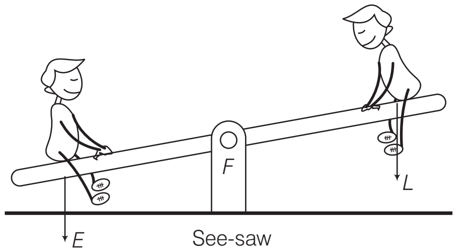
(i) Fulcrum lies in between the load and the effort.
(ii) By moving the fulcrum towards the load, i.e., by decreasing load arm. Mechanical advantage can be increased.
(iii) For class I lever, the mechanical advantage and velocity ratio can have any value either greater than 1 or equal to 1 or less than 1.

e.g.,

(i) The beam of a common balance (MA = 1)
(ii) A crowbar (MA > 1)
(iii) A pair of scissors (MA < 1)

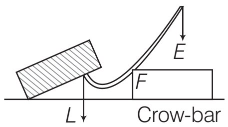
Examples of Class I Lever

(i) **A See-saw** Two boys are playing with a see-saw as shown in the figure. The lighter boy sits far away from the fulcrum as compared to the heavier boy such that the moments of both of them are same.



See-saw

(ii) **A Crow-bar** To have the less effort in lifting the load, longer crow-bar with more fulcrum is required. The reason behind the less effort is increasing mechanical advantage with increasing the effort arm.



Crow-bar

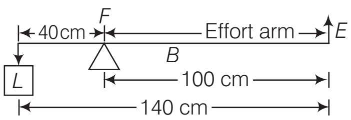
Another examples of class I lever are

(i) a pair of scissors
(ii) pliers
(iii) a claw hammer
(iv) human forearm

Example 5. **A crow-bar of length 140 cm has its fulcrum situated at a distance of 40 cm from the load. Calculate the mechanical advantage of the crow-bar.**

Sol. If fulcrum is situated in the middle of effort arm and load arm, it is a class I lever.

We have length of crow-bar = 140cm



Now,
Mechanical Advantage (MA) of crow-bar

$$= \frac{\text{Effort arm}}{\text{Load arm}} = \frac{100}{40} = \frac{5}{2} = 2.5\,\text{cm}$$

and distance of fulcrum from the load = 40 cm

$\therefore$ Load arm = 40 cm

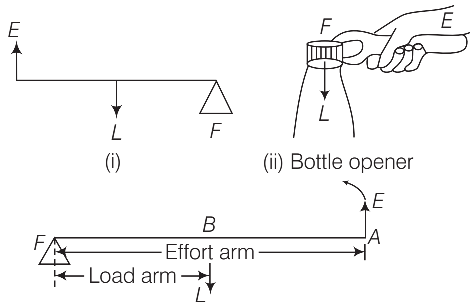
and effort arm = length of crow-bar – load arm

$= 140 - 40 = 100\,\text{cm}$

Class II Lever

In this type of lever, the load is situated between fulcrum and effort, e.g., A bottle opener, a wheel barrow, a paper cutter, raising the weight of the human body on toes, etc.

As, effort arm is always greater than the load arm, then MA and VR are always more than 1.



Characteristics of a Class II Lever

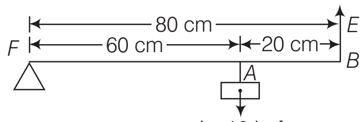
(i) Load lies in between the effort and the fulcrum.
(ii) Mechanical advantage and velocity ratio are always more than one because the effort arm is always longer than the load arm.
(iii) If load is moving towards the fulcrum, then load arm decreases and consequently the mechanical advantage increases.
(iv) Class II levers always act as a force multiplier.

Examples of Class II Lever

Some examples of class II lever are

(i) lemon squeezer (ii) nut cracker
(iii) hinged door

Example 6. The diagram below shows a lever in use.



(i) To which class of lever does it belong?
(ii) If $FA = 60$ cm, $AB = 20$ cm, find its MA.
(iii) Find the value of effort (E).

Sol. (i) From the given figure, it is clear that load lies in between fulcrum (F) and effort (E).

$\therefore$ Lever is of class II.

(ii) From the above figure, MA of lever

$$= \frac{\text{Effort arm } (FE)}{\text{Load arm } (FA)} = \frac{80\text{ cm}}{60\text{ cm}} = \frac{4}{3} = 1.33\,\text{cm}$$

(iii) On balancing the moments, we can write

$$E \times \text{effort arm } (FE) = L \times \text{load arm } (FA)$$

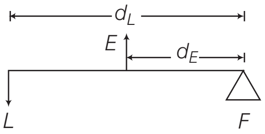
$\Rightarrow \quad E \times 80 = L \times 60$

$\therefore \quad E = L\left(\frac{60}{80}\right)$

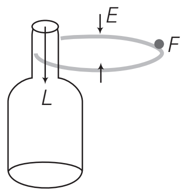
$$= 10 \times \frac{3}{4} = \frac{30}{4}\,\text{kgf} = 7.5\,\text{kgf}$$

Class III Lever

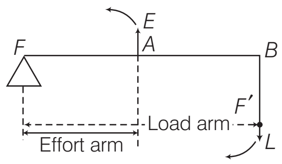
In this type of lever, effort is situated between the load and the fulcrum. As effort is situated between the load and the fulcrum, then MA and VR is always less than 1.
e.g., Sugar tongs, foot treadle, etc.



(i)



(ii) Sugar tongs



(iii) Class III lever

Characteristics of Class III Lever

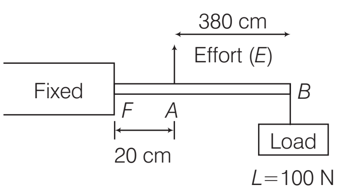
(i) Effort lies in between the fulcrum and the load.
(ii) Mechanical advantage and velocity ratio are always less than one, because the effort arm is always smaller than the load arm.
(iii) These class III levers are called speed multiplier as the load moves through a larger distance as compared to the effort.

Examples of Class III Lever

Some examples of class III levers are

(i) arms used to lift weight (ii) baseball bat
(iii) broom (iv) doors
(v) fishing rod (vi) sling
(vii) tweesers (viii) stapler

Example 7. The diagram below shows the use of a lever



(i) State the principle of moments as applied to the above lever.
(ii) Give an example of this class of lever.
(iii) If $FA = 20$ cm, $AB = 380$ cm, then calculate the mechanical advantage and minimum effort required to lift the load.

Sol. (i) Principle of moment for the given lever can be applied as

$$\text{Effort} \times AF = \text{Load} \times BF$$

or $\quad E \times (20) = (100)(AB + AF)$

$\therefore \quad 20E = (100)(400) \quad \text{...(i)}$

(ii) Fire tongs class III lever has effort in between F and L.

(iii) From Eq. (i), we can write

$$E = \frac{100 \times 400}{20} = 100 \times 20 = 2000\,\text{N}$$

Here, effort arm, $FA = 20\,\text{cm}$

Load arm, $BF = FA + AB = 20\,\text{cm} + 380\,\text{cm} = 400\,\text{cm}$

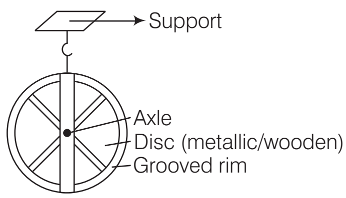
$$\therefore \quad \text{MA} = \frac{\text{Effort arm}}{\text{Load arm}} = \frac{20\text{ cm}}{400\text{ cm}} = \frac{1}{20} = 0.05$$

CHECK POINT 02

1 For a lever, if effort arm becomes equal to load arm, then what effect can be seen in the value of mechanical advantage (MA)?
2 State any two characteristics of lever of class I?
3 Fill up: a scissors is a .... multiplier.
4 Give one example each of class I lever, where the mechanical advantage is
(i) equal to 1 (ii) more than 1.
5 Which class of a lever always act as a force multiplier?
6 Give an example of lever of third order.
7 Which type of levers have mechanical advantage always less than 1? Give reason. Why are they then used?

Pulley

Pulley is a wheel on an axle that is designed to support movement and change the direction of a cable or belt along its circumference. A set of pulleys assembled so that they rotate independently on the same axle to form a block is called **pulley system**.



Pulley

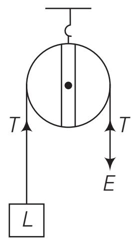
Single Fixed Pulley

A pulley which has its axis of rotation fixed in position is called single fixed pulley.

Mechanical Advantage

$$(\text{MA}) = \frac{\text{Load}}{\text{Effort}} = \frac{T}{T} = 1$$

($\because$ load, $L = T$, effort, $E = T$, if pulley is not rotating)



Single fixed pulley

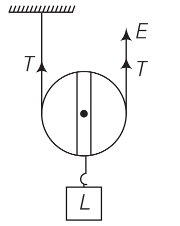
$$\text{Velocity Ratio (VR)} = \frac{d_E}{d_L} = \frac{d}{d} = 1$$

$$(d_E = d \text{ and } d_L = d)$$

$$\text{Efficiency } (\eta) = \frac{\text{MA}}{\text{VR}} = 1 \text{ or } 100\%$$

Single Movable Pulley

A pulley whose axis of rotation is not fixed in position is called a movable pulley.



Single movable pulley

Load is balanced by

$$T + T = 2\,T \qquad (\because \text{Load} = 2T)$$

$$\text{Mechanical Advantage (MA)} = \frac{\text{Load}}{\text{Effort}} = \frac{2T}{T} = 2$$

$$(\because L = T + T = 2T \text{ and } E = T)$$

$$\text{Velocity Ratio (VR)} = \frac{d_E}{d_L} = \frac{2d}{d} = 2 \;(\because d_E = 2d \text{ and } d_L = d)$$

$$\text{Efficiency } (\eta) = \frac{\text{MA}}{\text{VR}} \times 100 = \frac{2}{2} \times 100 = 100\% \text{ or } 1$$

Example 8.

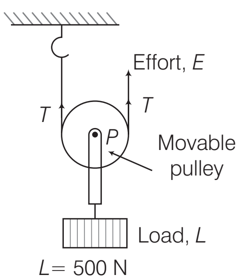
(i) Name the type of single pulley that can act as a force multiplier. Draw a labelled diagram of the above named pulley.

(ii) A pulley system has a velocity ratio of 4 and an efficiency 80%. Calculate

(a) the mechanical advantage of the system .

(b) the effort required to raise a load of 500 N by the system.

Sol. (i) Single movable pulley acts as a force multiplier.



(ii) Given, velocity ratio of a pulley system (VR) = 4

Efficiency of the pulley system (η) = 90%

We know that,

(a) Efficiency, $\eta = \dfrac{\text{Mechanical Advantage (MA)}}{\text{Velocity Ratio (VR)}}$

$$\Rightarrow \quad 80\% = \frac{\text{MA}}{4} \quad \Rightarrow \quad \text{MA} = \frac{80}{100} \times 4 = 3.2$$

(b) Load, $L = 500$ N, MA = 3.2 and effort, E = ?

$$\text{MA} = \frac{L}{E} \;\Rightarrow\; E = \frac{L}{\text{MA}} = \frac{500 \text{ N}}{3.2} = 156.25 \text{ N}$$

Difference between a Single Fixed Pulley and a Single Movable Pulley

Single Fixed Pulley	Single Movable Pulley
It is fixed to a rigid support.	It is not fixed to a rigid support.
Its Ideal Mechanical Advantage (IMA) is 1.	Its Ideal Mechanical Advantage (IMA) is 2.
Its Velocity Ratio (VR) is 1.	Its Velocity Ratio (VR) is 2.
The weight of pulley itself does not affect its mechanical advantage.	The weight of pulley itself reduces its mechanical advantage.
It is used to change the direction of effort from upwards to downwards.	It is used as a force multiplier.
Load moves in a direction opposite to that of effort.	Load moves in the direction of effort.

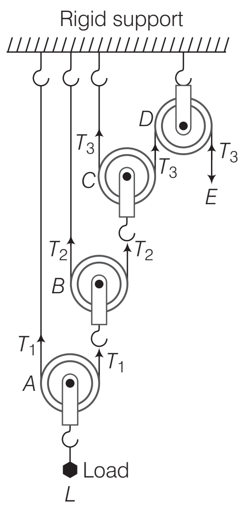
Combination of Pulleys

The combination can be made in two ways

(i) Using one fixed pulley and several movable pulleys.

(ii) Using several fixed pulleys in two blocks known as block and tackle system.

Using One Fixed Pulley and Other Movable Pulleys



If there are n movable pulleys with one fixed pulley, then the mechanical advantage of this system is

$$\text{MA} = 2^n$$

So, mechanical advantage of system which has one fixed pulley and three movable pulleys $= 2^3 = 8$

If there are n movable pulleys connected to a fixed pulley, then velocity ratio of this system is

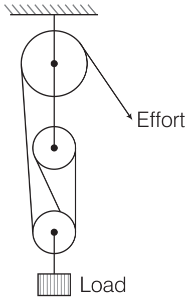
$$\text{VR} = 2^n$$

So, velocity ratio of system which has one fixed pulley and three movable pulleys $= 2^3 = 8$

Efficiency of this combination is

$$\eta = \frac{\text{MA}}{\text{VR}} = \frac{2^n}{2^n} = 1 \text{ or } 100\%$$

Example 9. Diagram given in below is representing a pulley system having a velocity ratio 3 and an efficiency of 80%. Calculate the mechanical advantage and efficiency.



Sol. Since, Mechanical Advantage,

$$MA = \frac{\text{Load}}{\text{Effort}} = VR \times \eta = 3 \times \frac{80}{100} = 2.4$$

$$\text{or efficiency} = \frac{\text{load}}{2.4} = \frac{300}{2.4} = 125\,\text{N}$$

Using Several Fixed Pulleys in Two Blocks (Block and Tackle System)

In this system, two blocks of pulleys are used, while usually upper block is fixed and the lower block is movable. If the total number of pulleys used in both the blocks is n and the effort is being applied in the downward direction.

In this case,

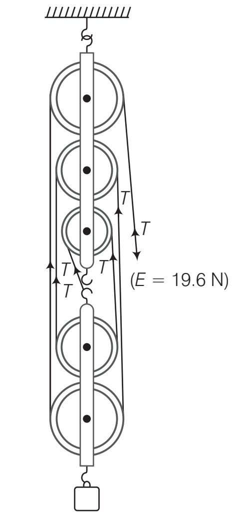
$$\text{Load} = nT \quad \text{and} \quad \text{Effort} = T$$

Mechanical Advantage (MA)

$$= \frac{\text{Load}}{\text{Effort}} = n$$

In a block and tackle system, if the load moves up through a distance d, the effort end moves through a distance nd because each section of the string supporting the load is loosened by a length d, i.e., if $d_L = d$, then $d_E = nd$

$$\therefore \quad \text{Velocity ratio} = \frac{nd}{d} = n$$



(L = 10 kgf or 98 N)

Block and tackle for five pulleys

Effect of Weight of Pulleys on MA, VR and η

But, if total weight of pulleys in the lower block be w,

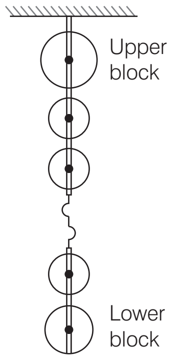
$$L + w = nT, E = T$$

$$L = nT - w, E = T$$

$$\text{Mechanical Advantage (MA)} = n - \frac{w}{E}, \ VR = n$$

$$\text{Efficiency, } \eta = \frac{MA}{VR} = \frac{(n - w/E)}{n} = 1 - \frac{w}{nE}$$

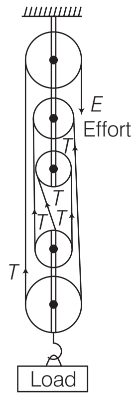
Example 10. The diagram below shows a system of 5 pulleys.



(i) Copy the diagram and complete it by drawing strings around the pulleys. Mark the position of load and effort.

(ii) If the load is raised by 2 m, through what distance will the effort move?

Sol. (i) *Complete diagram is shown in the given figure*

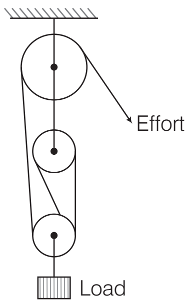


(ii) In block and tackle system, if the load moves through a distance d, the effort moves through a distance nd, where, n is the total number of pulleys in both blocks.

Here, as the load is raised by 2 m, the effort will move through a distance of $5 \times 2 = 10\,\text{m}$.

Example 11. A pulley system has a velocity ratio 4 and an efficiency of 70%. Draw a labelled diagram of this pulley system. Calculate the mechanical advantage of the system and the value of the effort required to raise a load of 400 N.

Sol. Labelled diagram of the pulley system is shown in figure.
Given, velocity Ratio (VR) = 4, efficiency, η = 70%,
load, L = 300 N



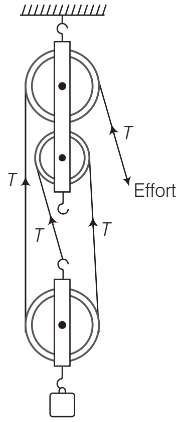
Mechanical Advantage (MA)= ? and effort, E = ?

$$MA = \frac{\text{Load}}{\text{Effort}} = VR \times \eta$$

$$= 4 \times \frac{70}{100} = 2.8$$

$$\text{and} \quad \text{effort} = \frac{\text{load}}{2.8} = \frac{500}{2.8} = 178.57$$

Example 12. A block and tackle system has the velocity ratio 4, labelled diagram of the system indicating the point of application and the directions of load and effort is given below. A man can exert a pull of 500 N. What is the maximum load he can raise with this pulley system if its efficiency is 80%?



Sol. Given, VR = 4

Efficiency, $\eta = 80\% = \dfrac{4}{5}$

$$MA = VR \times \eta$$

$$MA = 4 \times \frac{4}{5} = \frac{16}{5} = 3.2$$

But, $MA = \dfrac{L}{E}$

$\Rightarrow \quad 3.2 = \dfrac{L}{500\ \text{N}}$

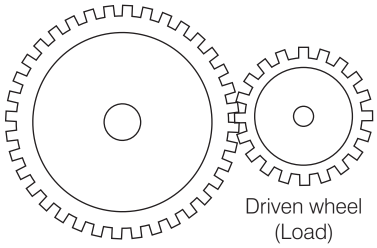
$\Rightarrow \quad L = 500 \times 3.2$

$\Rightarrow \quad L = 1600\ \text{N}$

The maximum load can be raised is 1600 N.

Gears

Gears are a set of toothed wheels arranged together in a machine to vary the speed of rotation and/or to transmit power from one part to another. The gear wheel closer to the source of power is called driving gear while the gear wheel which receives motion from the driver is called a driven gear.



(i) The number of teeth on a sheel depends on its circumference and hence on it's radius i.e., $\dfrac{N_D}{N_d} = \dfrac{r_o}{r_d}$.

(ii) Gear ratio is the ratio of number of teeth on the driving wheel (N_D) to that on the driven wheel (N_d)

i.e., Gear ratio $= \dfrac{N_D}{N_d}$

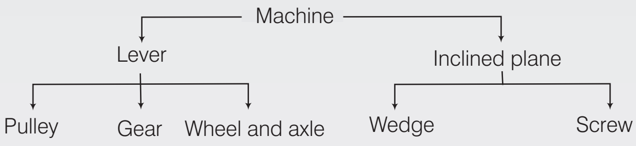
Note The mechanical advantage of an inclined plane is given by,
$MA = \dfrac{l}{h}$, where l = length of inclined plane
and h = height of inclined plane.

CHECK POINT 03

1. Name a machine which can be used to change the direction of force applied.
2. Define the term "single fixed pulley". State its mechanical advantage and velocity ratio.
3. Name the type of single pulley that has a mechanical advantage greater than one.
4. Why do we use single fixed pulley?
5. What is the value of ideal mechanical advantage of a single fixed pulley?
6. In the case of a single movable pulley, state whether the load moves in the direction of effort or opposite to effort ?
7. How many combination of pulleys are there? Name them.
8. Define gear ratio.

SUMMARY

- Machine is a device which helps us to do the work at one point and deliver it at another point with a view of accomplishing the work easily.



Classification of Machine

- Functions performed by machines are
  (i) as a force multiplies
  (ii) to increase or decrease speed
  (iii) in changing, the direction of effort
  (iv) to change the point of application of effort.
- Load It is the resistive or opposing force against which the machine does the work. It is denoted by L.
- Effort It is the force applied on the machine to overcome the load. It is denoted by E.
- Mechanical Advantage (MA) It is the ratio of the load to the effort. It is denoted by MA.
- Efficiency (η) It is the ratio of the work done on the load by the machine to the work put into the machine by the effort.
- Velocity Ratio (VR) It is the ratio of the distance moved by the effort d_E to the corresponding distance moved by the load d_L.
- For an ideal machine, η is 100%.
- In actual machine, the output energy is always less than the input energy.
- Relation between η, MA and VR If η is expressed as efficiency percentage, then $\eta = \frac{\mathbf{MA}}{\mathbf{VR}} \times \mathbf{100}$
- A lever is a straight or bent rod which can be turned or rotated about a fixed point called fulcrum.
- In class I lever, the effort (E) and the resistance (load, L) are situated on either side of the fulcrum (F) . e.g., A pair of scissors, handle of water pump, a catapult and the nodding of the human head, etc.
- In class II lever, the load is situated between fulcrum and effort. e.g., A bottle opener, a wheel barrow, a paper cutter, raising the weight of the human body on toes, etc.
- In class III lever, effort is situated between the load and the fulcrum. e.g., Sugar tongs, foot treadle, etc.
- Three classes of levers are found in the human body (i) class I lever in the action of nodding of head (ii) class II lever in raising the weight of the body on toes (iii) class III lever in raising a load by forearm.
- Pulley is a wheel on an axle that is designed to support movement and change the direction of a cable or belt along its circumference. A set of pulleys assembled so that, they rotate independently on the same axle to form a block is called pulley system.
- A pulley which has its axis of rotation fixed in position is called single fixed pulley. For this pulley MA = 1, VR = 1, η = 100%.
- A pulley whose axis of rotation is not fixed in position is called a movable pulley.
  For this pulley MA = 2, VR = 2, η = 100%.
- For combination of pulleys using one fixed pulley and other movable pulley MA = 2^n, VR = 2^n, η = 100%.
- For block and tackle system MA = n, VR = n with weight of pulley, MA = $n - \frac{W}{E}$, VR = n, $\eta = 1 - \frac{W}{nE}$.
- A gear is a wheel with teeth around its rim. A gear wheel closer to the source of power is called the driver (or the driving gear), while the gear wheel which receives motion from the driver is called the driven gear.
  For this,
  gear ratio = $\frac{N_A}{N_B}$, gain in torque = $\frac{N_B}{N_A} = \frac{r_B}{r_A}$ and gain in speed = $\frac{n_B}{n_A} = \frac{N_A}{N_B}$
- The inclined plane is a sloping surface that behaves like a simple machine whose mechanical advantage is always greater than 1.

$$\text{MA} = \frac{1}{\sin\theta}, \text{VR} = \frac{l}{h}$$

EXAM PRACTICE

a 2 Marks Questions

1. Write two functions of a machine.

Sol. *Two functions of a machine are given below*

(i) A machine can be used to lift a load in one direction by applying effort in convenient direction.

(ii) It can be used to overcome a load at some point by applying an effort at a convenient point. **[1+1]**

2. With reference to the terms mechanical advantage, velocity ratio and efficiency of a machine, name and define the term that will not change for a machine of a given design. **[2016]**

Sol. From the given variables, velocity ratio of a machine will not change for a machine of a given design. It is the ratio of the velocity of effort to the velocity of load. **[2]**

3. When does a machine act as

(i) a force multiplier?

(ii) a speed multiplier?

Sol. (i) A machine having MA > 1 works as force multiplier, e.g., Crow-bar. **[1]**

(ii) A machine having $MA < 1$ works as speed multiplier, e.g., A pair of scissors. **[1]**

4. Why cannot a machine be 100% efficient?

Sol. Due to the weights of different parts of machine and friction between its different parts the MA is less than the VR (i.e., MA < VR). Hence, a machine can never be 100% efficient. **[2]**

5. (i) What is meant by an ideal machine?

(ii) Write a relationship between the mechanical advantage (MA) and velocity ratio (VR) of an ideal machine.

Sol. (i) A machine having 100% efficiency is called an ideal machine. **[1]**

(ii) The relation between MA and VR is given by

$$MA = VR \qquad (\because \eta = 100\%)$$ **[1]**

6. What is a lever? State its principle.

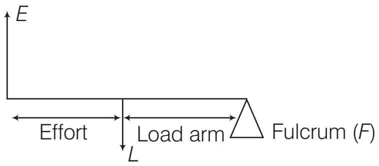
Sol. A simple machine that can rotate (capable of turning) freely about a point or axis is called lever. The principle of lever is **[1]**

$\Rightarrow$ effort $\times$ effort arm length = load $\times$ load arm length. **[1]**

7. Which class of lever will always have MA > 1 and why? **[2017]**

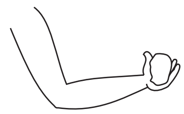
Sol. In class II lever, an effort arm is always greater than the load arm and the load is situated between fulcrum and effort. In this lever, the mechanical advantage and velocity ratio are always more than 1.

The sketch of such lever is shown below

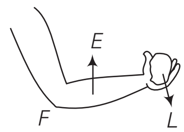


[1+1]

8. Copy the diagram of the forearm given below, indicate the positions of load, effort and fulcrum. **[2008]**

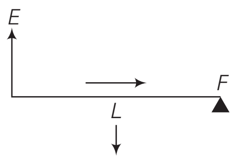


Sol. The below diagram shows the position of load (L), effort (E) and fulcrum (F).



[2]

9. The diagram below shows a lever in use



(i) To which class of levers does it belong?

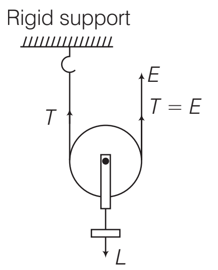
(ii) Without changing the dimensions of the lever, if the load is shifted towards the fulcrum what happens to the mechanical advantage of the lever? **[2018]**

Sol. (i) It belongs to class II lever because load is situated between fulcrum and effort. **[1]**

(ii) If load is shifted towards the fulcrum, then mechanical advantages will increase. **[1]**

10. Draw a diagram to show how a single pulley can be used so as to have its ideal MA = 2. **[2014]**

Sol.



[2]

11. A type of single pulley is very often used as a machine even though it does not give any gain in mechanical advantage. **[2013]**

(i) Name the type of pulley used.

(ii) For what purpose is such a pulley used?

Sol. (i) The pulley which is used in the arrangement is single fixed pulley. **[1]**

(ii) Single fixed pulley is used only to change the direction of the force applied. **[1]**

12. Give two reasons why the efficiency of a single movable pulley system is less than 100%.

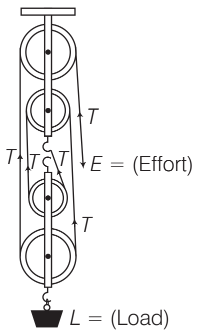
Sol. *We consider the following reasons*

(i) The friction in the pulley bearings or at the axle.

(ii) The weight of pulley and string, the mechanical advantage will be less than 2 and efficiency will be less than 100%. **[1+1]**

13. A block and tackle system of pulleys has a velocity ratio 4. Draw a labelled diagram of the system indicating clearly the points of application and directions of load and effort.

Sol. *The labelled diagram of the system is shown as below*



[2]

14. State the fundamental principle of gear tooth action.

Sol. The fundamental principle of gear and tooth action depends upon the Velocity Ratio (VR). Velocity ratio is also defined as the ratio of speed of rotation of driver gear to the speed of rotation of driven gear. **[1]**

$$\text{VR} = \frac{\text{Speed of rotation of driver gear } (v)_{\text{driver}}}{\text{Speed of rotation of driven gear } (v)_{\text{driven}}}$$ **[1]**

15. An effort is applied on the bigger wheel of a gear having 32 teeths. It is used to turn a wheel of 8 teeths. Where is it used? **[2016]**

Sol. If an effort is applied on the bigger wheel of gear having 32 teeths to turn a wheel of 8 teeths, it acts as speed multiplier. And it is used in bicycles and car to gain speed. **[2]**

b 3 Marks Questions

16. Derive a relationship between MA, VR and η of a machine. **[2014]**

Sol. Refer to theory (Page 45).

17. What step could be taken to increase the mechanical advantage of a lever?

Sol. As we know, $\text{MA} = \frac{\text{load}}{\text{effort}}$, to increase MA, length of effort arm should be greater than load arm, because

$$E \times E_d = L \times L_d$$

or $$\text{MA} = \frac{\text{effort arm}}{\text{load arm}}$$ **[3]**

18. (i) State the class of levers and the relative positions of load (L), effort (E) and fulcrum (F) in each of the following cases:

(a) A bottle opener (b) Sugar tongs

(ii) Why is less effort needed to lift a load over an inclined plane as compared to lifting the load directly? **[2012]**

Sol. (i) (a) A bottle opener is a class II lever. In this case, the load is in between the fulcrum and the effort.

(b) Sugar tongs is a class III lever. In this case, the effort is in between the fulcrum and the load. **[1+1]**

(ii) Less effort is needed to lift a load over an inclined plane as compared to lifting the load directly, as the mechanical advantage increases. **[1]**

19. Assume that a pair of scissors and a pair of pliers belong to the same class of levers.

(i) Which one has mechanical advantage less than one?

(ii) What is the usefullness of a machine whose mechanical advantage is less than one?

Sol. (i) A pair of scissors and a pair of pliers both belong to class I levers.

For class I levers, MA > 1 or MA = 1 or MA < 1

As, we know that

$$\text{Mechanical advantage} = \frac{\text{Load } (L)}{\text{Effort } (E)} = \frac{\text{Effort arm}}{\text{Load arm}}$$ **[1]**

In a pair of scissors effort arm is less than the load arm.

$\therefore$ Mechanical advantage of a pair of scissors is less than one. **[1]**

(ii) The machines with MA <1 can help us to apply the effort at a more convenient point or to gain in speed. **[1]**

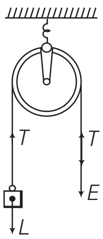
20. With the help of a diagram of a single fixed pulley, obtain expressions for its

(i) mechanical advantage

(ii) velocity ratio

(iii) efficiency in the ideal case.

Sol. *The diagram of a single fixed pulley is shown alongside.* Suppose, T is the tension in each of the string and in the ideal case string is massless and there is no friction in the pulley bearings, then in equilibrium,



$$E = T \text{ and } L = T$$

(i) Mechanical advantage $= \dfrac{L}{E} = \dfrac{T}{T} = 1$ **[1]**

(ii) If the effort E moves a distance d downwards, then load L moves the same distance d upwards.

So, velocity ratio $= \dfrac{d_E}{d_L} = \dfrac{d}{d} = 1$ **[1]**

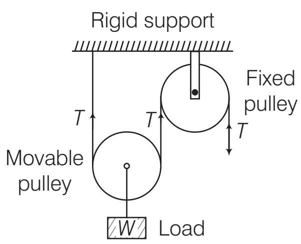
(iii) Efficiency $= \dfrac{\text{MA}}{\text{VR}} = \dfrac{1}{1} = 1$ (or 100%) **[1]**

21. A pulley system comprises two pulleys, one fixed and the other movable.

(i) Draw a labelled diagram of the arrangement and show clearly the directions of all the forces acting on it.

(ii) What change can be made in the movable pulley of this system to increase the mechanical advantage of the system?

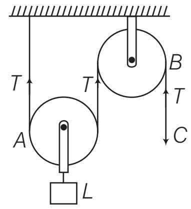
Sol. (i) *The labelled diagram of the above arrangement is as shown below*



[2]

(ii) To increase the mechanical advantage of the system we need to reduce the friction between the string and the movable pulley. **[1]**

22. From the diagram given below, answer the questions that follow:



(i) What kind of pulleys are A and B?

(ii) State the purpose of pulley B.

(iii) What effort has to be applied at C to just raise the load $L = 20$ kgf? (neglect the weight of pulley A and friction) **[2016]**

Sol. (i) According to questions,

A is a movable pulley while B is a fixed pulley. **[1]**

(ii) The purpose of pulley 'B' is to change the point of application of effort and load in the same direction. **[1]**

(iii) Given, load $= 20$ kgf, MA $= 2$ and we know that,

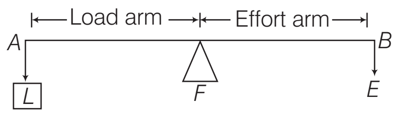
$$\text{MA} = \frac{\text{Load}}{\text{Effort}}$$

$$\therefore \quad \text{Effort} = \frac{20}{2} = 10 \text{ kgf}$$ **[1]**

C 4 Marks Questions

23. State and explain the working principle of a lever with proper diagram.

Sol. Consider a lever (for a straight rod) AB with balanced point at F (fulcrum for the lever), a load L acts at point A of the lever and effort E acts at point B as shown in the diagrams. **[2]**



A lever works on the principle of moment. In the equilibrium position of the lever, by the principle of moment,

moment of load at about the fulcrum

= moment of effort about the fulcrum **[1]**

The two moments are always in opposite directions. In figure, the moment of load is anti-clockwise while the moment of effort is clockwise. Thus, we can write

$$\text{load} \times \text{load arm} = \text{effort} \times \text{effort arm}$$

This is also called principle of lever.

or $\quad L \times AF = E \times BF$ **[1]**

24. Write the class of levers to which following belongs.

(i) A physical balance (ii) A see-saw
(iii) An oar of a boat (iv) Human-arm
(v) Pliers (vi) A claw-hammer
(vii) Rowing of a boat (viii) A fire tongs
(ix) Sugar tongs (x) A pair of scissors
(xi) Wheel barrow (xii) Nut cracker
(xiii) Forearm used for lifting a load.

Sol. *Above mentioned levers belong to the following classes*

(i) Class I (ii) Class I
(iii) Class II (iv) Class III
(v) Class I (vi) Class I
(vii) Class II (viii) Class III
(ix) Class III (x) Class I
(xi) Class II (xii) Class II
(xiii) Class I ***[1/3 ×12]***

25. Draw a diagram consisting of 4 pulleys in block and tackle arrangement.

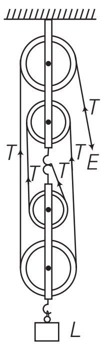
(i) State how many strands of tackle support the load?

(ii) Draw arrows to represent tension in each strand.

(iii) Find the mechanical advantage of the system stating the assumptions made.

(iv) If load is pulled up by a distance of 1 m, how much does the effort arm move?

Sol. The adjacent diagram shows a block and tackle system of 4 pulleys.



(i) Four strands of tackle support the load.

(ii) The tension in each strand is shown by the arrows marked as T.

(iii) If we neglect the friction of the pulleys and weight of the pulleys in the lower block, then

$$L = 4T \quad \text{and} \quad E = T$$

$$\therefore \quad MA = \frac{L}{E} = \frac{4T}{T} = 4$$

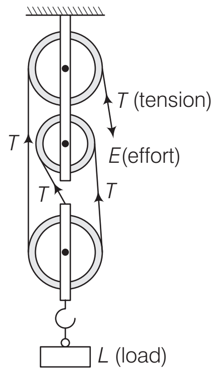
(iv) If load is pulled up by a distance 1 m, the effort end moves by 4 m. ***[1 × 4]***

26. (i) Draw a diagram to show a block and tackle pulley system having a velocity ratio of 3 marking the direction of load (L), effort (E) and tension (T).

(ii) The pulley system drawn lifts a load of 150 N when an effort of 60 N is applied. Find its mechanical advantage.

(iii) Is the above pulley system an ideal machine or not? ***[2018]***

Sol. (i) *The labelled diagram of the system is shown below*



[2]

(ii) Given, load (L) = 150 N

Effort (E) = 60 N

We know that, mechanical advantages

$$(MA) = \frac{\text{Load}}{\text{Effort}} = \frac{150}{60} = 2.5$$ ***[1]***

(iii) No, the above pulley system is not an ideal machine because velocity ratio (VR = 3) is not equal to mechanical advantages. ***[1]***

27. (i) Name a machine which can be used to change the direction of force applied.

(ii) Draw a labelled diagram of a block and tackle system of pulleys with two pulleys in each block. Indicate the directions of the load, effort and tension in the string.

(iii) Write down the relation between the load and the effort of the pulley system.

Sol. (i) Pulley is a machine which can change for direction of force applied. ***[1]***

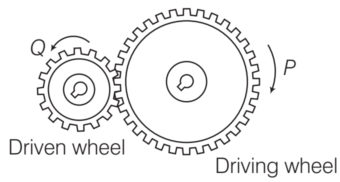
(ii) Refer to the Q. No. 26. ***[1½]***

(iii) Refer to the Q. No. 26. ***[1½]***

28. Explain how a gear system can be used to obtain

(i) gain in speed (ii) gain in torque.

Sol. (i) **Gain in Speed** Consider the figure shown in which the wheel P is used as driving gear and the wheel Q as the driven gear, i.e., if $N_P = 24$ and $N_Q = 12$, the velocity ratio will be $\frac{24}{12} = 2$ or gain in speed.

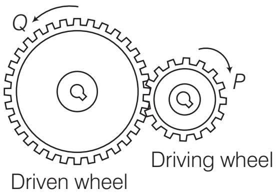


e.g., A toy motor car having a key and spring on the axle fitted with a driving gear having more teeth which engages the driven gear having less teeth to gain speed.

Gain in speed

$$= \frac{\text{Number of teeth in driving wheel } (N_P)}{\text{Number of teeth in driven wheel } (N_Q)}$$ **[2]**

(ii) **Gain in Torque** A gear system can be used to increase the turning effect when the smaller wheel drives the bigger wheel, i.e. the driven gear has more number of teeth than the driving gear, (i.e., $N_Q > N_P$) the ratio of number of teeth in driven gear to the number of teeth in driving gear gives gain in torque. **[2]**



29. (i) Write a relation expressing the mechanical advantage of a lever.

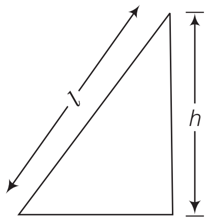
(ii) Write an expression for the mechanical advantage of an inclined plane.

(iii) Give two reasons as to why the efficiency of a single movable pulley system is always less than 100%. **[2010]**

Sol. (i) The relation expressing mechanical advantage of a lever is given by

$$MA = \frac{\text{Effort arm}}{\text{Load arm}}$$ **[1]**

(ii) The expression for the mechanical advantage of an inclined plane is given by



$$MA = \frac{l}{h}$$

where, l is the length of inclined plane and h is the height of inclined plane. **[1]**

(iii) (a) The weight of movable pulley with its frame is not negligible.

(b) The frictional force between pulley and string is not negligible. ($\because \eta = 100\%$) **[1 × 2]**

Numerical Based Questions

30. A crow-bar of length 150 cm has its fulcrum situated at a distance of 50 cm from the load. Calculate the mechanical advantage of crow-bar.

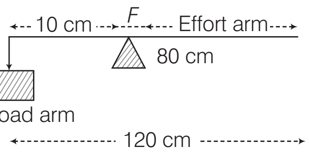
Sol. $$MA = \frac{\text{Length of effort arm from fulcrum}}{\text{Length of the load arm from fulcrum}}$$ **[1]**

i.e., $$= \frac{150 - 50}{50} = 2$$ **[1]**

31. A crow-bar of length 80 cm has its fulcrum situated at a distance of 10 cm from the load. Calculate the mechanical advantage of the crow-bar.

Sol. MA of crowbar,

$$MA = \frac{\text{Effort arm}}{\text{Load arm}} = \frac{80}{10} = 8$$



[2]

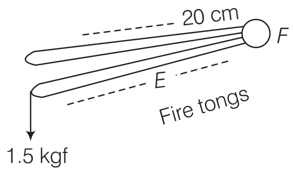
32. A fire tongs has its arms 30 cm long. It is used to lift a coal of weight 2 kgf by applying an effort at distance 20 cm from the fulcrum. Find

(i) the mechanical advantage of fire tongs and

(ii) the effort needed.

Sol. (i) MA = ?

Effort arm = 20 cm

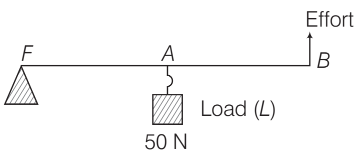


Load arm = 30 cm

$$MA = \frac{\text{Effort arm}}{\text{Load arm}} = \frac{20}{30} = \frac{2}{3} = 0.66$$ **[1]**

(ii) $$\text{Effort} = \frac{\text{Load}}{\text{Mechanical Advantage}} = \frac{2 \text{ kgf}}{2/3} = 3 \text{ kgf}$$ **[1]**

33. The diagram below shows a lever in use.



If $FA = 40$ cm, $AB = 60$ cm, then find the mechanical advantage of the lever. **[2011]**

Sol. Effort arm $= FA + AB = 40 + 60 = 100$ cm

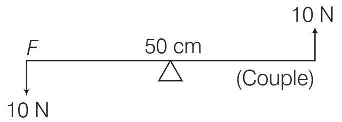
Load arm $= FA = 40$ cm **[1]**

$$\therefore \quad MA = \frac{\text{Effort arm}}{\text{Load arm}}$$

$$= \frac{FB}{FA} = \frac{100}{40} = 2.5$$ **[1]**

34. Two forces each of 10 N act vertically upwards and downwards, respectively on the two ends of a uniform meter rule which is placed at its mid-point as shown in the diagram. Determine the magnitude of the resultant moment of these forces about the mid-point.

Sol.

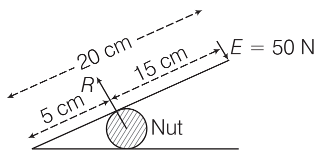


$$M = F \times d \text{ (or) } F \times s$$ **[1]**

$$\therefore \quad M = 10 \times \frac{50}{100} \text{ m}$$

$$= 10 \times 0.5 = 5 \text{ N-m}$$ **[1]**

35. In the diagram shown below, calculate the resistance (R) offered by the nut, when an effort of 50 N is applied.



Sol. Load arm $= 5$ cm

Effort arm $= 15 + 5 = 20$ cm **[1]**

As we know that,

load $\times$ load arm $=$ effort $\times$ effort arm

$\Rightarrow \quad R \times 5 \text{ cm} = 50 \text{ N} \times 20 \text{ cm} \Rightarrow R = 200$ N **[1]**

36. A cook uses a fire tong of length 28 cm to lift a piece of burning coal of mass 250 g. If he applies his effort at a distance of 7 cm from the fulcrum, what is the effort in SI unit? (Take, $g = 10 \text{ m/s}^2$)

Sol. Given, mass, $m = 250 \text{ g} = 0.25$ kg

Load, $L = 0.25 \times 10 \text{ N} = 2.5$ N **[1]**

Distance of load, $L_d = 28 \text{ cm} = 0.28$ m

Distance of effort, $E_d = 7 \text{ cm} = 0.07$ m

Effort, $E = ?$

According to the principle of moment, we have **[1]**

$$E \times E_d = L \times L_d$$

$$\Rightarrow \quad E = \frac{L \times L_d}{E_d} = \frac{0.25 \times 10 \times 0.28}{0.07} = 10 \text{ N}$$ **[1]**

37. A force of 10 kgf is required to cut a metal sheet. A shear used for cutting a metal sheet has its blades 10 cm long, while its handle is 20 cm long. What effort is needed to cut a sheet?

Sol. Length of blades $=$ Load arm $= 10 \text{ cm} = \frac{10}{100}$ m

Load, $L = 10$ kgf, effort needed, $E = ?$ **[1]**

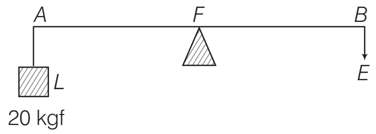
Length of handle $=$ Effort arm $= 20 \text{ cm} = \frac{20}{100}$ m

$\therefore E \times$ effort arm $= L \times$ load arm

$$\Rightarrow \quad E \times \frac{20}{100} = 10 \times \frac{10}{100}$$ **[1]**

$$\Rightarrow \quad E = \frac{100}{20} = 5 \text{ kgf}$$ **[1]**

38. The diagram below shows a lever in use.



(i) To which class of lever does it belong?

(ii) If $AB = 4$ m, $AF = 0.8$ m, find its mechanical advantage.

(iii) Find the value of E.

Sol. (i) It belongs to lever of class I.

(ii) We can write, $\text{MA} = \frac{FB}{FA} = \frac{4.0 - 0.8}{0.8} = \frac{3.2}{0.8} = 4$

(iii) Applying the law of moment,

$$20 \times 0.8 = E \times 3.2$$

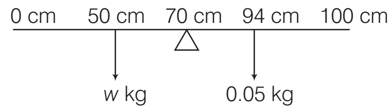
$$\text{or} \quad E = \frac{20 \times 0.8}{3.2} = \frac{160}{32} = 5 \text{ kgf}$$ **[1+1+1]**

39. A uniform meter scale can be balanced at the 70.0 cm mark, when a mass of 0.05 kg is hung from the 94.0 cm mark.

(i) Draw a diagram of the arrangement.

(ii) Find the mass of the meter scale. **[2011]**

Sol. (i) *The diagram of the above arrangement is shown as below* **[1]**



(ii) Let w be the weight of the scale.

By principle of moments, we get

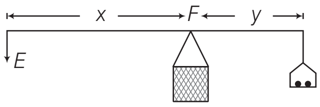
$$w \times (70 - 50) = 0.05(94 - 70)$$ **[1]**

$$\Rightarrow \quad w \times 20 = 0.05 \times 24$$ **[1]**

$$\Rightarrow \quad w = \frac{0.05 \times 24}{20} = 0.06 \text{ kg}$$ **[1]**

40. (i) Calculate the mechanical advantage of the lever shown in figure.

(ii) How do you define mechanical advantage of a machine?



Sol. (i) Clockwise moment $= y \times L$

and anti-clockwise moment $= x \times E$

According to the principle of moment,

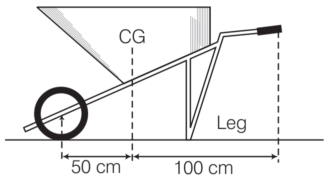
clockwise moment = anti-clockwise moment

$\therefore \quad y \times L = x \times E$ or $\dfrac{L}{E} = \dfrac{x}{y}$ **[1]**

(ii) Mechanical advantage is the ratio of the load lifted to the effort applied.

Hence, in figure, MA $= \dfrac{L}{E} = \dfrac{x}{y}$ **[1]**

41. If the weight of wheel barrow is 10 kgf and the weight of sand in it is 50 kgf, with the help of information given in figure. Calculate the minimum effort required to keep the leg just off the ground.



Sol. Total load of wheel barrow $= 50 + 10$ kgf

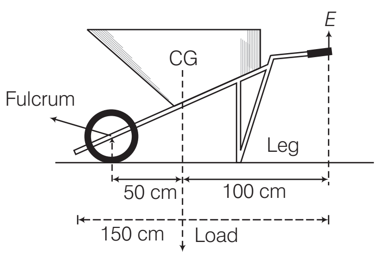
Load $= 60$ kgf

Load arm $= 50$ cm

Effort = ?

Effort arm $= 150$ cm **[1]**

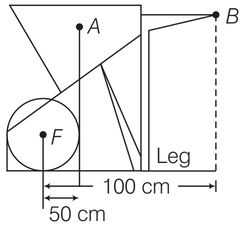
Load × Load arm = Effort × Effort arm



[1]

$\Rightarrow \quad 60 \times 50 = E \times 150 \quad \Rightarrow E = \dfrac{60 \times 50}{150} = 20$ kgf **[1]**

42. In the diagram of a stationary wheel barrow, the centre of gravity is at A. The wheel and the leg are in contact with the ground. The horizontal distance between A and F is 50 cm and that between B and F is 150 cm.



(i) What is the direction of the force acting at A? Name the force.

(ii) What is the direction of the minimum force at B to keep the leg off the ground? What is this force called?

(iii) The weight of the wheel barrow is 15 kgf and it holds sand of weight 60 kgf. Calculate the minimum force required to keep the leg off the ground.

Sol. (i) The direction of the force acting at A is vertically downwards. This force is named as load. **[1/2]**

(ii) The direction of the minimum force at B to keep the leg off the ground is acting vertically upwards. This force is called effort. **[1/2]**

(iii) Given, weight of wheel, $w_E = 15$ kgf

Weight of sand, $w_S = 60$ kgf

Minimum force, $E = ?$

Total load, $L = w_E + w_S$

$= 15 + 60 = 75$ kgf

Effort arm, $E_a = 50 + 100$ **[1]**

$= 150$ cm $= 1.5$ m

Load arm, $L_a = 50$ cm $= 0.5$ m

Applying the principle of lever,

load × load arm = effort × effort arm

$\Rightarrow \quad L \times L_a = E \times E_a$

$\Rightarrow \quad E = \dfrac{L \times L_a}{E_a} = \dfrac{75 \times 0.5}{1.5}$

$= 25$ kgf **[1]**

43. In a single movable pulley system a load of 300 kgf is lifted by an effort of 200 kgf. Find the percentage efficiency of system.

Sol. We know that, VR of single movable pulley = number of supporting segments of string = 2

MA of single movable pulley $= \dfrac{L}{E} = \dfrac{300}{200} = \dfrac{3}{2}$ **[1]**

Therefore, efficiency is $\eta = \dfrac{\text{MA}}{\text{VR}} = \dfrac{3}{2 \times 2} = \dfrac{3}{4}$

$= 0.75 = 75.00\%$ **[1]**

44. A pulley system has a velocity ratio of 4 and an efficiency of 90%. Calculate
(i) the mechanical advantage of the system.
(ii) the effort required to raise a load of 300 N by the system.

Sol. Given, velocity ratio, VR = 4

Efficiency, $\eta = 90\%$

(i) Mechanical Advantage, $\text{MA} = \text{VR} \times \frac{\eta}{100}$

$$= 4 \times \frac{90}{100} = 3.6 \qquad \left(\because \eta = \frac{\text{MA}}{\text{VR}}\right)$$ **[1]**

(ii) Effort, $E = ?$, load, $L = 300$ N

$$E = \frac{L}{\text{MA}} = \frac{300}{3.6} = 83.33 \qquad \left(\because \text{MA} = \frac{L}{E}\right)$$ **[1]**

45. A pulley system has four pulleys in all and is 75% efficient. Calculate
(i) MA
(ii) effort required to lift a load of 1000 N.

Sol. Given, $\eta = 75\%$,

VR = 4 (as the system has 4 pulleys)

(i) Since, $\eta = \frac{\text{MA}}{\text{VR}}$

$$\therefore \quad \text{MA} = \eta \times \text{VR} = \frac{75}{100} \times 4 = 3$$ **[1½]**

(ii) Also, $\text{MA} = \frac{\text{Load}}{\text{Effort}}$

$$\text{Effort} = \frac{\text{Load}}{\text{MA}} = \frac{1000}{3} = 333.33 \text{ N}$$ **[1½]**

46. A pulley system has three pulleys. A load of 120 N is overcome by applying an effort of 50 N. Calculate the mechanical advantage and efficiency of this system. **[2016]**

Sol. According to question, load = 120 N

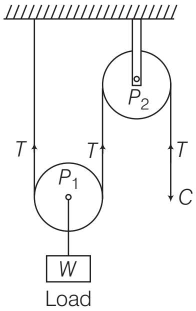
Effort = 50 N

$$\therefore \text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}} = \frac{120}{50} = 2.4$$ **[1]**

$$\text{Now, \% efficiency} = \frac{\text{MA}}{\text{VR}} \times 100$$

$$\Rightarrow \quad = \frac{2.4}{3} \times 100 = 80\%$$ **[2]**

47. Consider the combination of a movable pulley P_1 with a fixed pulley P_2 used for lifting a load W.



(i) What is the function of the fixed pulley P_2?
(ii) If the free end of the string moves through a distance y, find the distance by which the load W is raised.
(iii) Calculate the force to be applied at C to just raise the load W = 30 kgf, neglecting the weight of the pulley P_1 and friction.

Sol. (i) From the given diagram, it is clear that applying effort in the upward is very difficult, if no fixed pulley P_2 is used.

The fixed pulley changes the direction of effort from upwards to downwards, making the application of the effort more convenient and easier. **[1]**

(ii) As, the movable pulley doubles the effort,

$\therefore$ Force, $L = 2T$

i.e., $W = 2T$

$$\text{Mechanical Advantage, MA} = \frac{2T}{T} = 2$$

$$\text{VR} = \frac{\text{Distance travelled by effort}}{\text{Distance travelled by load}} = \frac{2y}{y} = 2$$

The distance travelled by load is half the distance moved by effort $= \frac{y}{2}$. **[1]**

(iii) Since, $W = 2T$

or 30 kgf = $2T$.

Here, T = Effort

$$\therefore \text{Effort applied} = \frac{30}{2} = 15 \text{ kgf}$$ **[1]**

48. A block and tackle system of pulleys has a velocity ratio 4. What is the value of the mechanical advantage of the given pulley system, if it is an ideal pulley system?

Sol. Given, velocity ratio,

$$VR = 4, \text{ load } L = 4T \text{ effort} = T$$

$$\therefore \quad MA = \frac{\text{Load}}{\text{Effort}} \qquad [1]$$

$$= \frac{4T}{T} = 4 \qquad [1]$$

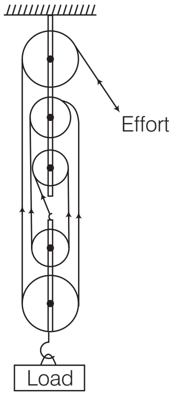
49. The pulley system shown in the figure is used to raise 500 kgf object. What is the mechanical advantage and what force is exerted?

Sol. Given, MA = number of segments holding the load = 5

Load, $L = 500$ kgf

Effort, $E = ?$

We know that, $MA = \frac{\text{Load}}{\text{Effort}}$



or $\quad \text{Effort} = \frac{\text{Load}}{MA} = \frac{500}{5} = 100 \text{ kgf} \qquad [1 + 1]$

50. A boy uses a single fixed pulley to lift a load of 50 kgf to same height. Another boy uses a single movable pulley to lift the same load to the same height. Compare the effort applied by them. Give a reason to support your answer. **[2017]**

Sol. In first case, the pulley is single fixed,

$$MA = 1$$

But, $\quad MA = \frac{L_1}{E_1}$

$$\Rightarrow \quad 1 = \frac{50}{E_1}$$

$$\Rightarrow \quad E_1 = 50 \text{ kgf} \qquad [2]$$

In second case, the pulley is single movable,

$$\therefore \quad MA = 2 \Rightarrow 2 = \frac{50}{E_2}$$

$$\Rightarrow \quad E_2 = 25 \text{ kgf}$$

$$\Rightarrow \quad \frac{E_1}{E_2} = \frac{50}{25} = \frac{2}{1} \qquad [2]$$

51. A pulley system with VR = 4 is used to lift a load of 175 kgf through a vertical height of 15 m. The effort required is 50 kgf in the downward direction. (Take, $g = 10$ N/kg).

Calculate

(i) distance moved by the effort

(ii) work done by the effort

(iii) MA of the pulley system

(iv) efficiency of the pulley system **[2017]**

Sol. (i) We known that, $VR = \frac{\text{distance moved by effort } (D_E)}{\text{distance moved by load } (E_L)}$ **[1]**

$$4 = \frac{D_E}{15} \Rightarrow D_E = 60 \text{ m}$$

(ii) Work done by the effort = Force × displacement

$$= 50 \times 10 \times 60 = 30000 \text{ J} \qquad [1]$$

(iii) $MA = \frac{L}{E} = \frac{175}{50} = 3.5$ **[1]**

(iv) Efficiency, $\eta = \frac{MA}{VR} = \frac{3.5}{4}$

$$= 0.875$$

$$= 87.5\% \qquad [1]$$

52. A block and tackle with five pulleys is found to have a MA of 3, when a load of 10 N is raised by it. Calculate (i) the effort applied (ii) VR (iii) efficiency and (iv) the total resistance R due to friction.

Sol. Number of pulleys in the block and tackle = 5

$$MA = 3, \; L = 10 \text{ N}, \; E = ?$$

Total resistance, $R = ?, \eta = ?$

(i) Now, we know that velocity ratio of a pulley block and tackle is equal to the total number of pulleys.

$$\therefore \quad E = \frac{L}{MA} = \frac{10}{3} = 3.33 \text{ N} \qquad [1]$$

Also, $L + R = VR \times E = 5 \times 3.33 = 16.65$

(ii) $VR = n = 5$ **[1]**

(iii) Efficiency $= \frac{MA}{VR} \times 100$

$$= \frac{3}{5} \times 100 = 60\% \qquad [1]$$

(iv) Resistance due to friction,

$$R = 16.65 - L = 6.25 - 10 = 6.65 \text{ N} \qquad [1]$$

CHAPTER EXERCISE

2 Marks Questions

1. Write an expression to show the relationship between mechanical advantage, velocity ratio and efficiency for a simple machine. ***[2007]***

2. Which class of levers has a mechanical advantage always greater than one? What change can be brought about in this lever to increase its mechanical advantage? ***[2007]***

3. What is the relationship between the mechanical advantage and the velocity ratio for
(i) ideal machine (ii) practical machine ?

4. To use a machine as a force multiplier, what types (class) of lever should preferably be used? Draw a sketch of such a lever.

5. Why is the mechanical advantage of a lever of third order is always less than 1? Give one example of this class of lever.

6. Draw a diagram of a class III lever. Give one example of this kind of lever.

7. Give two reasons why the efficiency of a single movable pulley system is not 100%.

8. A block and tackle pulley system has a velocity ratio 3. ***[2007]***
(i) Draw a labelled diagram of this system. In your diagram, indicate clearly the points of application and the directions of the load and effort.
(ii) Why should the lower block of this pulley system be of negligible weight?

3 Marks Questions

9. Name the type of single pulley that can act as a force multiplier. Draw a labelled diagram of the above named pulley. ***[2006]***

10. Draw a labelled sketch of a class II lever. Give one example of such a lever.

11. A pair of scissors and a pair of pliers belong to the same class of levers.
(i) Which one has mechanical advantage less than one?
(ii) State the usefullness of such a machine whose mechanical advantage is less than 1.

12. What is the relationship between the mechanical advantage and the velocity ratio for
(i) an ideal machine
(ii) a practical machine.

13. (i) Which simple machine is used by the labourers to load heavy barrels, etc., on a truck?
(ii Does a single fixed pulley help us to multiply the force? In what way is it useful?

4 Marks Questions

14. Draw diagrams to illustrate the positions of fulcrum, load and effort in each of the following.
(i) A common balance (ii) A see-saw
(iii) Forceps (iv) A nut-cracker

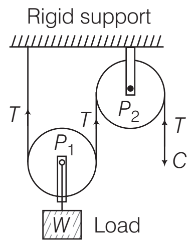
15. Define the following.
(i) Machine
(iI) Efficiency

Numerical Based Questions

16. A woman draws water from a well using a fixed pulley. The mass of the bucket and water together is 6.0 kg. The force applied by the woman is 70 N. Calculate the mechanical advantage. (Take, $g = 10 \text{ m/s}^2$) ***[2007]***

Ans. $6/7 = 0.857$

17. The alongside figure shows the combination of a movable pulley P_1 with a fixed pulley P_2 used for lifting up a load W. ***[3]***



(i) State the function of the fixed pulley P_2.
(ii) If the free end of the string moves through a distance x, find the distance by which the load W is raised.
(iii) Calculate the force to be applied at C to just raise the load $w = 20$ kgf, neglecting the weight of the pulley P_1 and friction.

Ans. (i) to change direction, (ii) $x/2$, (iii) Effort needed $= 10$ kgf

18. The radius of the driving wheel of a set of gears is 18 cm. It has 100 teeth and rotates at a speed of 30 rpm. The driven wheel rotates at a speed of 150 rpm. Calculate

(i) the gear ratio.

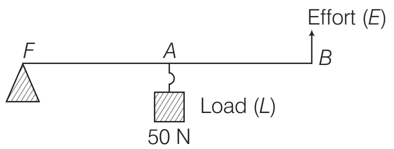
(ii) the number of teeth on the driven wheel.

(iii) the radius of the driven wheel.

Ans. (i)1:5, (ii) 20, (iii) 3.6 cm

19. A block and tackle system has VR = 5. Draw a neat labelled diagram of a system indicating the direction of its load and effort. Rohan exerts a pull of 200 kgf. What is the maximum load he can raise with this pulley system, if its efficiency 75%? ***Ans.*** 750 N

20. The diagram below shows a lever in use.



(i) Which class of lever does it belong?

(ii) If $FA = 30$ cm, $AB = 50$ cm, then find the mechanical advantage of the lever. ***Ans.*** 2

21. A crow-bar of length 100 cm has its fulcrum situated at a distance of 25 cm from the load. Calculate the mechanical advantage of crow-bar. ***Ans.*** 3

22. A pulley system has a velocity ratio of 3 and an efficiency of 80%. Calculate

(i) the mechanical advantage of the system.

(ii) the effort required to raise a load of 480 N by the system. ***Ans.*** (i) 2.4, (ii) 200 N

23. A boy draws water from a well using a fixed pulley. The mass of the bucket and water together is 5 kg. The force applied by the boy is 60 N. Calculate the mechanical advantage. (Take, $g = 10$ m/s^2)

Ans. 0.832

24. A cook uses a fire tong of length 30 cm to lift a piece of burning coal of mass 500 g. If he applies his effort at a distance of 10 cm from the fulcrum, what is the effort in SI unit? (Take, $g = 10$ m/s^2) ***Ans.*** 15 N

25. (i) A see-saw 8 m long is balanced in the middle. Two children of mass 30 kg and 40 kg are sitting on the same side of fulcrum at a distance of 1.5 m and 3.5m, respectively. Where must a man of mass 60 kg sit from the fulcrum so as to balance the see-saw?

Ans. 3.08 m

(ii) A block and tackle system of 5 pulleys is used to raise a load of 500 N steadily through a height of 20 m. The work done against friction is 2000 J. Calculate

(a) the displacement of the effort applied.

(b) the efficiency of the system. ***Ans.*** 80% (4 m)

26. The mechanical advantage of a machine is 4 and its efficiency is 60%. It is used to lift a load of 300 kgf to a height of 15 m. Calculate

(i) the effort required.

(ii) the work done on the machine.
(Take, $g = 10$ m /s^2) ***Ans.*** (i) 75kgf, (ii) 75000 J

27. A block and tackle system has VR = 5.

(i) Draw a neat labelled diagram of a system indicating the directions of its load and effort.

(ii) Shyam exerts a pull of 200 kgf. What is the maximum load he can raise with this pulley system, if its efficiency 80%? ***Ans.*** 800 kgf

28. A pulley system has a velocity ratio 5. Draw a neat labelled diagram of the pulley system to lift a load by applying the effort in a convenient direction. Mark the tension in your diagram.

(i) If the efficiency of the system is 80%, find its mechanical advantage.

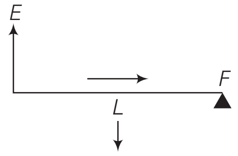
(ii) If a load of 10 kgf is pulled up by a distance of 2 m in 10 s, calculate the power developed by the effort. (Take, $g = 10$ m/s^2) ***Ans.*** 200 W

ARCHIVES* *(Last 7 Years)*

Collection of Questions Asked in Last 7 Years' (2018-2012) ICSE Class 10th Examinations

2018

1. The diagram below shows a lever in use



(i) To which class of levers does it belong?

(ii) Without changing the dimensions of the lever, if the load is shifted towards the fulcrum what happens to the mechanical advantage of the lever? ***[2]***

2. (i) Draw a diagram to show a block and tackle pulley system having a velocity ratio of 3 marking the direction of load (L), effort (E) and tension (T).

(ii) The pulley system drawn lifts a load of 150 N when an effort of 60 N is applied. Find its mechanical advantage.

(iii) Is the above pulley system an ideal machine or not? ***[4]***

2017

3. Which class of lever will always have MA > 1 and why? ***[2]***

4. A boy uses a single fixed pulley to lift a load of 50 kgf to some height. Another boy uses single movable pulley to lift the same load to the same height. Compare the effort applied by them. Give a reason to support your answer. ***[2]***

5. A pulley system with VR = 4 is used to lift a load of 175 kgf through a vertical height of 15 m. The effort required is 50 kgf in the downward direction. (Take, $g = 10\ \text{Nkg}^{-1}$)
Calculate

(i) distance moved by the effort.

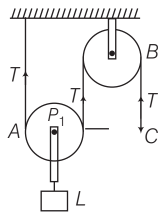
(ii) work done by the effort.

(iii) MA of the pulley system.

(iv) efficiency of the pulley system. ***[4]***

2016

6. From the diagram given below, answer the questions that follow:



(i) What kind of pulleys are A and B?

(ii) State the purpose of pulley B.

(iii) What effort has to be applied at C to just raise the load, $L = 20$ kgf ?

(neglect the weight of pulley A and friction). ***[3]***

7. (i) An effort is applied on the bigger wheel of a gear having 32 teeths. It is used to turn a wheel of 8 teeths. Where is it used? ***[4]***

(ii) A pulley system has three pulleys. A load of 120 N is overcome by applying an effort of 50 N. Calculate the mechanical advantage and efficiency of this system. ***[4]***

8. With reference to the terms mechanical advantage, velocity ratio and efficiency of a machine, name and define the term that will not change for a machine of a given design. ***[2]***

2015

9. A scissor is a .... multiplier. ***[2]***

10. A block and tackle system has VR = 5.

(i) Draw a neat labelled diagram of a system indicating the direction of its load and effort. ***[2]***

(ii) Rohan exerts a pull of 150 kgf. What is the maximum load he can raise with this pulley system, if its efficiency is 75%? ***[2]***

2014

11. What is the principle of an ideal machine? ***[2]***

12. Draw a diagram to show how a single pulley can be used so as to have its ideal MA = 2. ***[2]***

13. Derive a relationship between MA,VR and η of a machine. ***[2]***

2013

14. A type of single pulley is very often used as a machine even though it does not give any gain in mechanical advantage.

(i) Name the type of pulley used. ***[1]***

(ii) For what purpose is such a pulley used? ***[1]***

15. A block and tackle system of pulleys has a velocity ratio 4.

(i) Draw a labelled diagram of the system indicating clearly the points of application and directions of load and effort. ***[2]***

(ii) What is the value of the mechanical advantage of the given pulley system, if it is an ideal pulley system? ***[2]***

2012

16. State the class of levers and the relative positions of load (L), effort (E) and fulcrum (F) in each of the following cases. ***[2]***

(i) A bottle opener (ii) Sugar tongs

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 A women draws water from a well using a fixed pulley. The mass of the bucket and water together is 6 kg. The force applied by the women is 70 N. The mechanical advantage is

(a) 0.96 (b) 0.86 (c) 0.76 (d) 0.66

2 A boy uses a single movable pulley to lift a load of 50 kgf to some height. Another boy uses a single fixed pulley to lift the same load to same height. The ratio of efforts applied by them is

(a) 2 (b) 1 (c) $\frac{1}{2}$ (d) 4

3 A block and tackle system has VR = 5. Rahul exerts a pull of 150 kgf. What is the maximum load he can raise with this pulley system if its efficiency = 75%?

(a) 500.2 (b) 562.5 (c) 661.5 (d) 332.4

4 A pulley system has a VR = 5. If the efficiency of the system is 80%, find its MA.

(a) 1 (b) 2 (c) 3 (d) 4

5 A pulley system has MA = 4. If a load of 10 kgf is pulley by a distance of 2 m in 10 s, calculate the power developed by the effort.

(a) 15 W (b) 20 W (c) 25 W (d) 4.9 Watt

6 A fulcrum divides a crow-bar in the ratio 3 : 1. What weight will be lifted if an effort of 100 N is applied at the end of its longer arm?

(a) 400 N (b) 100 N
(c) 300 N (d) 500 N

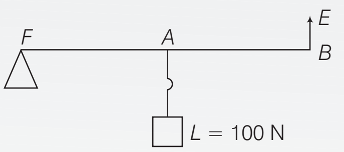
7 The MA of sugar tongs is

(a) <1 (b) $=1$ (c) >1 (d) None of these

8 A machine is driven by a 100 kg mass that falls 8 m on 4 seconds. It lifts a load of mass 500 kg. If the efficiency of the machine is 75%, what is the power output?

(a) 2000 W (b) 1000 W
(c) 2500 W (d) 150 W

9



If $FA = 40$ cm, $AB = 60$ cm, find MA of the lever.

(a) 1 (b) 1.5 (c) 2 (d) 2.5

10 The MA of a machine is 5 and its efficiency is 80%. It is used to lift a load of 200 kgf to a height of 20 m. What is the effort required?

(a) 10 kgf (b) 20 kgf (c) 40 kgf (d) 50 kgf

Answers

1. (b) **2.** (c) **3.** (b) **4.** (d) **5.** (d) **6.** (c) **7.** (a) **8.** (a) **9.** (d) **10.** (c)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 239.

CHAPTER

4

Refraction of Light

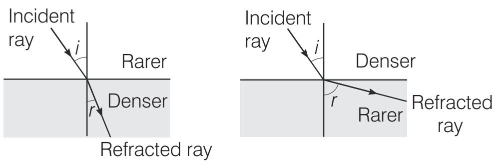
Chapter Objectives

- Laws of Refraction
- Refractive Index
- Refraction Through a Rectangular Glass Block
- Multiple Images in Thick Glass Plate/Mirror
- Simple Applications of Refraction of Light
- Some Consequences of Refraction of Light
- Prism
- Critical Angle
- Total Internal Reflection (TIR)

"Change in path of a light ray as it passes from one medium to another medium is called refraction of light."

When light travels from a rarer medium to a denser one, it bends towards the normal ($i > r$) and when travels from a denser medium to a rarer one, it bends away from the normal ($i < r$).

where, i = angle of incidence, r = angle of refraction.



Refraction of light

Some Important Terms Used in Refraction of Light

Some important terms used in refraction of light are as follow

(i) **Incident Ray** It is a ray of light which strikes the plane surface or a ray of light which travels towards the another optical medium.

(ii) **Point of Incidence** It is that point where an incident ray strikes the other optical medium.

(iii) **Normal** It is always perpendicular to the point of incidence.

(iv) **Angle of Incidence** It is an angle which an incident ray makes with the normal.

(v) **Refracted Ray** It is a ray of light which gets deviated from its path after entering in another optical medium.

(vi) **Angle of Refraction** It is an angle which the refracted ray makes with the normal.

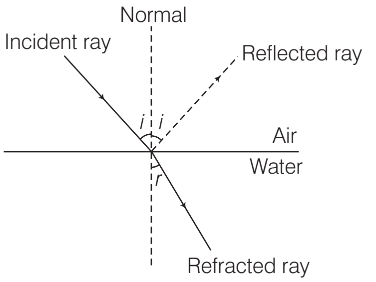
Causes of Refraction

The speed of light is different in different media. It is lesser in denser medium and greater in rarer medium. So, when light enters a denser medium its speed reduces and it bends towards the normal and when it enters rarer medium, its speed increases and it bends away from the normal.

Note When light is incident normally ($i = 0°$), the speed of light changes but the direction of light does not change.

Partial Reflection and Refraction due to Change in Medium

Partial reflection and refraction occurs when a wave is travelling between two mediums. Some of the wave is reflected back and the rest is refracted through the other medium.



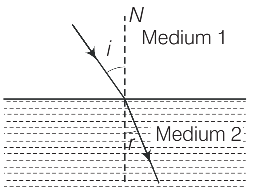
Note Partial reflection and refraction depends on angle of incidence. For 0° angle of incidence-mostly refraction, little or no reflection. For angle θ $(45° < \theta < 90°)$ little refraction, mostly reflection.

Laws of Refraction

There are two laws of refraction of light which are stated as below

First Law

The incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.



Law of refraction

Second Law

The ratio of sine of angle of incidence to the sine of angle of refraction is constant for a given pair of media. This constant is known as **refractive index** of the second medium w.r.t. first medium. It is expressed as

$$\mu = \frac{\sin i}{\sin r} = \text{constant}$$

This relation is also known as **Snell's law.**

CHECK POINT 01

1. Define refraction.
2. Mention the cause of refraction of light, when it passes from one medium to another.
3. What do you mean by optically rarer medium?
4. During the refraction of light, the frequency of light remains constant. Explain the reason.
5. State second law of refraction.

Refractive Index

The extent of the change in direction that takes place in a given pair of media is expressed in terms of the refractive index.

${}_1\mu_2$ represents refractive index of medium 2 with respect to medium 1, when light is going from medium 1 to medium 2.

$$\boxed{{}_1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\sin i}{\sin r}}$$

The refractive index of a medium with respect to vacuum, is called **absolute refractive index of the medium.** The absolute refractive index of a medium is simply called its refractive index.

For glass/water pair,

$$\boxed{{}_w\mu_g = \frac{{}_a\mu_g}{{}_a\mu_w}}$$

Note Refractive index of air is minimum and refractive index of diamond is maximum.

Refractive Index and Speed of Light

If c is the speed of light in air and v is the speed of light in medium, then the refractive index of the medium is

$$\boxed{\mu = \frac{\text{Speed of light in vacuum / air}}{\text{Speed of light in medium}} = \frac{c}{v}}$$

Hence for any two media, the refractive index of second medium with respect to first medium is equal to the ratio of the velocities of lights in the medium.

Refractive index of glass with respect to air,

$${}_a\mu_g = \frac{\text{Velocity of light in air}}{\text{Velocity of light in glass}} = \frac{c}{v_g} \quad \text{...(i)}$$

Refractive index of water with respect to air,

$${}_a\mu_w = \frac{\text{Velocity of light in air}}{\text{Velocity of light in water}} = \frac{c}{v_w} \quad \text{...(ii)}$$

On dividing Eq. (ii) from Eq. (i), we get

$$\frac{{}_a\mu_w}{{}_a\mu_g} = \frac{v_g}{v_w} = {}_g\mu_w$$

Values of μ for common substances,

$$\mu \text{ of water} = 1.33$$
$$\mu \text{ of glass} = 1.52$$
$$\mu \text{ of diamond} = 2.47$$

Example 1. If refractive index of water is 1.33, then determine the speed of light in this medium, if the speed of light in vacuum is given by $3\times 10^8\ \text{ms}^{-1}$.

Sol. Since, refractive index of water can be given by

$$\mu_w = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in water}}$$

$$\Rightarrow \quad 1.33 = \frac{3\times 10^8}{\text{Speed of light in water}}$$

$$\therefore \ \text{Speed of light in water} = \frac{3\times 10^8}{1.33} = 2.25\times 10^8\ \text{ms}^{-1}$$

Example 2. Refractive indices of water and glass are 4/3 and 3/2 respectively. A ray of light travelling in water is incident on the water glass interface at 30°. Calculate the angle of refraction.

Sol. Given, refractive index of water, ${}^a\mu_w = \frac{4}{3}$

Refractive index of glass, ${}^a\mu_g = \frac{3}{2}$

Angle of incidence in water, $i = 30°$

Angle of refraction, $r = ?$

As, $${}^w\mu_g = \frac{{}^a\mu_g}{{}^a\mu_w} = \frac{3/2}{4/3} \Rightarrow {}^w\mu_g = \frac{9}{8}$$

According to Snell's law,

$$\frac{\sin i}{\sin r} = {}^w\mu_g \quad \Rightarrow \quad \frac{\sin i}{\sin r} = \frac{9}{8}$$

$$\sin r = \frac{8}{9}\sin i \ \Rightarrow \ \sin r = \frac{8}{9}\sin 30° = \frac{8}{9}\times\frac{1}{2} = 0.444$$

$$\sin r = 0.444$$

$$\Rightarrow \quad r = \sin^{-1}(0.444) = 26.38°$$

Factors Affecting the Refractive Index of Medium

There are following two factors on which the refractive index of medium depends

(i) **Wavelength of Incident Light** The refractive index of a medium decreases with increase in wavelength of incident light.

Since, the speed of light is different for different colours thus, the light travels slower in case of low wavelength which leads to increase in refractive index.

$$\therefore \quad \mu_{\text{red}} < \mu_{\text{violet}}$$

(ii) **Temperature** The refractive index of a medium decreases with increase in temperature of medium.

($\because$ velocity of light increases with increase in temperature of medium)

$$\therefore \quad \mu_{T_1} > \mu_{T_2} \ \text{as}\ T_1 < T_2$$

(iii) **Optical Density of a Medium** Refractive index of a medium depends on optical density of a medium, more optical denser medium has larger value of refractive index and *vice-versa*.

Conditions for No Refraction

There are following two conditions under which a ray of light passes undeviated from medium 1 to medium 2

(i) When the refractive index of medium 2 is same as that of medium1.

(ii) When the angle of incidence at the boundary surface of the two media is zero ($i = 0°$).

Relation between Speed, Frequency and Wavelength of Light

The equation that relates wavelength and frequency is

$$v = f\lambda$$

where, v = speed of light in vacuum,

f = frequency of light and λ = wavelength of light.

Effect on Speed, Wavelength and Frequency Due to Refraction of Light

The effects due to refraction of light on speed, frequency and wavelength are given below as

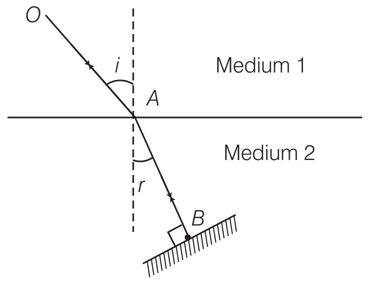
(i) Speed of light increases when light passes from denser to rarer medium and it decreases when light passes from rarer to denser medium.

(ii) Frequency is a characteristic light, therefore it remains same as light travels from one medium to another.

(iii) Wavelength of light increases when light passes from denser to rarer medium (as speed also increases) and it decreases when light passes from rarer to denser medium (as speed also decreases) but its frequency remains constant.

Principle of Reversibility of Light

When a light ray after suffering any number of reflections and refractions, its final path has reversed, it travels back along its entire initial path. This is called principle of reversibility of light.



Reversibility of light

In the given figure, OA is an incident ray in medium 1 and AB is the refracted ray in medium 2. By Snell's law, the refractive index of medium 2 relative to medium 1 is given by

$${}^1\mu_2 = \frac{\sin i}{\sin r} \qquad \text{...(i)}$$

where, i and r are the angles of incidence and refraction respectively.

Suppose, the ray AB is reflected back by a plane mirror. Now, BA is the incident ray and AO is the refracted ray.

Correspondingly, r is angle of incidence and i is angle of refraction. Again by Snell's law, the refractive index of medium 1 relative to medium 2 is given by

$$^2\mu_1 = \frac{\sin r}{\sin i} \qquad \text{...(ii)}$$

Multiplying Eqs. (i) and (ii), we have

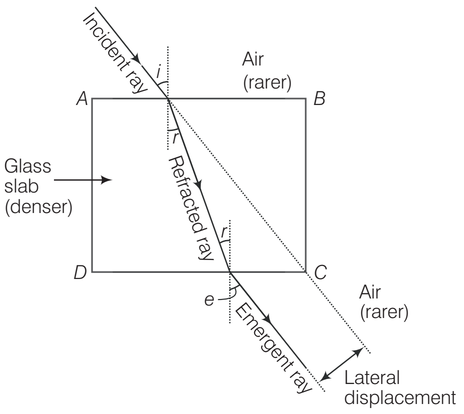
$$^1\mu_2 \times {}^2\mu_1 = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin i} = 1 \text{ or } \boxed{^1\mu_2 = \frac{1}{^2\mu_1}}$$

Thus, the refractive index of medium 2 relative to medium 1 is equal to the reciprocal of the refractive index of medium 1 relative to medium 2.

Refraction Through a Rectangular Glass Block

When a light ray enters in a glass slab, then the emergent ray is parallel to the incident ray but it is shifted sideward slightly. In this case, refraction takes place twice, first when ray enters glass slab from air and second when exits from glass slab to air.

Both refractions have been shown in figure (here, glass slab is denser medium and air is rarer medium). The extent of bending of the ray of light at opposite parallel faces AB and CD of rectangular glass slab is equal and opposite. So, the ray emerging from face CD is parallel to incident ray but shifted sideward slightly.



Refraction of light through a glass block

where, i = angle of incidence, r = angle of refraction and e = angle of emergence.

Lateral Displacement

The perpendicular distance between the emergent ray and incident ray when the light passes out of a glass slab is called lateral displacement.

It can be calculated by the formula,

$$\text{lateral displacement} = \frac{t \sin (i - r)}{\cos r}$$

where, t = thickness of the glass block,

i = angle of incidence and r = angle of refraction.

The lateral displacement depends upon the following factors

(i) thickness of the glass block,

(ii) angle of incidence and

(iii) refractive index of glass.

Example 3. **A ray of light is incident at angle of 45° on one face of a rectangular glass slab of thickness** 10 cm **and refractive index 1.5. Calculate the lateral shift produced.**

Sol. Here, $i = 45°$, $t = 10\,\text{cm}$, $\mu = 1.5$

Lateral shift = ?

So, $\mu = \frac{\sin i}{\sin r} \Rightarrow \sin r = \frac{\sin i}{\mu}$

$\sin r = \frac{\sin 45°}{1.5} \Rightarrow \sin r = \frac{0.707}{1.5}$

$\Rightarrow \sin r = 0.4713 \Rightarrow r = \sin^{-1}(0.4713)$

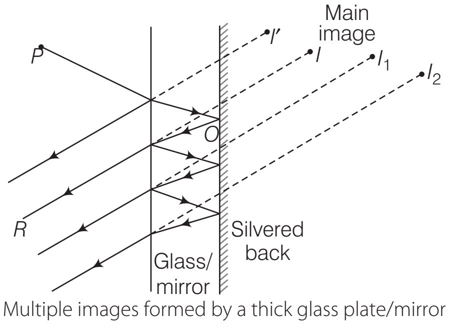
$\Rightarrow r = 28.14°$

$\therefore$ Lateral shift $= \frac{t \sin(i-r)}{\cos r} = \frac{10 \sin(45° - 28.14°)}{\cos 28.14°}$

$= \frac{10 \sin 16.86°}{\cos 28.14°} = \frac{10 \times 0.2900}{0.8818} = 3.3$ cm

Multiple Images in Thick Glass Plate/Mirror

When an object is placed in front of thick glass mirror, then its multiple images are formed. It happens due to multiple reflection from different layers (top and bottom surfaces). As only the second surface is silvered, therefore, the second image would be brightest.

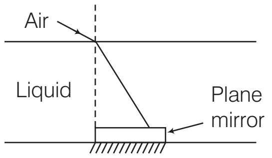


Multiple images formed by a thick glass plate/mirror

Further images would be formed due to multiple reflections. These images would become fainter due to absorption of light by medium.

CHECK POINT 02

1. Write the two factors on which the refractive index of a medium depends.
2. If a ray of light falls perpendicularly on a glass slab, what will be its angle of refraction? Give the reason in support of your answer.
3. State principle of reversibility.
4. A ray of monochromatic light enters a liquid as shown in diagram.
   i.e., $\angle i = 45°$, $\angle r = 30°$



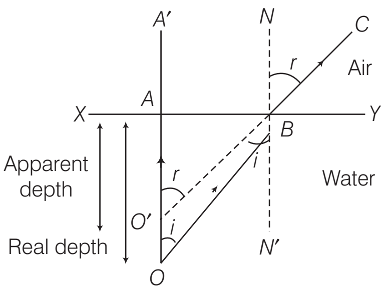
   Show the path of ray after it strikes the mirror and goes into air.
5. Which image formed by the thick glass plate is brightest?

Simple Applications of Refraction of Light

Simple applications of refraction of light are givne below.

Real and Apparent Depth

An object placed in a denser medium when viewed from a rarer medium, appears to be at a depth lesser than its real depth. This is because of refraction of light. Consider an object is placed in water (denser medium) and is being seen from air (rarer medium). Let O be a point object at an actual depth OA below the free surface of water XY. A ray of light incident normally on XY, along OA passes straight along OAA'.



Real depth and apparent depth

Another ray of light from O incident at $\angle i$ on surface XY along OB deviates away from normal. It is refracted at $\angle r$ along BC. On drawing backwards CB meets OA at O'. Therefore, O' is virtual image of O.

Hence, apparent depth = O′A

Real depth = OA

$$\therefore \quad \boxed{{}^a\mu_w = \frac{OA}{O'A} = \frac{\text{Real depth}}{\text{Apparent depth}}}$$

If x is the real depth of water surface and ${}^a\mu_w$ is the refractive index of water with respect to air, then the normal shift (d) in position of point object is given by

$$d = \text{Real depth} - \text{Apparent depth}$$

$$\therefore \quad d = x - \frac{x}{{}^a\mu_w}$$

$$\left(\because \text{Apparent depth} = \frac{\text{Real depth}}{{}^a\mu_w} = \frac{x}{{}^a\mu_w}\right)$$

$$\text{or} \quad \boxed{d = x\left(1 - \frac{1}{{}^a\mu_w}\right)}$$

The shift by which an object seemed to be raised, depends upon

(i) refractive index of the medium,
(ii) thickness of the denser medium and
(iii) the colour of the incident light.

Note The apparent depth of an object lying in a denser medium is always less than its real depth for all angles of observation in a rarer medium.

Example 4. **A mark is made at the bottom of a beaker and a microscope is focused on it. The microscope is then raised through 0.015 m. To what height water must be poured into the beaker to bring the mark again at focus?**

$$\left(\text{Take, } {}^a\mu_w = \frac{4}{3}\right)$$

Sol. Given, ${}^a\mu_w = \frac{4}{3}$

Normal shift = 0.015 m

If x is the height upto which water must be poured into the beaker, then

$$\text{normal shift, } d = x\left(1 - \frac{1}{{}^a\mu_w}\right)$$

$$0.015 = x\left(1 - \frac{1}{4/3}\right) \Rightarrow 0.015 = x\left(\frac{1}{4}\right) \Rightarrow x = 0.060\text{m}$$

Example 5. **Velocity of light in glass is 2×10^8 m/s and that in air is 3×10^8 m/s. By how much would an ink dot appear to be raised, when covered by a glass plate 6 cm thick?**

Sol. Given, velocity of light in glass, $v = 2 \times 10^8$ m/s

Velocity of light in air, $c = 3 \times 10^8$ m/s

Thickness of glass plate, $x = 6$ cm

Normal shift, $d = ?$

Refractive index of glass with respect to air

$$\mu = \frac{c}{v} = \frac{3 \times 10^8}{2 \times 10^8} = 1.5$$

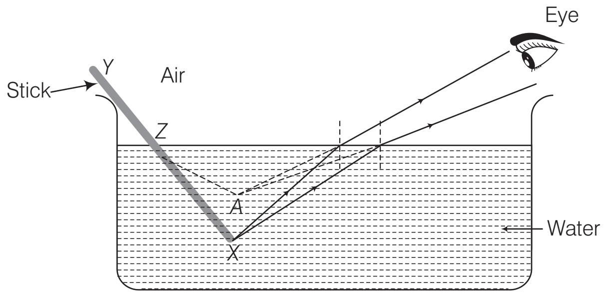
$$\text{Normal shift, } d = x\left(1 - \frac{1}{\mu}\right)$$

$$d = 6\left(1 - \frac{1}{1.5}\right) = \frac{6 \times 0.5}{1.5} = 2\,\text{cm}$$

Apparent Bending of Stick Under Water

A stick partially immersed in water appears to be bent because of the refraction of light coming from the part of stick that is under water.

If we consider a stick YX immersed obliquely in water, with its part ZX is submerged within the water. Consider a point X on the tip of the stick.



Apparent bending of stick under water

A divergent beam coming from it after refraction will bend away from the normal. So the moment, the refracted beam refracted the eye, the eye retraces back a straight line path.

Due to this, the rays appear to originate from point A,which is higher than X. Thus, it is true for any point between X and Y. So, the stick appears to be bent and short within the water. It appears magnified because the image is formed close to the eye.

Some Consequences of Refraction of Light

Some consequences of refraction of light are given below.

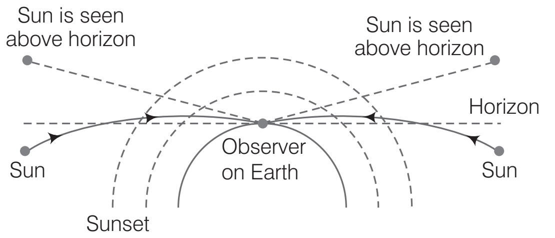
1. Advanced Sunrise and Delayed Sunset

The density of atmosphere around the earth is not uniform throughout due to which, it has layers of different densities which work as optically rarer and denser medium. The refraction of light due to these atmospheric layers is called **atmospheric refraction.**

The Sun is visible to us about two minutes before the actual sunrise and about two minutes after the actual sunset.

This is because of atmospheric refraction. When the Sun is slightly below the horizon, the sunlight coming from less dense to more dense air, is refracted downwards.

Because of this, the Sun appears to be raised above the horizon and so the rising of Sun can be seen about two minutes before actual sunrise. Similarly, due to atmospheric refraction, the Sun can be seen for about two minutes even after the Sun has set below horizon.



Note At sunrise and sunset, the Sun appears flattened. This apparent flattening of the Sun's disc is also due to atmospheric refraction.

2. Planets do not Twinkle

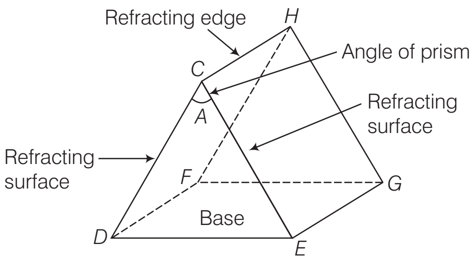
Planets are much closer to the Earth and hence appear larger in size as compare to stars. So, they can be taken as a collection of large number of point sized sources of light. The total variation in the amount of light entering our eye from all these individual point sized sources will average out to zero which nullify the twinkling effect of each other. So, planets do not twinkle.

3. Shimmering Effect Around a Camp Fire

During camping, when we sit around a camp fire, the face of the person sitting opposite to you, appears to shimmer. This occurs due to the refraction of light. The rays of light reflected from the face of the person sitting opposite to you on passing the hot fire get refracted. As, we know that the hot air is rapidly moving and its optical density is continuously changing, due to which the path of the refracted rays also changes. This gives rise to the shimmering effect.

Prism

A transparent refracting medium bounded by at least two lateral surfaces, inclined to each other at certain angle is called a **prism.** It has two triangular bases and three rectangular lateral surfaces. The angle between two lateral surfaces is called **angle of prism** (A).

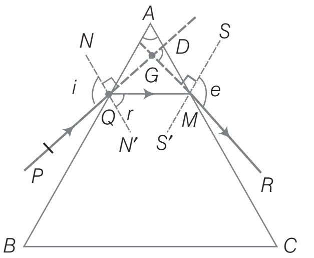


Prism

The two rectangular plane inclined surfaces through which the light passes, are known as **refracting surfaces**. The line along which the two surfaces (refracting) meet is called the **refracting edge**.

Refraction of Light through a Glass Prism

In the diagram given below, a ray of light PQ is entering from air to glass at the first surface AB. The light ray on refraction gets bent toward the normal. At the second surface AC, the light ray enters from glass to air, so it bents away from the normal.



Refraction of light through a triangular glass prism

The above diagram shows refraction through a prism, where,

PQ = incident ray, QM = refracted ray,

MR = emergent ray, $\angle A$ = angle of prism,

$\angle i$ = angle of incidence, $\angle r$ = angle of refraction,

$\angle e$ = angle of emergence and $\angle D$ = angle of deviation.

Note When a ray of light passes through a prism, it bends towards the thicker part of the prism.

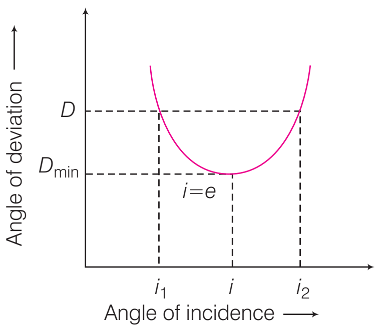
Angle of Deviation (D)

It is the angle at which the emergent ray (produced backward) makes with the incident ray (produced forward). It is given by $\angle D = \angle i + \angle e - \angle A$.

There are four factors on which the value of angle of deviation produced by the prism depends.

They are as follow

(i) **Dependence of Angle of Deviation on the Angle of Incidence (i)** Experimentally, it has been observed that with the increase in the incident angle, the angle of deviation first decreases, then reach a minimum value and then it also increases. This has depicted in (i-D) graph shown below.



The position of prism with respect to the incident ray at which the incident ray suffers minimum deviation is known as position of minimum deviation.

At this position of minimum deviation,

$$D = D_{min}, \; i = e \text{ and } r_1 = r_2 = r$$

Hence, $A = 2r$

$$\therefore D_{min} + 2r = 2i \Rightarrow D_{min} = 2i - 2r \;\Rightarrow\; D_{min} = 2i - A$$

As, refractive index of prism, $\mu = \dfrac{\sin i}{\sin r}$

$$\therefore \quad \boxed{\mu = \dfrac{\sin\left(\dfrac{D_{min} + A}{2}\right)}{\sin\left(\dfrac{A}{2}\right)}}$$

(ii) **Dependence of Angle of Deviation on the Refractive Index (μ)** Experimentally, it is found that as the refractive index of the material decreases, the angle of deviation decreases.

(iii) **Dependence of Angle of Deviation on the Colour or Wavelength of Light (λ)** For a given prism deviates, the violet light most and the red light least.

(iv) **Dependence of Angle of Deviation on the Angle of Prism (A)** The angle of deviation (D) increases with increase in the angle of prism.

Example 6. **What should be the angle of incidence, if a ray of light incident on the refracting surface of a equilateral prism suffers a minimum deviation of 40°?**

Sol. We know from the relation, $A + D = i + e$

The minimum deviation can be calculated as

$$D = D_{min} \text{ and } i = e$$

$$\Rightarrow \quad D_{min} = 2i - A \quad \text{or} \quad i = \frac{D_{min} + A}{2}$$

Given, $D_{min} = 40°$ and $A = 60°$

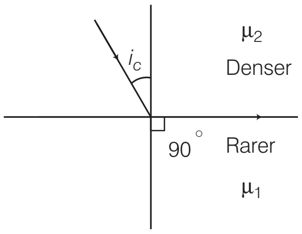
It is not true always, $i = \dfrac{40° + 60°}{2} = 50°$

CHECK POINT 03

1. What is the relation between real and apparent depth?
2. Define atmospheric refraction.
3. Why planets do not twinkle?
4. What are the different factors on which the angle of deviation depend?
5. Name the factors on which angle of deviation depends.
6. Does refractive index increases with the increase in angle of deviation?
7. Calculate refractive index of a equilateral glass prism for a light of red colour. Angle of minimum deviation for red colour is 30°.

Critical Angle

The angle of incidence in denser medium for which angle of refraction in rarer medium is 90° is called critical angle. Its value depends on the nature of two media in contact.



From Snell's law, $\mu_2 \times \sin i_c = \mu_1 \times \sin 90°$

$$\therefore \quad \frac{\mu_1}{\mu_2} = \frac{\sin i_c}{\sin 90°} \Rightarrow \frac{\mu_1}{\mu_2} = \sin i_c \quad \Rightarrow \quad \frac{\mu_2}{\mu_1} = \frac{1}{\sin i_c}$$

$$\Rightarrow \quad \boxed{{}^1\mu_2 = \frac{1}{\sin i_c} = \operatorname{cosec} i_c}$$

The critical angle for a given pair of media depends on their refractive index, which in turn depends on the following two factors.

(i) **Effect of Colour of Light** As violet light has the highest value of refractive index, while red light has the least value of refractive index. So, due to this reason, the critical angle for a pair of media is least for violet light and most for red light. Therefore, the critical angle increases with increase in the wavelength of light.

(ii) **Effect of Temperature** When the temperature of medium is increased, its refractive index decreases, due to which, the critical angle for that pair of media increases. Therefore, the critical angle increases with an increase in temperature.

Example 7. If the refractive index of a glass is 1.5. Determine the critical angle for it.

Sol. Since, we know that

$$ {}^1\mu_2 = \frac{1}{\sin i_c} \quad \text{or} \quad {}^a\mu_g = \frac{1}{\sin i_c}$$

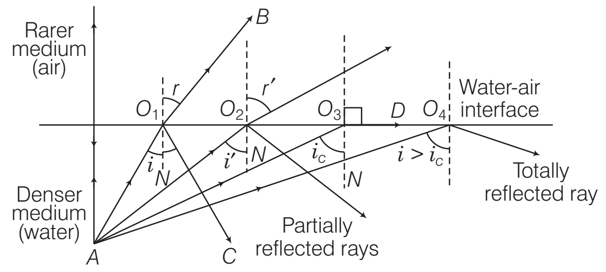
$$\therefore \quad 1.5 = \frac{1}{\sin i_c} \Rightarrow \sin i_c = \frac{1}{1.5} \Rightarrow i_c = \sin^{-1}\left(\frac{1}{1.5}\right)$$

$$\Rightarrow \quad i_c = \sin^{-1}(0.666) \Rightarrow i_c = 41.80° \approx 42°$$

Total Internal Reflection (TIR)

When a ray of light travelling from a denser medium to rarer medium, is incident at the interface of the two media at an angle greater than the critical angle for the two media, then the ray is totally reflected back to denser medium.

This phenomenon is called total internal reflection (TIR).



Refraction and internal reflection of rays from a point *A* in the denser medium (water) incident at different angles at the interface with a rarer medium (air)

Necessary conditions for total internal reflection to takes place are as follow

(i) The ray incident on the interface of two media should travel in the denser medium.

(ii) The angle of incidence should be greater than critical angle for the two media.

Total Internal Reflection in a Prism

The phenomenon of total internal reflection has been considered in three different prism which are given below as

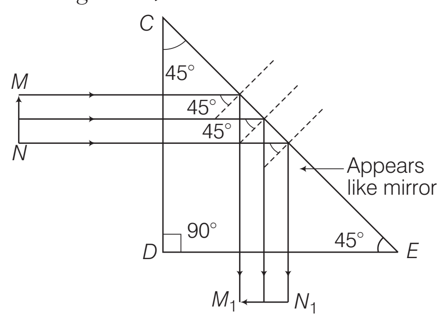
1. TIR in Prism of Angles (45°, 45° and 90°) i.e., Right-Angled is Isosceles Prism

When a prism has 90° angle between its two refracting surfaces and the two other angles each of 45°, then the prism is called **total reflecting prism.**

As, the light incident normally on any of its face, it then gets total internally reflected. Because of this property, this prism is used for the following three purposes.

(i) Deviation through 90° Angle

When a parallel beam of light strikes normally on the face *DC*, it does not suffer any refraction and then strikes the face *CE* at an angle of 45°.

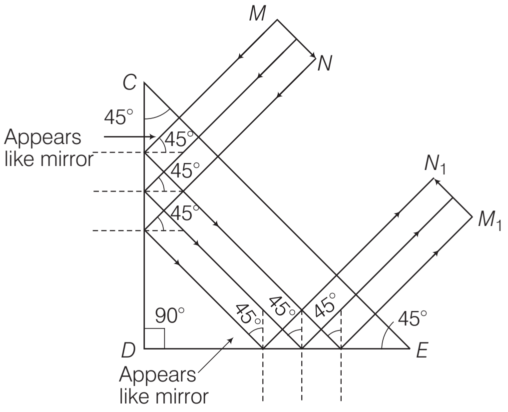


Deviation through 90° angle

As, we know that the critical angle for, the glass is 42°, so total internal reflection takes place. Due to this, the beam makes an angle of reflection of 45° and turns completely through 90°. It strikes the face *DE* normally and emerges out of the air and behaves like a mirror.

(ii) Deviation through 180° Angle

If a parallel beam of light is incident normally on the face *CE* of the right angled isosceles prism, the beam passes undeviated till it strikes the face *CD* at an angle of 45°.



Deviation through 180° angle

Then, total internal reflection takes place and the beam turns completely through an angle of 90° in order to strike the face *DE* at an angle of 45°.

Then at the face *DE*, another TIR takes place and again the beam turns through an angle of 90° in order to strike the face *CE* normally.

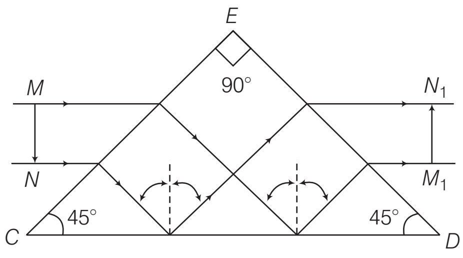
Finally, the beam comes out of the prism without suffering any refraction.

As a result, the beam turns through 180°.

(iii) No Deviation

The rays of light parallel to the hypotenuse (*CD*) strikes the surface *EC*.

These rays then suffers refraction and strike the face *CD* with an angle greater than 42°. Due to this, total internal reflection takes place. Then, the rays turn and strike the face *ED*.

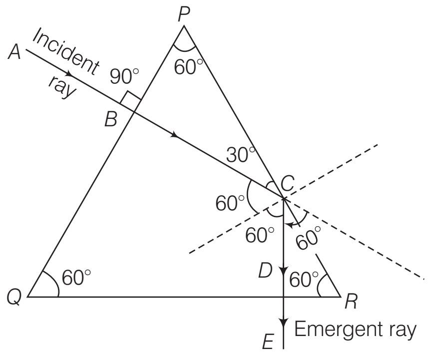


No deviation

On finally coming out from the face *ED*, these refracted rays suffer another refraction. During this, the rays revert themselves, i.e., the inverted image *MN* appears as N_1M_1.

2. TIR through a Prism where Each Angle is 60° i.e., Equilateral Prism

The figure given below shows an equilateral prism i.e., each angle of 60°. If a ray falls normally on the face *PQ*, then without any refraction it falls on the face *QR* at an angle 60° since, this angle is greater than the critical angle of glass. So, total internal reflection takes place. Thus, this prism can be used to deviate a ray of light by 60°.

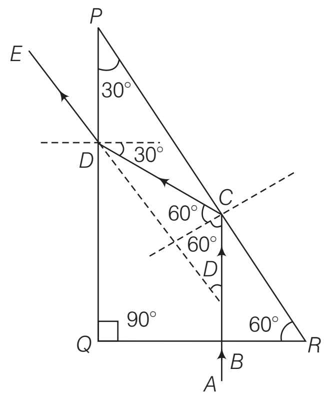


Total internal reflection through an equilateral prism

3. TIR through Prism of Angles (30°, 60° and 90°) i.e., Right-Angled Prism

The figure given below shows a prism with angles, 30°, 60° and 90° i.e., right angled prism. If a ray of light falls normally on the face *QR*, then it falls on the face *PR* without any deviation.

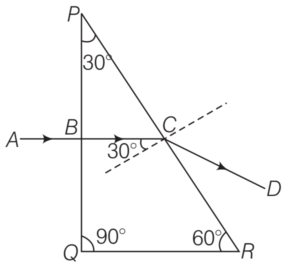
Since, the angle of incidence is 60° which greater than the critical angle of glass (42°) so TIR takes place, on reflection, the ray falls on the face *PQ*, where it gets refracted with an angle less than 60°. Therefore, this prism can be used to deviate a light ray through an angle less than 60° by TIR.

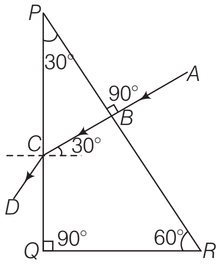


TIR through right angled prism

If the ray of light falls on other two faces i.e., *PR* and *PQ*, then the previous case does not take place i.e., no total internal reflection happens.

This has been depicted in the figures given below.





Comparison between Total Internal Reflection and Reflection from a Plane Mirror

Total Internal Reflection	Reflection from a Plane Mirror
This is the phenomenon in which light travels from denser to rarer medium at an angle greater than the critical angle for that pair of media, then the rays are totally reflected back.	In this light falls on plane mirror at any angle of incidence and then a little part of light gets reflected and rest get refracted and absorbed.
The energy of the reflected ray is same as that of incident ray i.e., no loss of energy.	The energy of the reflected rays is less than that of incident ray i.e., there is loss of energy.
The brightness of the image is very good and does not decrease even after a long use of TIR device.	The brightness of the image is not very good and decreases with the increase in time.

Some Consequences of Total Internal Reflection

Total internal reflection is also very prominent in our daily life also.

Some of these consequences are given below

(i) Optical fibre are used to transmit light over large distances without any loss of energy.

(ii) If a glass vessel is cracked, then it often shines like a mirror.

(iii) Brilliance of diamond.

(iv) In deserts, in daytime, a person often see a pool of water at a distance. It is because of the phenomenon of mirage.

CHECK POINT 04

1. Among the following substances, which one has the highest value of critical angle? Turpentine, glass, water, diamond.
2. How does the critical angle changes with the change in the temperature of surrounding?
3. State total internal reflection.
4. Name any two instruments in which total reflecting prism is used.
5. Mention one difference between refraction of light from a plane mirror or and total internal reflection from a prism.

SUMMARY

- The phenomenon of bending of light entering from one medium to another is called refraction of light.
- When a ray of light travels from a rarer medium to a denser medium, it bends towards the normal.
- When a ray of light travels from a denser medium to a rarer medium, it bends away from the normal.
- There are two laws of refraction.

  First Law The incident ray, the refracted ray and the normal at the point of incidence, all lie on the same plane.

  Second Law The ratio of sine of angle of incidence to the sine of angle of refraction is constant for a given pair of media.This is also called Snell's law.
- Refractive index (n) of a medium is the ratio of speed of light in vacuum (c) to the speed of light in the medium (v) and is given by
$$n = \frac{c}{v}$$
- Refractive index of one medium w.r.t to another medium is given by, $^{1}n_2 = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}}$
- When a light ray, after suffering many reflections and refractions, has its final path reversed and travels back along its initial path is called principle of reversibility of light.
- The perpendicular distance of separation between the incident ray and the emergent ray is called lateral displacement.
- The shift by which an object appears to be raised when it is immersed in water is called the apparent depth.
$$\text{Refractive index} = \frac{\text{Real depth}}{\text{Apparent depth}}$$
- A transparent refracting medium bounded by five plane surfaces inclined at some angles is known as prism.
- The angle between two refracting surfaces is called angle of prism (A) and the angle between the incident ray and the emergent ray is called the angle of deviation (D).
- Critical angle for a pair of media is defined as the angle of incidence in denser medium for which the angle of refraction becomes 90°.
- When a ray of light is travelling from a denser medium to rarer medium, is incident at the interface of the two media at an angle greater than the critical angle, the ray is totally reflected back to the denser medium. This phenomenon is called total internal reflection.

EXAM PRACTICE

a 2 Marks Questions

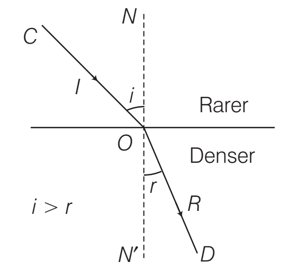
1. When a ray of light does not change its path during refraction, state what will be the angle of incidence and refraction of this ray?

Sol. The moment, a ray of light is incident perpendicularly to the interface surface of the two medium, then it passes without any deviation. ***[1]***

So, due to this reason, the angle of incidence and angle of refraction, both will be zero degree. ***[1]***

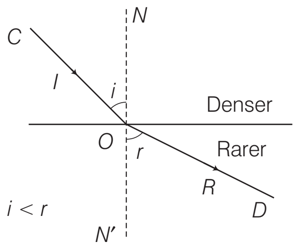
2. With the help of a suitable diagram, represent the refraction of light rays from
(i) rarer to denser.
(ii) denser to rarer. Also, label each diagram.

Sol. (i) Rarer to denser



where, OC = incident ray, OD = refracted ray and NN' = normal. ***[1]***

(ii) Denser to rarer



where, OC = incident ray, OD = refracted ray and NN' = normal. ***[1]***

3. State the laws of refraction of light.

Sol. Refer to theory (Page 67).

4. How can you define the term "refractive index of a medium"? State whether it can be less than 1 or not?

Sol. The ratio of the velocity of light in vacuum to the velocity of light in a medium is known as the refractive index of that medium.

i.e., Refractive index of a medium

$$= \frac{\text{Velocity of light in vacuum}}{\text{Velocity of light in that medium}}$$ ***[1]***

The absolute refractive index of a substance cannot be less than one because it would mean that the speed of light is more in that substance than in free space, which is not possible. The relative refractive index can be less than one if the first medium is less denser than the second medium. ***[1]***

5. If ${}^a\mu_g$ is refractive index of glass with respect to air and ${}^g\mu_a$ is refractive index of air with respect to glass. Express the refractive index of glass with respect to water (${}^w\mu_g$) in terms of refractive index of water and glass with respect to air.

Sol. As, we know that according to the definition of refractive index,

$${}^w\mu_g = \frac{v_w}{v_g}$$ ***[1]***

Now, multiply and divide in numerator and denominator by v_a,

$$\Rightarrow \quad {}^w\mu_g = \frac{v_w \cdot v_a}{v_g \cdot v_a}$$

$$\Rightarrow \quad {}^w\mu_g = \frac{v_a / v_g}{v_a / v_w}$$

$$\left(\text{But } \frac{v_a}{v_g} = {}^a\mu_g \text{ and } \frac{v_a}{v_w} = {}^a\mu_w\right)$$

$$\therefore \quad {}^w\mu_g = \frac{{}^a\mu_g}{{}^a\mu_w}$$ ***[1]***

6. "Refractive index of a medium is least for the red colour of light". Justify this statement.

Sol. Since, in prism the red colour of light is bent the least and its is a fact that the bending of light rays increases on increasing the refractive index of the medium. ***[1]***

As, wavelength of red is maximum, refractive index of a medium is least for the red colour of light. ***[1]***

7. If a light of a single colour is passed through a liquid having a piece of glass suspended in it, so on changing the temperature of the liquid, at a particular temperature, the glass piece is not seen.
(i) At what situation, the glass piece will not be seen?
(ii) Why is the light of a single colour used?

Sol. (i) The glass piece cannot be seen when the refractive index of the liquid becomes equal to refractive index of the glass. **[1]**

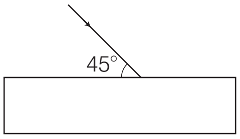
(ii) Since, the refractive index of medium is different for different colour of light.

So due to this, light of a single colour is used. **[1]**

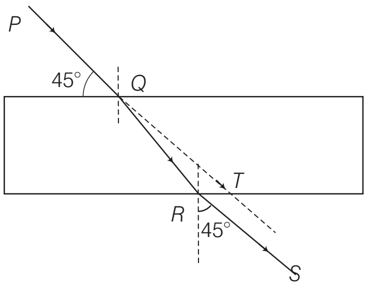
8. A boy uses blue colour of light to find the refractive index of glass. He then repeats the experiment using red colour of light. Will the refractive index be the same or different in the two cases? Give a reason to support your answer. ***[2016]***

Sol. Since, the refractive index of the medium is always inversely proportional to the wavelength of light. Moreover, it is known that wavelength of the red colour is more than that of the blue colour. So, the refractive index in case of blue colour of light will be greater than that of red colour of light. **[2]**

9. Draw the diagram given below and clearly show the path taken by the emergent ray. ***[2014]***

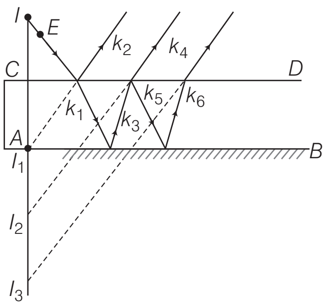


Sol. *The emergent ray RS is shown below as*



[2]

10. "If a lighted candle is placed in front of thick glass plane mirror, then several images can be observed, but the second image is brightest." Explain, the reason for this statement.



Sol. Since, first image is formed by reflected ray k_2 from the transparent surface CD.

The reflection from the transparent surface CD is very small due to which I_1 is not so much bright. Image I_2 is formed by the refracted ray k_4. As, most part of the incident ray E refract by refracted ray k_1, so a small part of k_1 can be absorbed by the mirror at the same time, the maximum part of k_1 is reflected by reflected ray k_3. **[1]** Some part of k_3 is reflected by ray k_5 but its most part is refracted by k_4. Other image is formed by ray k_5, which is less bright than by k_4. So, due to this reason I_2 is brightest than beyond I_2. **[1]**

11. How is the refractive index of a material related to

(i) real and apparent depth?

(ii) velocity of light in vacuum or air and the velocity of light in a given medium? ***[2017]***

Sol. (i) When an object is placed under water (any other medium), then observing it from outside the water (or medium) it appears to be raised above.

The ratio of real depth and apparent depth is equal to the refractive index of the medium.

$$\text{Refractive index, } \mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$ **[1]**

(ii) **Relation between Refractive Index and Velocity of Light**. The refractive index of the medium is the ratio of the velocity of light in vacuum (or air) to the velocity of light in that medium.

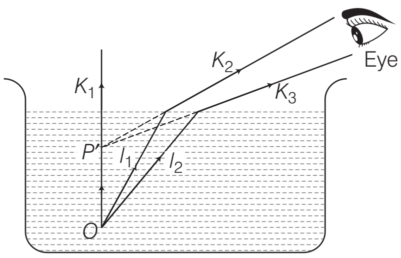
$$\mu = \frac{\text{Velocity of light in vacuum } (c)}{\text{Velocity of light in medium } (v)}$$ **[1]**

12. Does the depth of the tank of a water appear to change or remains the same when viewed normally from the above? ***[2012]***

Sol. No, when the depth of a tank of water is viewed normally, no refraction takes place as the light rays passes through the medium undeviated. Thus, the depth of the tank remains the same because it is a case of normal incidence, where $\angle i = \angle r = 0°$. **[2]**

13. Fish swimming in a pond seems to be nearer than its actual depth. Explain why?

Sol. A fish can be seen by observer when the rays of light coming from the fish enters into observers eyes.



[1]

Consider the above figure, if I_1 and I_2 are the two rays coming from a point on fish O.

These rays passes water (denser) to air (rarer) and then deviate from the normal through path K_2, K_3 and form an image at P', which is virtual and above O. Due to this reason, fish in the water seems to be very nearer than its actual depth. ***[1]***

14. Light passes through a rectangular glass slab and through a glass prism. In what way does the direction of the two emergent beams differ? ***[2014]***

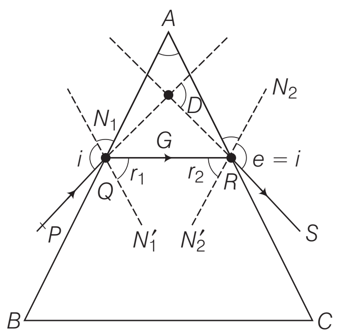
Sol. In a rectangular glass slab, the emergent ray is parallel to the incident ray but they are not along the same line, whereas in the prism, the emergent ray is not parallel to the incident ray. ***[1]***

This differ because in glass slab, the two surfaces at which refraction occurs is parallel to each other, but in prism they make some angle. ***[1]***

15. Draw a ray diagram to show the refraction of a monochromatic ray through a prism when it suffers minimum deviation. ***[2017]***

Sol. When a ray of light passes through a prism, it bends towards the thicker part of the prism.

Let the incident ray PQ falls on the face AB of prism and emerges out from the face AC as RS.



Sectional view of prism

Here, PQ = incident ray, QR = refracted ray

RS = emergent ray, $\angle A$ = angle of prism

$\angle i_1$ = angle of incidence,

$\angle r_1, \angle r_2$ = angles of refraction,

$\angle e$ = angle of emergence and $\angle D$ = angle of deviation.

When the ray suffers minimum deviation, $e = i$. ***[2]***

16. State the dependence of angle of deviation.

(i) On the refractive index of the material of the prism.

(ii) On the wavelength of light. ***[2016]***

Sol. (i) Since, refractive index of the prism is directly proportional to the angle of deviation.

So, larger the refractive index, larger will be the deviation angle.

(ii) Since, refractive index of material is inversely proportional to the wavelength of light. So, smaller the wavelength of light larger will be the deviation angle. ***[2]***

17. Name the factors affecting the critical angle for the pair of media. ***[2014]***

Sol. *The main factors affecting the critical angle for the pair of media are*

(i) the refractive index of a medium. ***[1]***

(ii) the temperature of surrounding. ***[1]***

18. (i) State the relation between the critical angle and the absolute refractive index of a medium.

(ii) Which colour of light has a higher critical angle? Red light or Green light. ***[2018]***

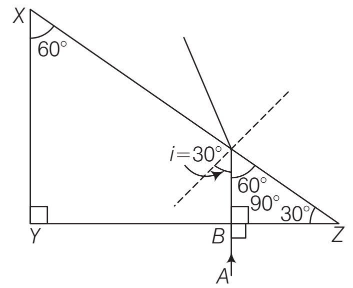
Sol. (i) The relation between the critical angle C and the absolute refractive index (μ) of medium is given by

$$\mu = \frac{1}{\sin C} \text{ or } \sin C = \frac{1}{\mu}$$ ***[1]***

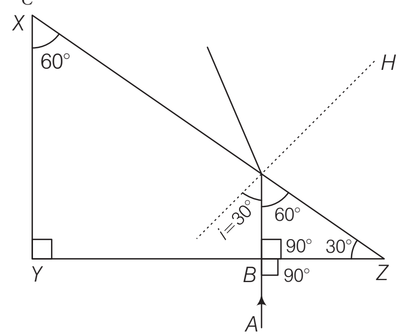
(ii) As $\mu_{green} > \mu_{red}$

Therefore, critical angle (C) for red colour is higher than green colour light. ***[1]***

19. The following diagram shows a 60°, 30°, 90° glass prism of critical angle 42°. Copy the diagram and complete the path of incident ray AB emerging out of the prism marking the angle of incidence on each surface. ***[2018]***



Sol. Given, $i_C = 42°$



[1]

As angle of incidence on face XZ is less than i_C so, ray is refracted. ***[1]***

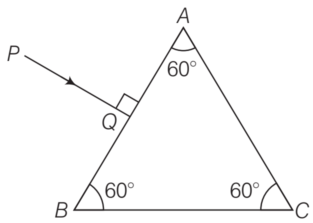
20. State the conditions required for total internal reflection of light to take place. ***[2017]***

Sol. *The necessary conditions for the total internal reflection are as follows*

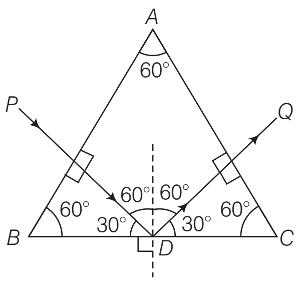
(i) The light must travel from a denser medium to a rarer medium.

(ii) The angle of incidence must be greater than the critical angle (i_c) for the pair of media. ***[2]***

21. Copy the diagram given below and complete the path of light ray till it emerges out of the prism. The critical angle of glass is 42°. In your diagram, mark the angles wherever necessary. ***[2016]***



Sol. *The ray diagram is given below*



[2]

b 3 Marks Questions

22. (i) Write a relationship between angle of incidence and angle of refraction for a given pair of media.

(ii) When a ray of light enters from one medium to another having different optical densities it bends. Why does this phenomenon occur?

(iii) Write one condition where it does not bend when entering a medium of different optical density.

Sol. (i) For a given pair of media, the relationship between the angle of incidence and angle of refraction is given by

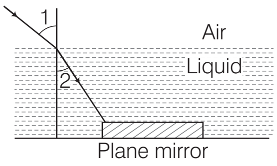
$$_1\mu_2 = \frac{\sin i}{\sin r}$$

where, i = angle of incidence, r = angle of refraction and $_1\mu_2$ = refraction index of the second medium with respect to the first medium. ***[1]***

(ii) The phenomenon of refraction occurs because light travels at different speeds in different medium. If a ray of light travels through air and enter a more dense medium, such as water, they slow down and bend towards the normal. ***[1]***

(iii) When a ray of light is incident normally to the surface, then it passes straight from one medium to another medium without any bending. ***[1]***

23. When a ray of monochromatic green light enters a liquid from air as shown in the figure given alongside.



The angle 1 is 45° and angle 2 is 30°.

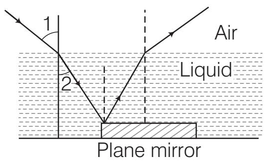
(i) Determine the refractive index of the liquid.

(ii) Represent in the diagram showing the path of the ray after it strikes the mirror and re-enters air. Mark in the diagram wherever necessary.

(iii) Draw the diagram again if plane mirror becomes normal to the refracted ray inside the liquid. Name the principle used.

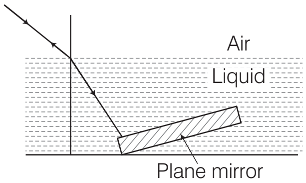
Sol. (i) Refractive index of liquid $= \dfrac{\sin 45°}{\sin 30°} = \dfrac{0.7}{0.5} = 1.4$ ***[1]***

(ii) *The path of the reflected and refracted ray is shown below.*



[1]

(iii) The principle used is the principle of reversibility of path of light.



[1]

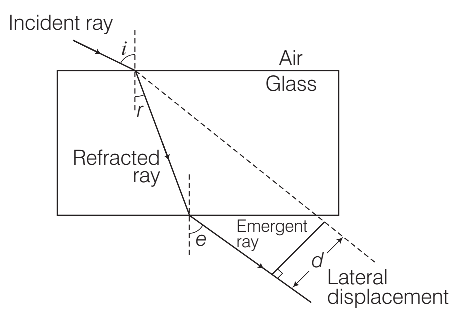
24. A ray of monochromatic light is incident from air on a glass slab. ***[2010]***

(i) Draw a labelled ray diagram showing the change in the path of the ray till it emerges from the glass slab.

(ii) Name the two rays that are parallel to each other.

(iii) Mark the lateral displacement in your diagram.

Sol. (i) **Ray diagram**



[1]

(ii) Two rays that are parallel to each other are incident ray and emergent ray. **[1]**

(iii) The perpendicular d istance between the incident ray and emergent ray is the lateral displacement, which is marked as d in the above diagram. **[1]**

25. If an obliquely incident light ray bends at the surface due to change in speed, when passing from one medium to another. While the ray does not bend when it is incident normally.

State with the reason, whether the ray will have the different speed in the other medium.

Sol. Definitely yes, the ray will have the different speed in the other medium because this is the case of no refraction (no bending) of light on going perpendicular from one medium to another. **[1½]**

All the parts of the ray will reach from one medium to another at the same time, enters the other medium at the same time, get slowed down or speed up at the same time. Due to this, no bending of light occurs but speed changes. **[1½]**

26. How does the value of angle of deviation produced by a prism change with an increase in the **[2009]**

(i) value of angle of incidence and

(ii) wavelength of incident light ?

Sol. (i) If the value of angle of incidence increases, then there is a corresponding decrease in the angle of deviation. For a particular value of angle of incidence, the angle of deviation becomes minimum after which it starts rising with further increase in the value of angle of incidence. **[1½]**

(ii) If the value of the wavelength of incident light increases, then angle of deviation decreases. **[1½]**

27. Explain the meaning of reversibility of light.

Sol. Refer to theory (Pages 68 and 69).

28. If the refractive index of air with respect to glass is expressed as ${}^g\mu_a = \dfrac{\sin i}{\sin r}$, answer the following:

(i) Express the similar expression for ${}^a\mu_g$ in terms of i and r.

(ii) If angle $r = 90°$, what is the corresponding angle (i) is called?

(iii) Write down the physical significance of angle (i) in part (ii).

Sol. (i) The similar expression for ${}^a\mu_g$ in terms of i and r can be expressed as

$${}^a\mu_g = \frac{\sin r}{\sin i}$$ **[1]**

(ii) If angle of refraction $r = 90°$, then the corresponding angle i is called critical angle. **[1]**

(iii) If angle of incidence is more than the critical angle, then the light gets reflected back into glass from the interface. This phenomenon is known as total internal reflection. **[1]**

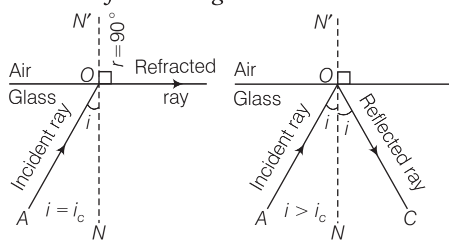
29. (i) Draw a labelled ray diagram to illustrate

(a) critical angle

(b) total internal reflection for a ray of light moving from one medium to another.

(ii) Write a formula to express the relationship between refractive index of the denser medium with respect to rarer medium and its critical angle for that pair of media. **[2008]**

Sol. (i) *The labelled diagram of critical angle and total internal reflection is given below* **[1]**



(a) Critical angle (b) Total internal reflection **[1]**

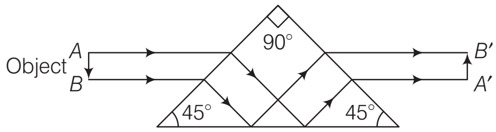
(ii) The formula to express the relationship between refractive index of the denser medium with respect to rarer medium and critical angle is given by

$$\mu = \frac{1}{\sin i_c} = \operatorname{cosec} i_c$$

where, i_c is the critical angle. **[1]**

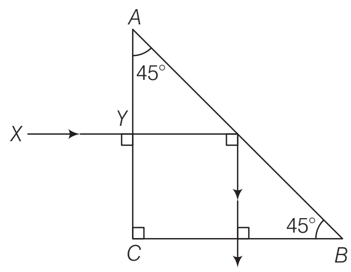
30. Draw the diagram of a right angled isosceles prism which is used to make an inverted image erect. **[2018]**

Sol.



[3]

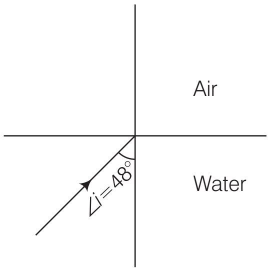
31. A ray of light XY passes through a right angled isosceles prism as shown below.



(i) What is the angle through which the incident ray deviates and emerges out of the prism?
(ii) Name the instrument where this action of prism is put into use.
(iii) Which prism surface will behave as a mirror? *[2018]*

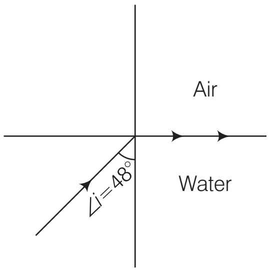
Sol. (i) 90°
(ii) Periscope
(iii) Surface AB behaves like a mirror. Because on this surface total internal reflection occurs. *[3]*

32. A ray of light travels from water to air as shown in the diagram given below.



(i) Copy the diagram and complete the path of the ray. Given, the critical angle for water is 48°.
(ii) State the condition, so that total internal reflection occurs in the above diagram. *[2017]*

Sol. (i)



[1½]

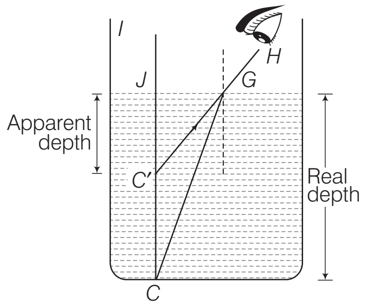
(ii) Required condition for TIR in the above diagram is angle of incidence should be greater for TIR than the critical angle, i.e., $\angle i > 48°$. *[1½]*

C 4 Marks Questions

33. It has been observed that water in a pond appears to be only three quarters of its actual depth.
(i) Mention the property of light that is responsible for this observation.
(ii) Elaborate your answer with the help of a suitable diagram.

Sol. (i) Refraction of light is the property of light due to which the water in a pond appears to be only three quarters of its actual depth. *[1]*

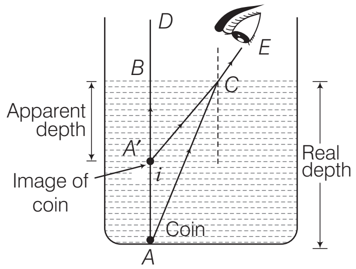
(ii) A ray from the bottom of the tank C on striking normally at J goes straight. Another ray from C strikes the interface at G is refracted towards GH and when produced back, it appears to come from C'. When JI and GH enter the eye, these form the image of C at C'. Therefore, the depth appears to be $C'J$ instead of actual depth CJ. *[2]*



[1]

34. (i) With the help of a well-labelled diagram, show that the apparent depth of an object such as a coin in water is less than its real depth.
(ii) How is the refractive index of water related to the real depth and the apparent depth of a column of water? *[2007]*

Sol. (i) A ray from bottom of the tank A (coin) is striking normally at B goes straight.



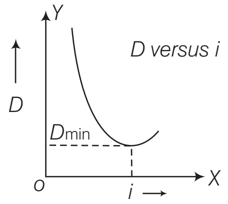
Another ray from A striking the interface at C is refracted towards E and when produced back, it appears to come from A'. When BD and CE enter the eye, these form an image of A (coin) at A' (coin). Thus, the depth appears to be at $A'B$ instead of the actual AB. *[2]*

(ii) The refractive index of water related to the real depth and the apparent depth of a column of water is given by

$$\text{Refractive index, } \mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$ *[2]*

35. (i) In which manner, does the angle of deviation produced by a prism change with increase in the angle of incidence? With the help of a suitable diagram, show the variation in the angle of deviation with the angle of incidence at the prism surface.
(ii) Using the curve in part (i) above, how do you infer that for a given prism, the angle of minimum deviation D_{min} is unique for the given light?

Sol. (i) Angle of deviation decreases with increase in incidence angle but upto a certain extent. After reaching a minimum value, angle of deviation will increase again.



Here, it is shown graphically. **[1 + 1]**

(ii) Since, we can see in the graph that in the position of minimum deviation.

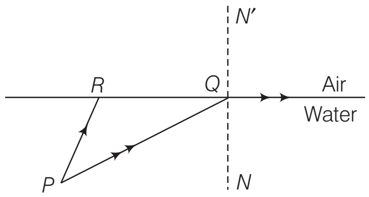
$$D = D_{min} \Rightarrow i_1 = i_2 = i$$ **[1]**

where, i_1 is the angle of incidence and i_2 is the angle of emergence.

Then, $D_{min} = 2i - A$

For a given prism and given colour of light, D_{min} is unique. **[1]**

36. *PQ* and *PR* are two light rays emerging from the object *P* as shown in the figure. **[2006]**



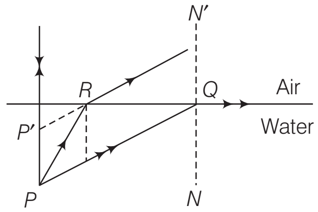
(i) What is the special name given to the angle of incidence ($\angle PQN$) of ray *PQ*?

(ii) Copy the ray diagram and complete it to show the position of the image of the object *P*, when seen obliquely from above.

(iii) Name the phenomenon that occurs, if the angle of incidence $\angle PQN$ is increased still further.

Sol. (i) The special name given to the angle of incidence $\angle PQN$ of ray *PQ* is critical angle. **[1]**

(ii) *The complete diagram is shown below.*



The image of the object *P* will be formed at *P*' when seen obliquely from above. **[2]**

(iii) Total internal reflection occurs, if the angle of incidence $\angle PQN$ is increased still further. **[1]**

37. Answer the following questions.

(i) Write a note on "total reflecting prism".

(ii) State three actions that it can produce.

(iii) With the help of a diagram, show one action of total reflecting prism.

Sol. (i) A prism having an angle of 90° between its two refracting surfaces and the other two angles each equal to 45°, is known as total reflecting prism. It is because the light incident normally on any of its faces, suffers total internal reflection inside the prism. **[1]**

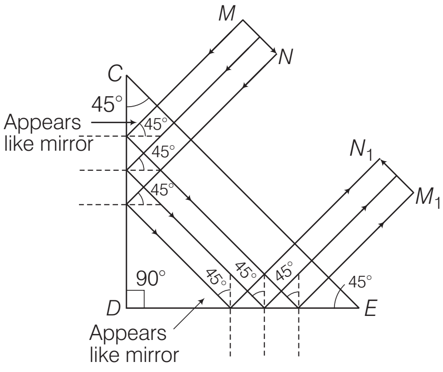
(ii) *Given below are the three actions produced by it,* i.e.,

(a) It can deviate a ray of light through 180° i.e., in prism binoculars.

(b) It can erect the image (inverted) without producing deviation in its path.

(c) It can deviate a ray of light through 90°. **[2]**

(iii)

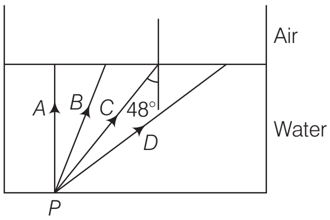


Deviation through 180° angle **[1]**

38. Mention some differences between the reflection of light from a plane mirror and total internal reflection of light from a prism. **[2007]**

Sol. Refer to theory (Page 75).

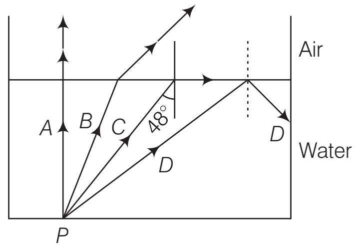
39. The diagram below shows a point source *P* inside a water container. Four rays *A*, *B*, *C* and *D* starting from the source *P* are shown upto the water surface.



(i) Show in the diagram, the path of these rays after striking the water surface. The critical angle for water-air surface is 48°.

(ii) Name the phenomenon which the rays *B* and *D* exhibit. **[2017]**

Sol. (i) **Ray diagram**



[2]

(ii) Ray B exhibits refraction ray D exhibits total internal reflection. [2]

Numerical Based Questions

40. If the speed of light in air is $3\times10^8\ \text{ms}^{-1}$, determine the speed of light in glass. The refractive index of glass is 1.5. [2]

Sol. Given, speed of light, $c=3\times10^8\ \text{ms}^{-1}$

Refractive index, $\mu=1.5$

$$\because \quad \mu=\frac{c}{v}=\frac{\text{Velocity of light in air}}{\text{Velocity of light in a medium}} \quad [1]$$

$$\Rightarrow \quad 1.5=\frac{3\times10^8}{v} \quad \Rightarrow \quad v=\frac{3\times10^8}{1.5}$$

$$\Rightarrow \quad v=2\times10^8\ \text{m/s.} \quad [1]$$

41. The speed of light in diamond is 125000 km/s, if the speed of light in air is 3×10^8 m/s, then determine the refractive index of the diamond.

Sol. Velocity of light in air, $v_a=3\times10^8$ m/s

Velocity of light in diamond, $v_d=125\times10^6$ m/s [1]

$$^a\mu_d=\frac{v_a}{v_d}=\frac{3\times10^8}{125\times10^6}=\frac{300\times10^6}{125\times10^6}\Rightarrow {}^a\mu_d=\frac{12}{5}=2.4 \quad [1]$$

42. When a ray of light travelling in air is incident on the glass surface at angle of incidence 60°. Determine the angle of refraction in glass, if refractive index of glass is 3/2.

Sol. Given, $\angle i=60° \quad \Rightarrow \quad {}^a\mu_g=\frac{3}{2}$

$$\text{As,} \quad {}^a\mu_g=\frac{\sin i}{\sin r} \quad \Rightarrow \quad \sin r=\frac{\sin i}{{}^a\mu_g} \quad [1]$$

$$\Rightarrow \quad \sin r=\frac{\sin 60°}{\frac{3}{2}}=\frac{\sqrt{3}\times2}{2\times3} \quad \Rightarrow \sin r=\frac{1}{\sqrt{3}} \quad [1]$$

$$\therefore \quad \sin r=\sin 35° \quad \Rightarrow \quad r=35° \quad [1]$$

43. When a coil is placed at the bottom of a beaker containing water of refractive index $\frac{4}{3}$ to a depth of 12 cm, so by what height, does the coin appear to be raised when seen from vertically above?

Sol. Shift of image = Real depth of water $\left(1-\frac{1}{\mu_w}\right)$

$\because$ Real depth of water = 12 cm (given)

$$\mu_w=\frac{4}{3} \quad \text{(given)} \quad [1]$$

$\therefore$ Shift of image of coin

$$=12\left(1-\frac{1}{4/3}\right)=12\left(1-\frac{3}{4}\right)=12\left(\frac{1}{4}\right) \quad [1]$$

$\therefore$ Shift of coin = 3 cm

44. Determine the angle of incidence and emergence for a ray of light which suffers minimum deviation. Determine the angle of minimum deviation ($D_{\min}$).

Sol. When ray suffers minimum deviation, then angle of incidence, i = angle of emergence (e)

$$\Rightarrow \quad i=e=48° \text{ and } \angle A=60°$$

$$\because \quad D+A=i+e$$

$$D_{\min}=48°+48°-60°$$

$$=96°-60° \quad [1]$$

$$D_{\min}=36° \quad [1]$$

45. Determine the time taken by a ray of light when it passes through a glass sheet of thickness 2 m, $^a\mu_g=\frac{3}{2}$.

Sol. As we know, $^a\mu_g=\frac{v_a}{v_g}$

$$\Rightarrow \quad v_g=\frac{v_a}{{}^a\mu_g}=\frac{3\times10^8}{3/2}$$

$$\Rightarrow \quad v_g=2\times10^8\ \text{m/s.} \quad [1]$$

$$\text{Time}=\frac{\text{Distance}}{\text{Speed}}$$

$$=\frac{2\ \text{mm}}{2\times10^8\ \text{m/s}}=\frac{2\times10^{-3}}{2\times10^8}=10^{-11}\ \text{s}$$

$\therefore$ Time to pass in 2 mm glass $=10^{-11}$ s. [1]

46. If a ray of light of wavelength 5400 Å suffers refraction from air to glass, determine the wavelength of light in glass. (Take, $^a\mu_g=3/2$)

Sol. Given, $\lambda = 5400$, Å $= 5400 \times 10^{-10}$ m
$^a\mu_g = 3/2$

As, frequency remains same, $v = f\lambda$ **[1]**

$\Rightarrow \quad 3 \times 10^8 = f \times 54 \times 10^{-8}$

$\Rightarrow \quad f = \dfrac{3 \times 10^8}{54 \times 10^{-8}} \Rightarrow f = \dfrac{3}{54} \times 10^{16}$ **[1]**

$\Rightarrow \quad f = \dfrac{300}{54} \times 10^{14} \Rightarrow f = 5.5 \times 10^{14}$

$\because \quad {}^a\mu_g = \dfrac{3}{2} \Rightarrow {}^a\mu_g = \dfrac{\text{Velocity of light in vacuum}}{\text{Velocity of light in glass}}$

$\Rightarrow \quad v = \dfrac{c}{^a\mu_g} = \dfrac{3 \times 10^8}{3} \times 2 = 2 \times 10^8 \text{ ms}^{-1}$ **[1]**

Now, $v = f\lambda \Rightarrow 2 \times 10^8 = 5.5 \times 10^{14} \times \lambda$

$\Rightarrow \quad \lambda = \dfrac{2 \times 10^8}{5.5 \times 10^{14}} \Rightarrow \lambda = 3600$ Å **[1]**

47. A coin placed at the bottom of a beaker appears to be raised by 4.0 cm. If the refractive index of water is 4/3, find the depth of the water in the beaker.

Sol. Since, we know that

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}} \Rightarrow \frac{4}{3} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

Let real depth $= x$ **[1]**

Therefore, apparent depth $= x - 4$

$\Rightarrow \quad \dfrac{4}{3} = \dfrac{x}{x-4}$

$\Rightarrow \quad 4x - 16 = 3x$ **[1]**

$\Rightarrow \quad x = 16 \quad$ ($\therefore$ real depth = 16 cm)

48. If the refractive index of glass is $3/2$, determine the critical angle for glass-air surface.
(Take, $\sin 42° = 2/3$)

Sol. Given, $\mu = \dfrac{3}{2}$

If i_c is the critical angle, then

$$\sin i_c = \frac{1}{\mu} = \frac{1}{3/2} = \frac{2}{3}$$ **[1]**

$\Rightarrow \quad \sin i_c = \sin 42°$

$\Rightarrow \quad i_c = 42°.$ **[1]**

49. Determine the approximate value of critical angle for
(i) glass-air surface (ii) water-air surface.

Sol. (i) Since, $\sin i_c = \dfrac{1}{^a\mu_g}$

$\because \quad {}^a\mu_g = \dfrac{3}{2}$

$\therefore \quad \sin i_c = \dfrac{2}{3} \Rightarrow \sin i_c = 0.6667$

$\Rightarrow \quad \sin i_c = \sin 42° \Rightarrow i_c = 42°$ **[1]**

So, critical angle for glass-air surface is 42°.

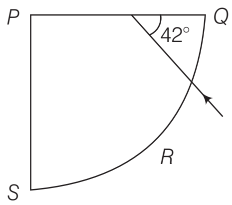
(ii) As, ${}^a\mu_w = \dfrac{4}{3}$, then critical angle for water-air surface can be calculated by

$\sin i_c = \dfrac{1}{^a\mu_w} \Rightarrow \sin i_c = \dfrac{3}{4} \Rightarrow \sin i_c = \sin 48.6$ **[1]**

$\Rightarrow i_c = 48.6°$

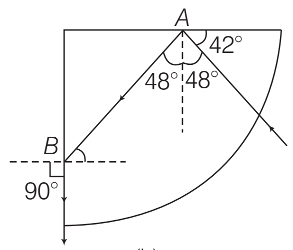
So, critical angle for water-air surface is 48.6°.

50. A ray of light enters a glass slab *PQRS*, as shown in the diagram. The critical angle of the glass is 42°. Copy the diagram and complete the path of the ray till emerges from the glass slab. Mark the angles in the diagram wherever necessary. ***[2011]***



(a)

Sol. At point *A* in fig. (b), $i = 48°$ and $i_c = 42° \Rightarrow i > i_c$



(b) **[1]**

While at point *B*, $i = 42°$ and $i_c = 42° \Rightarrow i = i_c$

Therefore, $r = 90°$ **[1]**

CHAPTER EXERCISE

2 Marks Questions

1. How does the refractive index of a medium depend upon its temperature?

2. "The upper surface of water contained in the beaker and held above the eye level appear silvery". Justify the statement along with a reason.

3. The critical angle for glass-air is 45° for the yellow colour of light.

Mention whether it will be less than equal to or more than 45° for

(i) red light

(ii) blue light

4. What will be the change occurred in the angle of minimum deviation produced by a prism, if

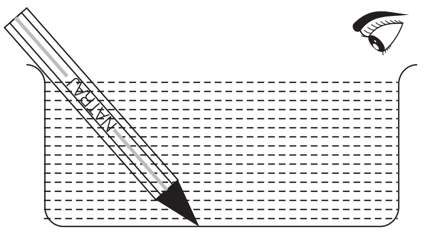
(i) the wavelength of the incident light and

(ii) the refracting angle of prism increases?

3 Marks Questions

5. If a girl puts her pencil into an empty trough and see the pencil from the position as given in the figure below.

(i) What kind of variation will be noticed in the appearance of pencil, when water is poured into the trough?



(ii) Mention the name of the phenomenon which accounts for the above stated observation.

(iii) Complete the given diagram to show how the girl's eye observes the pencil through water.

6. Explain the factors affecting the critical angle for a given pair of media.

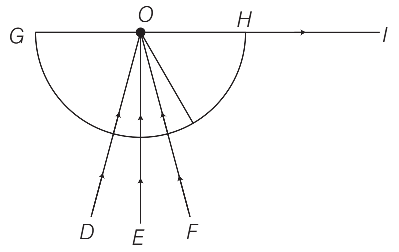
7. With the help of a suitable diagram, explain mathematically the refraction and total internal reflection of light rays at different angle of incidences.

8. If an object is viewed through a glass prism with its vertex pointing upwards, then it appears to be displaced upwards. Explain why?

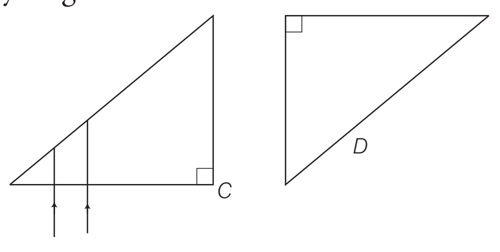
4 Marks Questions

9. Given below is a diagram showing the section of a semi-circular glass block having centre at O. D, E, F are the monochromatic rays of light of the same colour.

Mark the critical angle by i_c. Draw the path of rays F and D after they strike the edge GH. Name the phenomenon which the rays F and D exhibit.

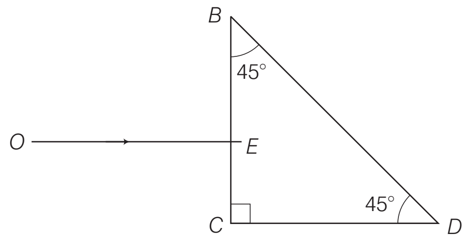


10. A diagram given below is to be completed in order to show the rays coming out of prism D. Mention the principle used for completing the ray diagram.



11. Briefly state, how is the angle of emergence related to the angle of incidence when prism is in the position of minimum deviation. Explain your answer with the help of a labelled diagram using an equilateral prism.

12. If a ray of light OE passes through a right angled prism as shown in the figure.

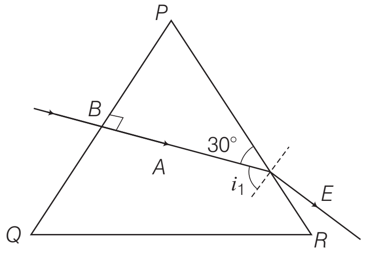


(i) Mention the angle of incidence at the faces BD and CD.

(ii) Give the name of phenomenon which the ray suffers at the face BD.

13. A water pond appears to be 2.7m deep. If the refractive index of water is 4/3. Determine the actual depth of the pond. ***Ans.*** 3.6 m

14. If a ray of light is incident normally on one face of the equilateral glass prism, answer the following questions.



(i) Determine the angle of incidence on first face of prism. ***Ans.*** 0°

(ii) Calculate the angle of refraction from first face of the prism. ***Ans.*** 0°

(iii) Find the angle of incidence (i_1) at the second face of the prism. ***Ans.*** 60°

(iv) Will the ray of light suffers minimum deviation by the prism? ***Ans.*** No

15. A ray of light incident at an angle of 48° on a prism of refracting angle 60° suffers minimum deviation. Determine the angle of minimum deviation. ***Ans.*** 36°

ARCHIVES* *(Last 6 Years)*

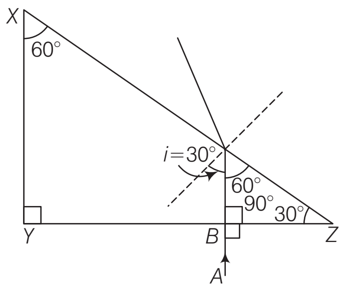
Collection of Questions Asked in Last 6 Years' (2018-2013) ICSE Class 10th Examinations

2018

1. (i) State the relation between the critical angle and the absolute refractive index of a medium.

(ii) Which colour of light has a higher critical angle? Red light or Green light. ***[2]***

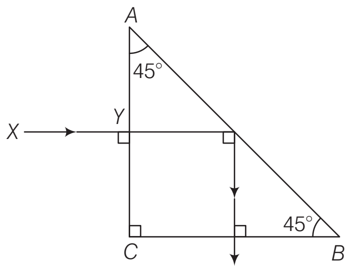
2. The following diagram shows a 60°, 30°, 90° glass prism of critical angle 42°. Copy the diagram and complete the path of incident ray *AB* emerging out of the prism marking the angle of incidence on each surface.



[2]

3. Draw the diagram of a right angled isosceles prism which is used to make an inverted image erect. ***[3]***

4. A ray of light *XY* passes through a right angled isosceles prism as shown below.



(i) What is the angle through which the incident ray deviates and emerges out of the prism?

(ii) Name the instrument where this action of prism is put into use.

(iii) Which prism surface will behave as a mirror? ***[3]***

2017

5. How is the refractive index of a material related to

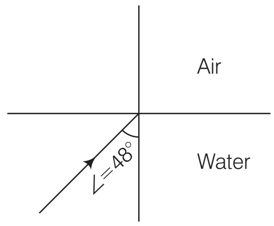
(i) real and apparent depth?

(ii) velocity of light in vacuum or air and the velocity of light in a given medium? ***[2]***

6. State the conditions required for total internal reflection of light to take place. ***[2]***

7. Draw a ray diagram to show the refraction of a monochromatic ray through a prism when it suffers minimum deviation. ***[2]***

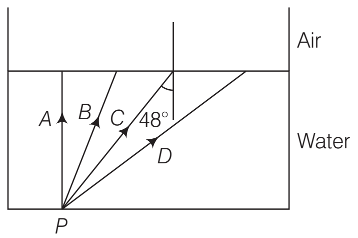
8. A ray of light travels from water to air as shown in the diagram given below



(i) Copy the diagram and complete the path of the ray. Given the critical angle for water is 48°.

(ii) State the condition, so that total internal reflection occurs in the above diagram. ***[3]***

9. The diagram below shows a point source *P* inside a water container. Four rays *A*, *B*, *C* and *D* starting from the source *P* are shown upto the water surface.



(i) Show in the diagram, the path of these rays after striking the water surface. The critical angle for water-air surface is 48°.

(ii) Name the phenomenon which the ray *B* and *D* exhibit. ***[4]***

2016

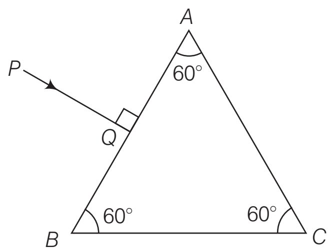
10. (i) Write a relationship between angle of incidence and angle of refraction for a given pair of media.

(ii) When a ray of light enters from one medium to another having different optical densities it bends. Why does this phenomenon occur?

(iii) Write one condition where it does not bend when entering a medium of different optical density. ***[3]***

11. A boy uses blue colour of light to find the refractive index of glass. He then repeats the experiment using red colour of light. Will the refractive index be the same or different in the two cases? Give a reason to support your answer. ***[3]***

12. Copy the diagram given below and complete the path of light ray till it emerges out of the prism. The critical angle of glass is 42°. In your diagram, mark the angles wherever necessary. ***[2]***



13. State the dependence of angle of deviation.

(i) On the refractive index of the material of the prism.

(ii) On the wavelength of light. ***[2]***

2015

14. Name one factor that affects the lateral displacement of light as it passes through a rectangular glass slab. ***[2]***

15. (i) Why does the sun appear red at sunrise? ***[1]***

(ii) Name the subjective property of light related to its wavelength. ***[1]***

16. Jatin puts a pencil into a glass container having water and is surprised to see the pencil in the different state.

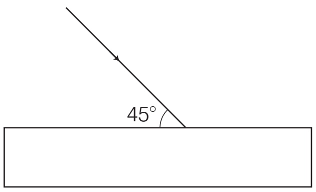
(i) What change is observed in the appearence of the pencil? ***[1]***

(ii) Name the phenomenon responsible for the change. ***[1]***

(iii) Draw a ray diagram showing how the eye sees the pencil. ***[1]***

2014

17. Draw the diagram given below and show the path taken by the emergent ray.



[2]

18. (i) A ray of light passes from water to air. How does the speed of light change? ***[1]***

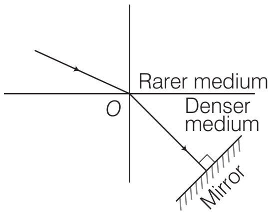
(ii) Which colour of light travels fastest in any medium except air? ***[1]***

19. Light passes through a rectangular glass slab and through a triangular glass prism. In what way does the direction of two emergent beams differ and why? ***[2]***

20. Name the factors affecting the critical angle for the pair of media. ***[2]***

2013

21. A ray of light is moving from rarer to a denser medium and strikes a plane mirror placed at 90° to the
direction of the ray as shown in the diagram.



(i) Copy the diagram and mark the arrows to show the path of the ray of light after it is reflected from the mirror. ***[1]***

(ii) Name the principle you have used to mark the arrow to show the direction of the ray. ***[1]***

22. (i) The refractive index of glass with respect to air is 1.5. What is the value of the refractive index of air with respect to the glass? ***[1]***

(ii) A ray of light is incident as a normal ray on the surface of separation of two different mediums. What is the value of angle of incidence in this case? ***[1]***

23. (i) Can the absolute refractive index be less than one? ***[1]***

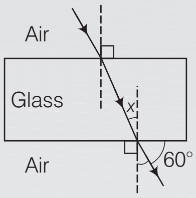
(ii) A coin placed at the bottom of beaker appears to be raised by 4 cm. If the refractive index of water is 4/3, then find the depth of the water in the beaker. ***[2]***

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1. How does the light should enter the glass to produce a large amount of bending?
(a) Obliquely, making a small angle of incidence
(b) Obliquely, making a large angle of incidence
(c) Perpendicularly to the glass surface
(d) All of the above

2 For a certain parallel-sided glass block, the value of $\frac{\sin i}{\sin r}$ is 1.50.

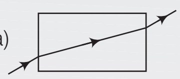


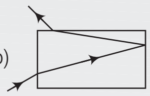
A ray of light passes through the block and emerges at an angle of 60° to the surface of the block.

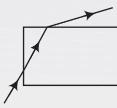
What is the value of the angle marked X?
(a) 19.5° (b) 35° (c) 40° (d) 48.5°

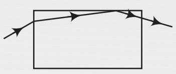
3 A ray of light is incident on one side of a rectangular glass block. Its path is plotted through the block and out through another side.

Which path is not possible?

(a) 

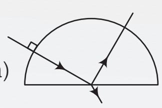
(b) 

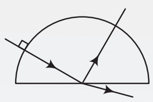
(c) 

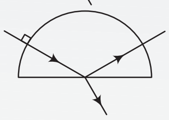
(d) 

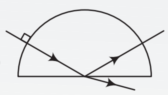
4 A ray of red light enters a semi-circular glass block normal to the curved surface.

Which diagram shows the partial reflection and refraction of the ray ?

(a) 

(b) 

(c) 

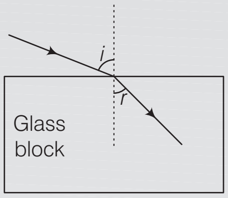
(d) 

5 Absolute refractive index of some materials A, B, C and D are given as below:

Medium	*A*	*B*	*C*	*D*
Refractive index	1.54	1.33	2.42	1.65

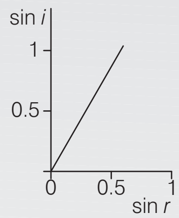
In which of these materials, light travels fastest?
(a) A (b) B (c) C (d) D

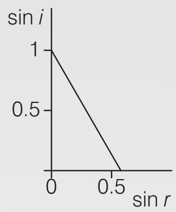
6 A ray of light enters a glass block at an angle of incidence i, producing an angle of refraction r in the glass.

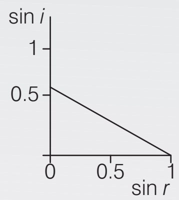


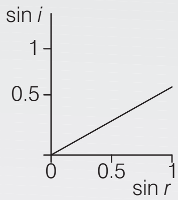
Several different values of i and r are measured and a graph is drawn of $\sin i$ against $\sin r$.

Which graph is correct ?

(a) 

(b) 

(c) 

(d) 

7 **Assertion** (A) In case of refraction of light through glass slab, angle of incidence is equal to angle of emergence.

Reason (R) A glass slab is cuboid made of glass in which refraction occurs twice from the corresponding parallel surfaces.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true, but R is not the correct explanation of A
(c) A is true, but R is false
(d) R is true, but A is false

8 A ray of light travels from a medium of refractive index n_1 to a medium of refractive index n_2. If angle of incidence is i and angle of refraction is r, then $\frac{\sin i}{\sin r}$ is equal to

(a) n_1 (b) n_2 (c) $\frac{n_2}{n_1}$ (d) $\frac{n_1}{n_2}$

Answers

1. (b) **2.** (a) **3.** (c) **4.** (d) **5.** (b) **6.** (a) **7.** (a) **8.** (c)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 240.

CHAPTER

5

Lenses

We all are familiar with the use of lenses in our daily life through spectacles and other resources. The shape of lenses is responsible for their applications in a particular area. On the basis of shape mainly there are two types of lenses: convex and concave. In this chapter, we will explore these two types of lenses with their related aspects.

Chapter Objectives

- Lens
- Refraction Through Equi-convex Lens and Equi-concave Lens
- Image
- Ray Diagram for Principal or Construction Rays
- Image Formation of Lenses
- Lens Formula
- Linear Magnification
- Power of a Lens
- Magnifying Glass or Simple Microscope
- Applications of Lenses

Lens

It is a transparent refracting medium bounded by two surfaces of which, one or both surfaces are spherical.

Lenses are of two types

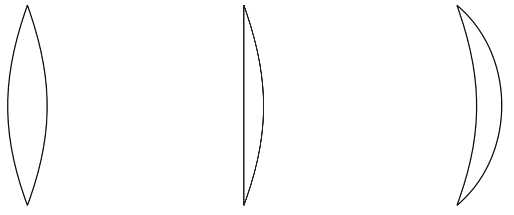
(i) Convex or converging lens

(ii) Concave or diverging lens

(i) Convex or Converging Lens

A lens which is thicker at the centre and thinner at its end is called convex lens. It is also known as converging lens because it converges a parallel beam of light rays passing through it.

Convex lenses are of three types as shown below



(a) Double-convex lens (b) Plano-convex lens (c) Concave-convex lens

(a) A double-convex lens has two outward curving sides and is simply called convex lens.

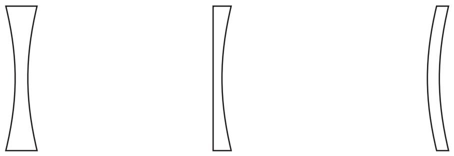
(b) The plano-convex lens is flat on one side and curved outward on the other side.

(c) The concave-convex lens has an inward curved from one side and has a more outward curve on the other side in the same direction.

(ii) Concave or Diverging Lens

A lens which is thinner at the centre and thicker at its ends is called a concave lens. It is also known as diverging lens because it diverges a parallel beam of light rays passing through it.

Concave lenses are of three types as shown below



(a) Double-concave lens (b) Plano-concave lens (c) Convex-concave lens

(a) A double-concave lens has two inward curving sides and is simply called concave lens.

(b) Plano-concave lens has a flat surface and one inward curving side.

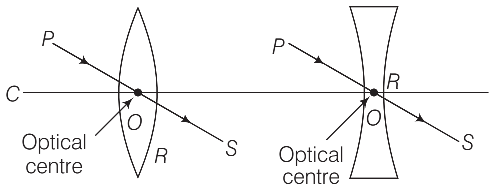
(c) Convex-concave lens has one outward curving side with one greater inward curving side in the same direction.

Some Definitions Related to Lenses

Some of definitions related to lenses are discussed as follow.

Optical Centre

The centre point of a lens is known as its optical centre. It is a point of the lens, directed to which the incident rays refract without any deviation in the path.



Optical centres of convex lens and concave lens

Centres of Curvature

The centres of the two imaginary spheres of which the lens is a part are called centres of curvature of the lens. A lens has two centres of curvature with respect to its two curved surfaces.

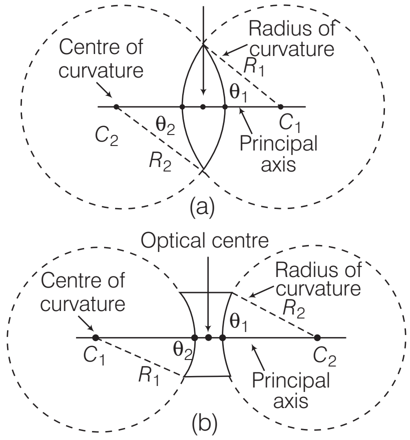
Radii of Curvature

The radii of the two imaginary spheres of which the lens is a part are called radii of curvature of the lens. A lens has two radii of curvature. These may or may not be equal.

Note A plane surface can be considered as to be a spherical surface of infinite ratii of curvature.

Principal Axis

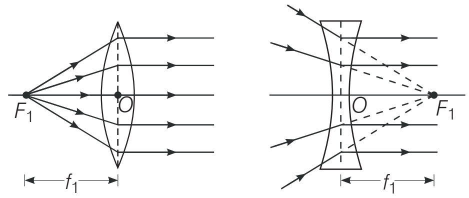
The imaginary line joining the two centre of curvature is called principal axis of lens. It also passes through the optical centre.



Principal Focus

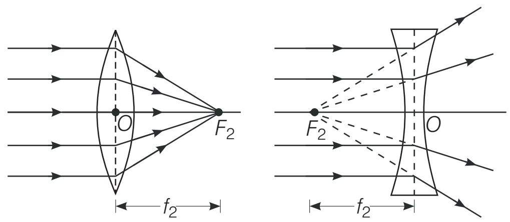
Rays of light can pass through any side of the lens in any direction. Hence, there will be two principal foci on either side of the lens. They are referred to as the first principal focus and the second principal focus of a lens.

(i) **First Principal Focus** The point on the principal axis such that the rays starting from this point (in convex lens) or appearing to go towards this point (in concave lens), after refraction through the lens become parallel to the principal axis, is called first principal focus.



First principal focus on convex and concave lenses

(ii) **Second Principal Focus** It is the point on the principal axis at which the rays coming parallel to the principal axis converge (in convex lens) or passing through it appear to diverge (from concave lens) after refraction from the lens.



Second principal focus on convex and concave lenses

Both the foci of convex lens are real while that of concave lens are virtual.

Focal Length of Lens

The distance between the focus and optical centre of a lens is called focal length of lens.

Note
- Focal length of a lens implies the second focal length.
- If the medium on both sides of the lens is same, the first and second focal lengths are equal.
- Focal length of a lens depends on the refractive index of material of lens.
- If a lens is placed in water instead of air, its focal length increases.
- A thick lens has less focal length than a thin lens of same material.

Focal Plane

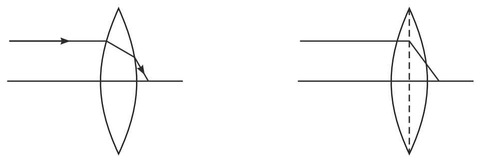
The plane passing through the focus and perpendicular to the principal axis is called focal plane.

Aperture

The effective diameter of the circular outline of a spherical lens is called its aperture.

Refractive Axis

It is an imaginary axis, passing through the optical centre and perpendicular to the principal axis of the lens.



(a) Real path of ray

(b) Path of ray as shown with reference to refraction axis

CHECK POINT 01

1 What do you mean by concave-convex lens?
2 Why and which lens is called diverging lens?
3 Define principal focus of convex lens.
4 What type of lens is an air bubble inside the water?
5 Draw a diagram to represent the refractive and principal axis of a concave lens.

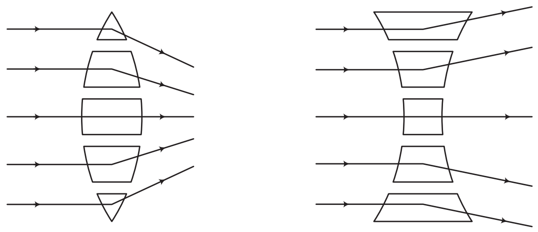
Converging and Diverging Action of Lenses

The converging and diverging action of lenses can be explained by considering a lens made up of large number of different small angles prisms.

A converging lens can be supposed to be made up of a number of prisms with the base of each prism **towards** the centre of the lens.

A diverging lens can be supposed to be made up of a number of prisms with the base of each prism **away from** the centre of the lens.

A prism has a tendency to bend a light ray towards its base, on this basis converging and diverging action can be explained.

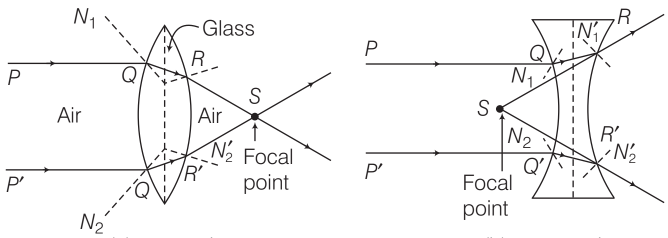


Converging action of convex lens

Diverging action of concave lens

Refraction Through Equi-convex Lens and Equi-concave Lens

Figure given below, shows the refraction of a ray of light at the two surfaces of an equi-convex lens and an equi-concave lens.



(a) convex lens

(b) concave lens

It is clear from the figure, that a convex lens bends the ray of light towards its middle i.e., it converges the light. While a concave lens bends a ray of light towards its edges (or away from its middle) i.e., it diverges the light.

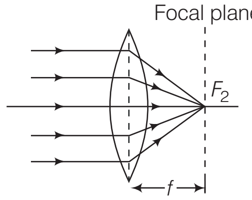
Image

The point where the rays meet or appear to meet after refraction from the lens is called image of that point of the object.

There are two types of images

Real Image

If the rays from a point of an object after refraction through the lens actually meet at a point, the image formed is called real image.

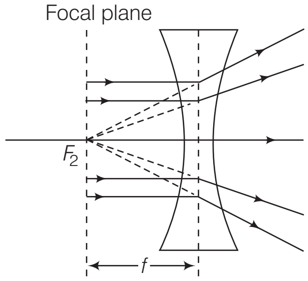


Real Image

Virtual Image

If the rays from a point of an object after refraction through the lens do not actually meet at a point, but they appear to diverge or converge from to a point, the image formed is called virtual image.

Focal plane

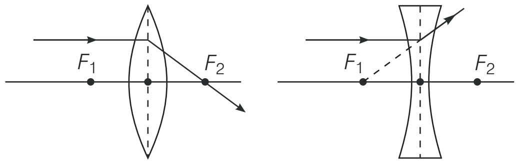


Virtual Image

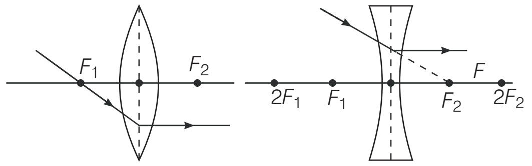
Ray Diagram for Principal or Construction Rays

We can represent image formations by lenses using ray diagrams. By drawing these diagrams, we can determine the position, size and nature of the image formed by a lens. The figures given below show the path through a concave lens and convex lens separately each for the three principal rays generally used for the construction of the ray diagrams.

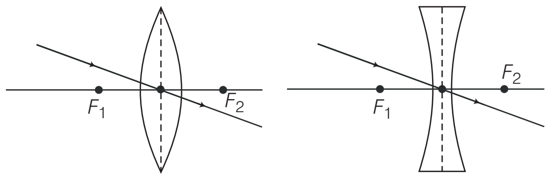
(i) Rays which are **parallel to the principal axis** after refraction, will pass through principal focus in case of convex lens and will appear to be coming from principal focus in case of concave lens.



(ii) Ray **passing through or directed to the focus** will emerge parallel to the principal axis.



(iii) Ray **directed to optical centre** will emerge out undeviated.



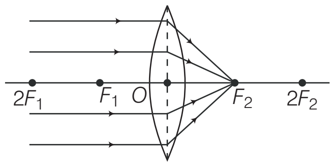
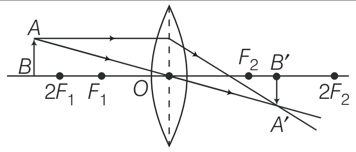
CHECK POINT 02

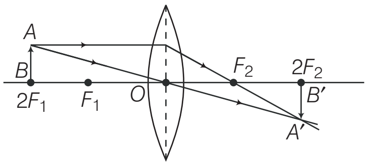
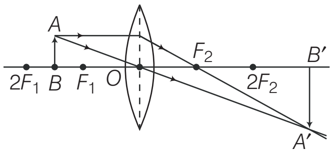
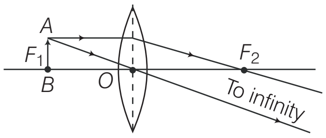
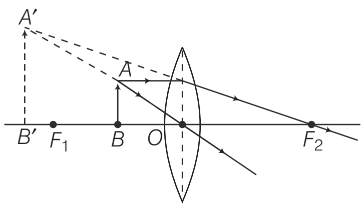
1 How many times does a ray incident on a lens gets refracted after being deviated from its path?
2 Write one difference between real and virtual image.
3 Draw a ray diagram to show a ray passing through the focus convex lens.
4 Give the position from which a ray passes undeviated through optical centre of the lens.
5 Which lens always forms a virtual of an object?

Image Formation of Lenses

Formation of Image by a Convex Lens

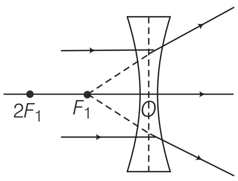
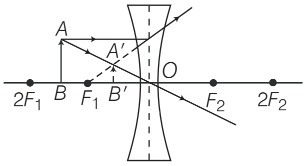
The table given below illustrates the ray diagrams along with the position and nature of an image, formed by convex lens for various positions of an object.

Position of Object	Ray Diagram	Position of Image	Nature and Size of Image
At infinity		At F_2	Real, inverted and extremely diminished
Beyond $2F_1$ (at finite distance)		Between F_2 and 2 F_2	Real, inverted and diminished

Position of Object	Ray Diagram	Position of Image	Nature and Size of Image
At $2F_1$		At $2F_2$	Real, inverted and of same size as that of object
Between F_1 and $2F_1$		Beyond $2F_2$	Real, inverted and magnified
At F_1		At infinity	Real, inverted and highly magnified
Between lens and F_1		On same side of the lens as the object	Virtual, erect and magnified

Formation of Image by a Concave Lens

For studying the image formation by concave lens, there are only two positions of an object that are considered. Firstly, when the object is at infinity and the second position is when the object is at finite distance from the lens. The table given below illustrates the ray diagrams along with the position and nature of image, formed by concave lens for the above two positions of the object.

Position of Object	Ray Diagram	Position of Image	Nature and Size of Image
At infinity		At focus on same side of lens as object	Virtual, erect and highly diminished
At finite distance		Between focus and optical centre on the same side of lens as object	Virtual, erect and diminished

To Differentiate Between a Convex and a Concave Lens

(i) **By Touching** If the lens is thick in the middle and thin at the edges, the lens is convex and if the lens is thin in the middle and thick at the edges, the lens is concave.

(ii) **By Seeing the Image**

(a) On keeping the lens near a printed page, if letters appear magnified, the lens is convex and if the letters appear diminished, the lens is concave.

(b) On seeing a distant object through the lens, if its inverted image is seen, the lens is convex and if the upright image is seen, the lens is concave.

Lens Formula

It is a relation between focal length of a lens and distance of object and image from optical centre of the lens.

If u = object distance, v = image distance and f = focal length, then

$$\boxed{\frac{1}{f} = \frac{1}{v} - \frac{1}{u}}$$

This is called the lens formula.

Linear Magnification

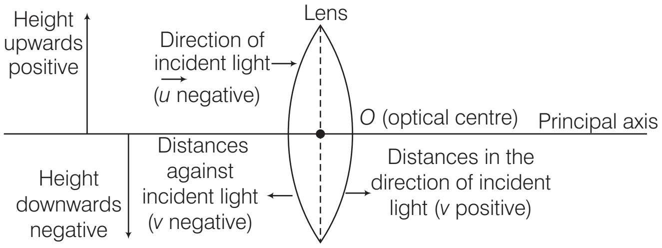
The ratio of height of image to the height of object is called linear magnification (m).

Linear magnification, $\boxed{m = \frac{h_i}{h_o} \quad \text{or} \quad m = \frac{v}{u}}$

It is **positive**, when image formed is **virtual** and is **negative**, when image formed is **real.**

Sign Convention for Spherical Lenses

To derive the relevant formulae for refraction by spherical lenses, we must first adopt a sign convention for measuring distances.



According to the cartesian sign convention,

(i) all the distances are measured from the optical centre (O) of the lens.

(ii) the principal axis of the lens is taken as X-axis and the optical centre as origin.

(iii) distances measured in the direction of the incident light are taken as positive and opposite to the direction of incident light as negative.

(iv) the heights measured upwards with respect to X-axis and normal to the principal axis of the mirror or lens are taken as positive and the heights measured downwards are taken as negative.

Example 1. A convergent beam of light passes through the diverging lens of focal length 0.2 m and comes to focus 0.3 m behind the lens. Find the position of the point at which the beam would converge in the absence of the lens.

Sol. Given, focal length, $f = 0.2\,\text{m}$

Image distance, $v = -0.3\,\text{m}$

Object distance, $u = ?$

According to lens formula,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{u} = \frac{1}{v} - \frac{1}{f} \Rightarrow \frac{1}{-0.3} - \frac{1}{0.2} = \frac{-0.5}{0.06}$$

$$u = \frac{-0.06}{0.5}$$

Object distance, $u = -0.12\,\text{m}$

Example 2. A concave lens has a focal length 15 cm. At what distance should an object be placed from the lens so that it forms an image at 10 cm from the lens? What is the nature of the image?

Sol. Given, focal length, $f = -15\,\text{cm}$

Image distance, $v = -10\,\text{cm}$

Object distance, $u = ?$

According to lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

i.e., $$\frac{1}{-10} - \frac{1}{u} = \frac{1}{-15}$$

$\therefore$ $$\frac{1}{u} = \frac{-1}{10} + \frac{1}{15} = \frac{-1}{30} \Rightarrow u = -30\,\text{cm}$$

As, it is a concave lens, the image is virtual erect and diminished.

Example 3. A 5 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. The distance of the object from lens is 30 cm. Determine the

(i) position (ii) nature

(iii) size of image formed.

Sol. Given, object size, $h_o = 5\,\text{cm}$

Object distance, $u = -30\,\text{cm}$

Focal length, $f = +20\,\text{cm}$

Using lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$$\Rightarrow \frac{1}{v} = \frac{1}{u} + \frac{1}{f} \Rightarrow \frac{1}{v} = -\frac{1}{30} + \frac{1}{20} = \frac{1}{60} \Rightarrow v = 60\text{ cm}$$

Since, magnification, $m = \frac{h_i}{h_o} = \frac{v}{u}$

$$\Rightarrow m = \frac{h_i}{5} = \frac{60}{-30} \Rightarrow h_i = -10\,\text{cm}$$

Therefore, the image is real, inverted and magnified.

Power of a Lens

The ability of a lens to deviate light rays towards or away from its principal axis is called power of lens. It is defined as the reciprocal of the focal length in metres. It is expressed as

$$\text{Power, } P = \frac{1}{f\text{ (in metre)}}$$

Its SI unit is dioptre (D). The power of convex lens is positive and that of concave lens is negative.

If many thin lenses are in contact with each other, then the total power is the algebraic sum of powers of individual lenses.

i.e., $P = P_1 + P_2 + P_3 + \dots$

Example 4. **Calculate the power of a convex lens having the focal length of 50 cm.**

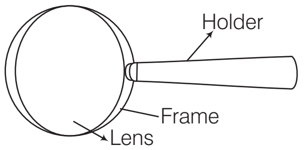
Sol. Given, focal length, $f = 50\,\text{cm} = 0.5$ m

Power, $P = \dfrac{1}{\text{Focal length}} = \dfrac{1}{0.5} = 2\,\text{D}$

Magnifying Glass or Simple Microscope

Principle

It is based on the principle that when an object is placed between the first principal focus and the optical centre of a convex lens, it forms an erect, virtual and enlarged image on the same side of the object.



Magnifying glass (or simple microscope)

Construction

Magnifying glass is a kind of convex lens of short focal length mounted in a metallic frame with a holder.

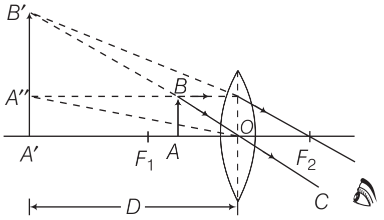
Way of Using the Microscope

The lens is placed near the eye and the object is at such a distance from the lens such that the image is formed at the least distance of distinct vision $(D) = 25$ cm from the lens.

Note The minimum distance, at which an object can be seen most distinctly without any strain is called the least distance of distinct vision (D). For a healthy normal eye of an adult, it is 25 cm.

Ray Diagram and Magnification

Consider a ray diagram for location of image $(A'B')$ of an object *(AB)* due to a simple microscope. The object *AB* is placed between focus F_1 and optical centre O of the lens.



Ray diagram for location of image and magnification

Magnified and erect image $A'B'$ is formed atleast distance of distinct vision *(D)* from O. The magnifying power of the microscope is defined as the ratio of the $\angle B'OA'$ subtended by the image $A'B'$ at the eye to the $\angle A''OA'$ subtended by *AB* at the eye.

It is expressed as

$$m = \frac{A'B'}{AB}$$

Applications of Lenses

Some of applications of lenses are discussed as follows

(i) We usually use spectacles when our eyesight weakens. They either consist of convex lens or concave lens or both.

A person suffering from long sightedness, i.e., hypermetropia, use convex lens while a person suffering from short sightedness, i.e., myopia, uses concave lens.

(ii) They are used in a spectroscope which uses convex lens for obtaining pure spectrum.

(iii) In telescope, camera, slide projector, etc, convex lens is used which forms a real and inverted image of an object.

(iv) In galilean telescope, a concave lens is used as an eyelens to obtain an erect final image of the object.

(v) Convex lens of short focal length fitted in a steel frame with a handle, is used as a magnifying glass.

Note
- In order to photograph a distant object, the lens is moved closer to the film and for near object, the lens is moved away from the film. This adjustment of the lens is called focussing.
- The maximum variation in the power of the lens for focussing near or far objects clearly at retina is called power of accomodation.
- The time for which impression or sensation of an object continues in the eye is called persistance of vision. It is about (1/16)th of a second.

CHECK POINT 03

1. Name the lens which acts as magnifying glass.
2. Which type of lens produce
   (i) diminished neutral image
   (ii) magnified vertical image?
3. What is the minimum distance between an object and its real image formed by a convex lens?
4. What happens to the image formed by a convex lens if its lower part is blackened?
5. Two lens of power – 3 D and + 2.5 D are placed in contact. Find the total power of combination of Lens. Calculate the focal length of this combination.

SUMMARY

- Lens is a transparent medium bounded by two surfaces in which, one or both surfaces are spherical.
- Convex lens is a lens which is thicker at the centre and thinner at its end.
- Concave lens is a lens which is thinner at the centre and thicker at its end.
- The centre point of a lens is known as its optical centre.
- The centre of the two imaginary spheres of which the lens is a part is known as centre of curvature of lens.
- The radii of the two imaginary spheres of which the lens is a part are called radii of curvature of lens.
- The imaginary line joining the two centres of curvature is called principal axis of lens.
- The distance between focus and optical centre of a lens is known as focal length of lens.
- The plane passing through the focus and perpendicular to the principal axis is known as focal plane.
- The effective diameter of the circular outline of a spherical lens is known as aperture of lens.
- An imaginary axis, passing through the optical centre and perpendicular to the principal axis of the lens is called refractive axis.
- The converging and diverging action of lenses can be explained by considering a lens made up of large number of different small angled prisms.
- Image formation by convex lens for different positions of object

Position of Object	Position of Image	Relative Size of Image	Nature of Image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between focus F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Highly magnified	Real and inverted
Between focus F_1 and optical centre O.	On the same side of the lens as the object	Enlarged	Virtual and erect

- Image formation by concave lens for different positions of object

Position of Object	Position of the Image	Relative Size of Image	Nature of Image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
At finite distance	Between focus F_1 and optical centre O	Diminished	Virtual and erect

- Lens Formula
  It is given by, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

where, v = distance of image from the optical centre of lens,
u = distance of object from the optical centre of lens
and f = focal length of lens.

- Linear Magnification

$$m = \frac{\text{Height of image } (h_i)}{\text{Height of object } (h_o)} \quad \text{or} \quad m = \frac{\text{Image distance } (v)}{\text{Object distance } (u)}$$

  If m is positive, image is virtual and if m is negative, image is real.
- The ability of a lens to converge or diverge light rays is known as power of lens. It is denoted by P.
- The SI unit of power is dioptre (D).

$$\text{Power, } P = \frac{100}{\text{Focal length } f \text{ (in cm)}}$$

- For concave lens, power and focal length are negative.
  For convex lens, power and focal length are positive.
- Magnifying glass is a kind of convex lens of short focal length mounted in a metallic frame with a holder.

EXAM PRACTICE

a 2 Marks Questions

1. Define convex lens and give its nature of refraction.

Sol. A lens which is thicker at the centre and thinner at its end is called convex lens. ***[1]***

It is also called converging lens as it converges the light rays passing through it. ***[1]***

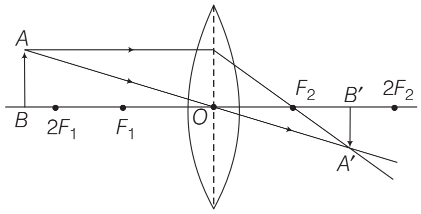
2. What is the difference between double convex and a bi-convex lens?

Sol. In double convex lens, the two surfaces may have any values for the two radii of curvature of the two surfaces while the bi-convex lens, the radii of curvature of the two surfaces have the same value. So, all double convex lens may not be bi-convex, but every bi-convex lens is a double convex lens. ***[2]***

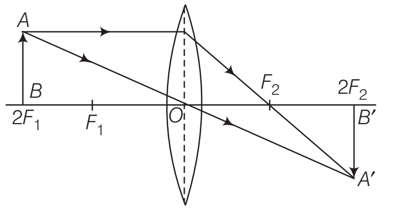
3. (i) An object is placed infront of a converging lens at a distance greater than twice the focal length of the lens. Draw a ray diagram to the formation of the image. ***[2007]***

(ii) An object is placed infront of a convex lens such that the image formed has the same size as that of the object. Draw a ray diagram to illustrate this. ***[2006]***

Sol. (i) *The ray diagram to show the formation of the image is shown below* ***[1]***

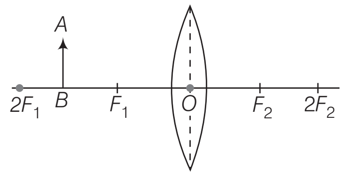


(ii) *The ray diagram to show the formation of the image is shown below*



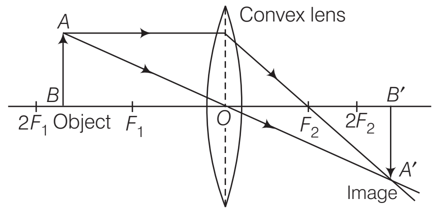
[1]

4. An object AB is placed between $2F_1$ and F_1 on the principal axis of a convex lens as shown in the diagram.



Copy the diagram and using these rays starting from point A, obtain the image of the object formed by the lens.

Sol. *The formation of image is shown below*



[2]

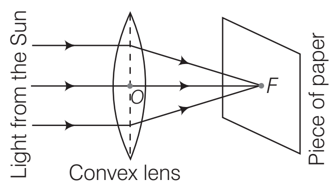
5. We can burn a piece of paper by focusing the sun rays by using a particular type of lens. ***[2010]***

(i) Name the type of lens used for the above purpose.

(ii) Draw a ray diagram to support your answer.

Sol. (i) To collect all Sun's rays to a particular point (called focus) we use a converging lens, i.e., convex lens. ***[1]***

(ii) *The ray diagram is shown below*



[1]

6. State two characteristics of the image of an extended source, formed by a concave lens.

Sol. The two characteristics of the image of an extended source formed by a concave lens are

(i) virtual and ***[1]***

(ii) highly diminished, if the object is at infinity/ diminished, if the object is between optical centre and infinity. ***[1]***

7. State the position of the object in front of a converging lens if

(i) it produces a real and same size image of the object.

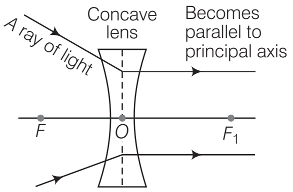
(ii) it is used as a magnifying lens. ***[2018]***

Sol. (i) To get real and same size image, object is placed at '$2F$'. ***[1]***

(ii) To use a converging lens as magnifying lens object must be placed between lens and first focus. ***[1]***

8. A ray of light, after refraction through a concave lens, emerges parallel to the principal axis. Draw a ray diagram to show the incident ray and its corresponding emergent ray. Can we obtain a real image with the help of a concave lens?

Sol. *The ray diagram to show the incident ray and its corresponding emergent ray is shown below*



[1]

When a concave lens is kept in front of a convex lens (additional) it produces real image. ***[1]***

9. (i) When does a ray of light falling on a lens pass through it undeviated? ***[2011]***

(ii) Which lens can produce a real and inverted image of an object?

Sol. (i) A ray of light parallel to the principal axis of convex lens when passes through the optical centre, then the ray coming out from the lens will be undeviated. ***[1]***

(ii) A real and inverted image of an object can be produced by using convex lens or converging lens. ***[1]***

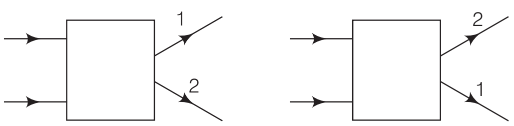
10. You are provided with a printed piece of paper. Using this paper, how will you differentiate between a convex lens and concave lens? ***[2012]***

Sol. When the printed piece of paper is moved near to both the lenses and the letters appear as

(i) erect and diminished, then the lens is concave lens. ***[1]***

(ii) erect and magnified, then the lens is convex lens. ***[1]***

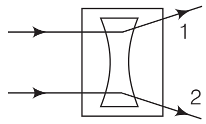
11. Figs. (a) and (b) are shown below, the incident and transmitted rays through lens kept in a box in each case. Draw the lens and complete the path of rays through it.



(a) (b)

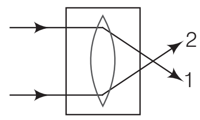
Sol. *The ray diagram is as follows*

(i) From fig. (a) we see after passing through a box, rays are diverses, hence a concave lens will be there inside the box.



(a) ***[1]***

(ii) From fig. (b) we see after passing through a box, rays are converses, hence a convex lens will be there inside the box.



(b) ***[1]***

12. The power of a lens is -5D.

(i) Find its focal length.

(ii) Name the type of lens. ***[2018]***

Sol. Given, power of lens $= -5$ D

(i) We know that,

$$\text{Power of lens } (P) = \frac{1}{f\,(\text{focal length})} \text{ or } f = \frac{1}{P}$$

$$\Rightarrow \quad f = \frac{1}{-5} = -0.2 \text{ m}$$

$$= -20 \text{ cm}$$ ***[1]***

(ii) The power of lens is negative, therefore lens is concave. ***[1]***

b 3 Marks Questions

13. State the changes in the position, size and nature of the image of an object when brought from infinity upto a concave lens. Illustrate your answer by drawing diagrams.

Sol. When an object is brought from infinity upto a concave lens, then position of image is shifted from focus toward optical centre of concave lens, size of image increases, while nature of image is same (i.e., virtual). ***[1]***

When object is placed at infinity.

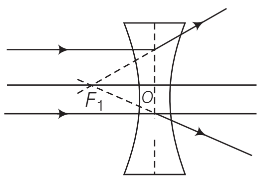


Image is formed at focus. ***[1]***

When object is placed at finite distance.

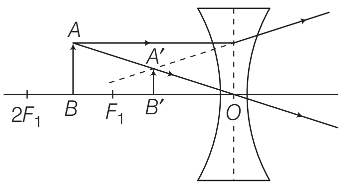
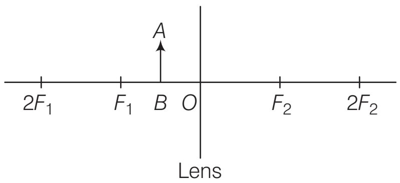


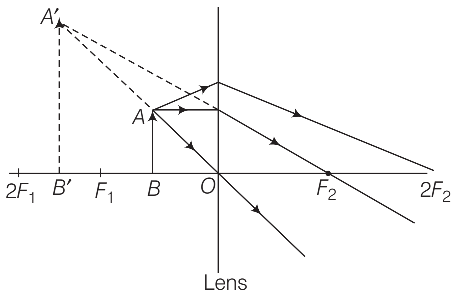
Image is formed between focus and optical centre **[1]**

14. An object AB is placed between O and F_1 on the principal axis of a converging lens as shown in the diagram.



Copy the diagram and by using three standard rays starting from point A, obtain an image of the object AB. ***[2018]***

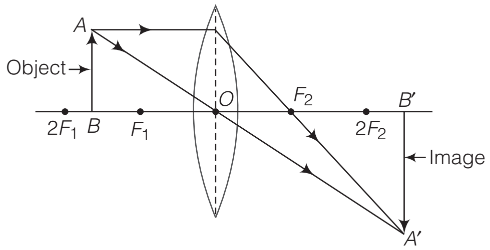
Sol.



[3]

15. Draw a labelled diagram showing how an image of a small slide can be projected on large screen. State two characteristics of the image.

Sol. *The ray diagram is shown below*



[1]

Characteristics of an image are

(i) image is real and inverted

(ii) image is enlarged. **[1+1]**

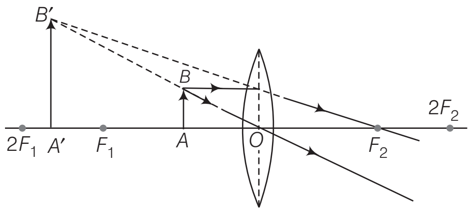
16. A lens forms an erect, magnified and virtual image of an object.

(i) Name the lens.

(ii) Draw a labelled ray diagram to show the image formation. ***[2014]***

Sol. (i) A convex lens forms an erect, magnified and virtual image of an object. **[1]**

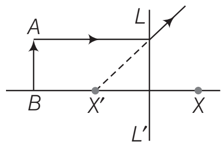
(ii) *The ray diagram showing the formation of image is shown below*



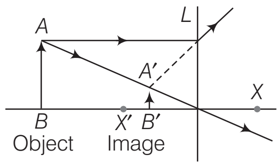
In this case, object is between optical centre (O) and focus (F_1) of lens. **[2]**

17. (i) Copy and complete the diagram to show the formation of the image of an object AB.

(ii) What is the name given to X? ***[2009]***



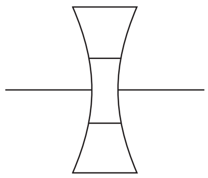
Sol. (i) The ray diagram showing the formation of the image ($A' B'$) of the object AB is shown below



[2]

(ii) X is the principal focus. **[1]**

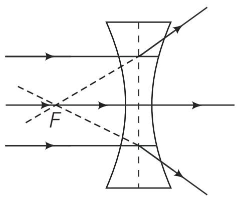
18. Figure below shows a lens treated as a combination of two prisms and a glass block.
(i) Name the lens formed by the combination.
(ii) Draw the refraction of two incident rays to illustrate the property of the lens mentioned by you in part (ii).



Sol. (i) The lens is formed by the combination is a concave lens. **[1]**

(ii) The lens is a diverging lens. **[1]**

(iii) *The ray diagram is shown as below*



[1]

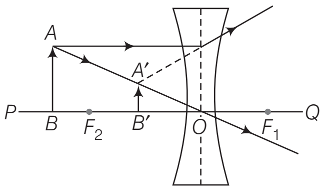
19. A linear object is placed on the axis of a lens. An image is formed by refraction in the lens. For all positions of the object on the axis of the lens, the positions of the image are always between the lens and the object.

(i) Name the lens.

(ii) Draw a ray diagram to show the formation of the image of an object placed in front of the lens at any position of your choice except infinity. **[2008]**

Sol. (i) The lens is concave lens. [1]

(ii) *The ray diagram showing the formation of image is shown below*



AB = object, $A'B'$ = image

The object is placed between focus (f) and $2f$. [2]

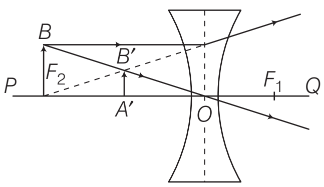
20. A lens forms an upright and diminished image of an object when the object is placed at the focal point of the given lens.

(i) Name the lens.

(ii) Draw a ray diagram to show the image formation. **(2017)**

Sol. (i) The lens is concave lens. [1]

(ii) *The ray diagram is shown below*



AB = object, $A'B'$ = image [2]

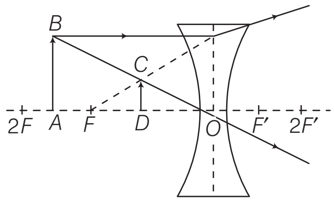
21. A lens produces a virtual image between the object and the lens.

(i) Name the lens.

(ii) Draw a ray diagram to show the formation of this image. **(2016)**

Sol. (i) Concave lens is the lens which produces a virtual image between the object and the lens. [1]

(ii) *The ray diagram is given below*



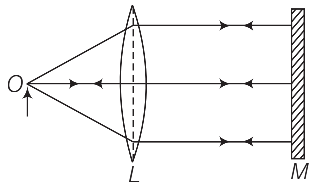
[2]

22. The given ray diagram illustrates the experimental set up for the determination of the focal length of a converging lens using a plane mirror.

(i) State the magnification of the image formed.

(ii) Write two characteristics of the image formed.

(iii) What is the name given to the distance between the object and optical centre of the lens in the given diagram? **[2005]**



Sol. (i) As, the distance of image from lens is same as that of object, therefore its magnification is equal to one.

(ii) The image formed is real, inverted and of same size as that of object.

(iii) The distance between the object and optical centre of the lens is named as focal length of the lens. [1 × 3]

23. Define the power of a lens. Write its formula expression and its SI unit.

Sol. It is defined as the ability of a lens to converge or diverge light rays. It is the reciprocal of focal length in metre. [1]

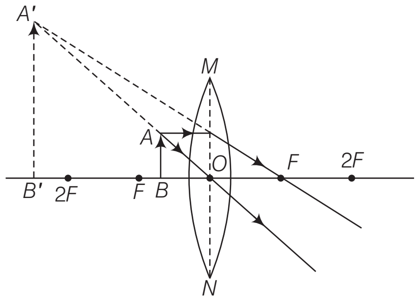
$$P = \frac{1}{f\,(\text{in metre})}$$ [1]

Its SI unit is diopter (D). [1]

C 4 Marks Questions

24. Draw a ray diagram to illustrate the action of a convergent lens as a reading lens or a magnifying glass.

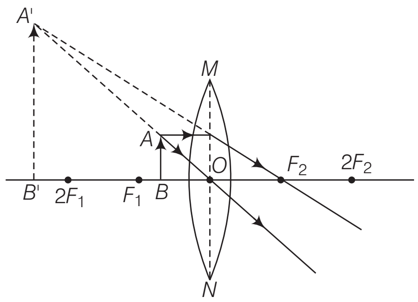
Sol. A convex lens of small focal length can be used as a reading glass or a magnifying glass.



When an object is placed within the focal length of the lens, then a virtual, erect and magnified image is formed. ***[2 + 2]***

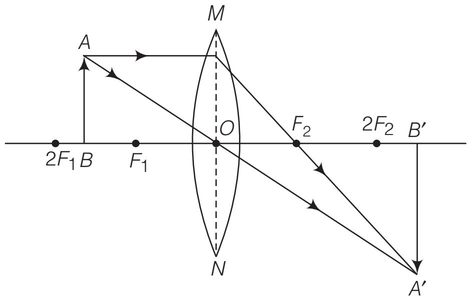
25. Draw ray diagrams showing the image formation by a convex lens when an object is placed
(i) between optical centre and focus of the lens.
(ii) between focus and twice the focal length of the lens.
(iii) at twice the focal length of the lens.
(iv) at infinity.

Sol. (i) An enlarged, virtual and erect image of an object forms beyond F on the same side as that of object.



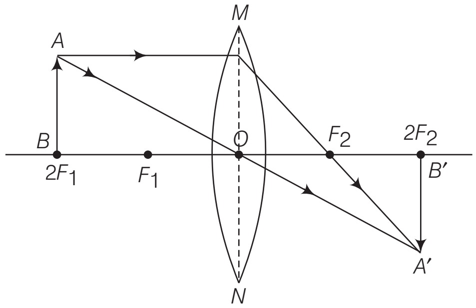
[1]

(ii) An enlarged, real and inverted image of an object forms beyond $2F$ on the other side of the lens.



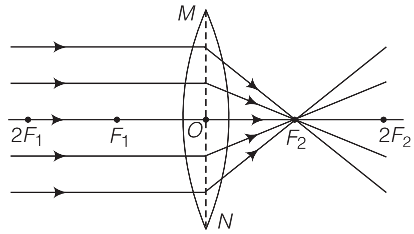
[1]

(iii) An real and inverted image of an object an equal to the size of the object, forms at $2F$ on the other side of the lens.



[1]

(iv) The real, inverted and highly diminished image of the object forms at focus F on the other side of the lens.

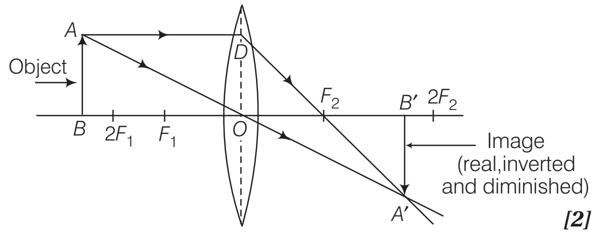


[1]

26. A converging lens is used to obtain an image of an object placed in front of it. The inverted image is formed between F_2 and $2F_2$ of the lens.
(i) Where is the object placed?
(ii) Draw a ray diagram to illustrate the formation of the image obtained. ***[2012]***

Sol. (i) The object is placed beyond $2F_1$. ***[2]***

(ii) *The ray diagram to illustrate the formation of the image is shown below*



[2]

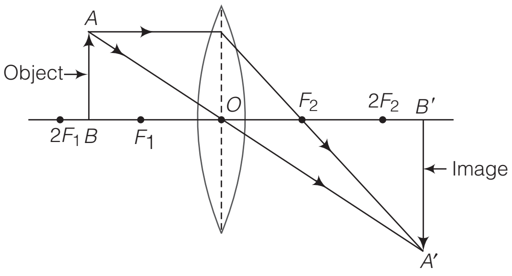
27. A thin converging lens form a real magnified image and a virtual magnified image of an object in front of it.
(i) Write the positions the objects in each case.
(ii) Draw ray diagrams to show the image formation in each part.
(iii) How will the following be affected on cutting this lens into two halves along the principal axis?
(a) Focal length
(b) Intensity of the image formed by half lens

Sol. (i) (a) Object is placed between F and $2F$.

(b) Object is placed between optical centre and F. ***[1]***

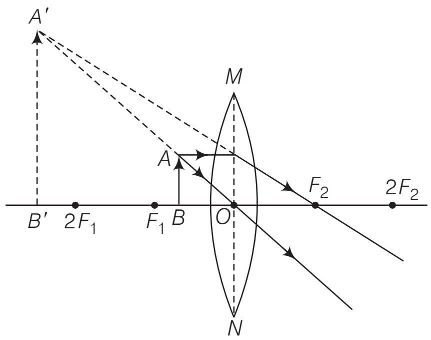
(ii) *The ray diagrams are as shown below*

Part (a)



[1]

Part (b)



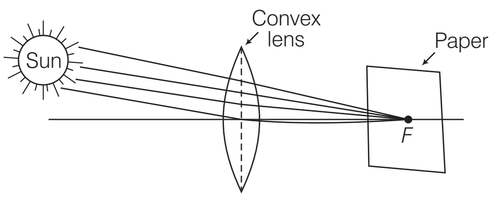
[1]

(iii) (a) There will be no change in focal length.

(b) Intensity will become one-fourth. ***[1]***

28. A student wants to burn a piece of paper using a convex lens in day light, rather than using match stick or any direct flame. Will he be able to, if yes justify your answer with a ray diagram?

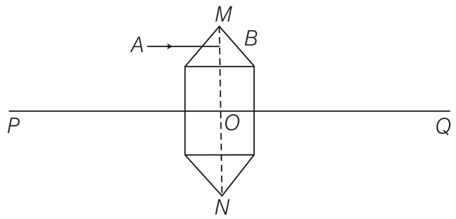
Sol. Yes, he will be able to burn a piece of paper using a convex lens in day light without using match sticks or any flame. When the sun rays coming from infinity passes through the convex lens and the paper being kept at the focus of the lens. Then, rays after passing the lens would converge at the focus as shown in figure below.



[2]

When the paper and the lens are held in the same position for sometime, then the paper will burn out. This is because of the heat produced by the Sun's rays as they are concentrated on the spot, where these rays are bring to focus at lens focal point. ***[2]***

29. A ray is directed towards a lens as shown in the figure below. The lens is being depicted as a combination of a glass slab and two prisms.



Answer the following questions.

(i) Name the lens which is formed by this combination.

(ii) What is PQ line called?

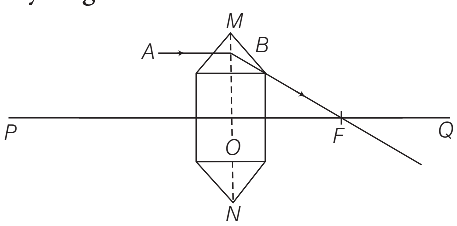
(iii) Complete the ray diagram.

(iv) The incident ray after refraction actually meet or appears to meet line PQ at a point. What is this point called?

Sol. (i) The lens is convex. ***[1]***

(ii) The line PQ is called principal axis. ***[1]***

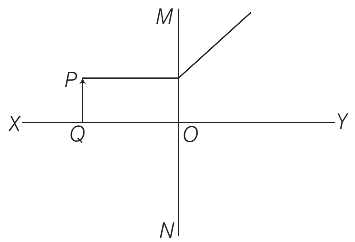
(iii) **Ray diagram**



[1]

(iv) When a incident ray parallel to the principal axis falls on a convex lens, then after refraction the emergent ray actually meet at a point on PQ. This point is known as focal point of the lens. ***[1]***

30. The figure given below shows a ray directed towards a lens MN.



Study the above ray diagram and answer the following questions.

(i) Name the lens.

(ii) What is line XY called?

(iii) The image of the object PQ is formed between which points.

(iv) Write the nature of the image.

Sol. (i) The lens is concave. **[1]**

(ii) The line XY is called principal axis. **[1]**

(iii) The image of the object PQ is formed between points Q and O. **[1]**

(iv) The image will be virtual and erect. **[1]**

Numerical Based Questions

31. The focal length of a convex lens is 25 cm. Calculate the power of the lens. **[2014]**

Sol. Given, focal length, $f = 25\text{ cm} = 0.25$ m

Power, $P = ?$ $\Rightarrow$ $P = \dfrac{1}{f} = \dfrac{1}{0.25} = 4\text{D}$ **[2]**

32. Express the power of a concave lens of focal length 20 cm with its sign.

Sol. Power, $P = \dfrac{1}{f}$, where f is focal length.

As, $f = -20$ cm

$\Rightarrow$ $P = -\dfrac{1}{20} = -\dfrac{100}{20} = -5$ D

Hence, power of a concave lens is -5 D. **[2]**

33. Two lenses have power of (i) + 2 D (ii) – 4 D. What is the nature and focal length of each lens?

Sol. (i) Given, $P = +2$ D

Since, power is positive, so the lens is convex lens.

Focal length, $f = \dfrac{1}{P} = \dfrac{1}{2} = 0.5$ m

$= 50$ cm ($\because P =$ power of lens) **[1]**

(ii) Given, $P = -4$D

Since, power is negative, so the lens is concave lens.

Focal length, $f = \dfrac{1}{P} = \dfrac{1}{-4} = -0.25\text{ m} = -25\text{ cm}$ **[1]**

34. Rohit while playing with an old lens discovers that, if he holds the lens 20 cm away from a wall opposite to a window, he can see sharp but inverted images of outside world on the wall. What is the power of the old lens holded by him?

Sol. Since, the rays from far away objects in outside world get focussed at principal focus, the distance between lens and wall is equal to focal length 20 cm. **[1]**

$\therefore$ Power of lens, $P = \dfrac{100}{f(\text{ in cm})} = \dfrac{100}{20} = 5$ D **[1]**

35. A convex lens has focal length of 20 cm. At what distance from the lens should the object be placed, so that the image is formed at 40 cm on the other side of the lens? Also, state the nature of the image formed.

Sol. Given, $f = 20$ cm, $v = 40$ cm, $u = ?$

Now by using, $-\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$

We have, $-\dfrac{1}{u} = \dfrac{1}{f} - \dfrac{1}{v} = \dfrac{1}{20} - \dfrac{1}{40}$

or $-\dfrac{1}{u} = \dfrac{1}{40}$

or $u = -40$ cm **[1]**

Thus, the object should be placed at a distance of 40 cm in front of the convex lens. Negative sign shows, the image formed is real and inverted. **[1]**

36. An object is placed at a distance of 12 cm from a convex lens of focal length 8 cm. Find

(i) the position of the image

(ii) nature of the image. **[2018]**

Sol. Given, distance of object $(u) = -12$ cm

Focal length of lens $(f) = 8$ cm

(i) We know that, $\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u} \Rightarrow \dfrac{1}{8} = \dfrac{1}{v} - \dfrac{1}{(-12)}$

$\dfrac{1}{v} = \dfrac{1}{8} - \dfrac{1}{12} \Rightarrow \dfrac{1}{v} = \dfrac{3-2}{24}$

$\dfrac{1}{v} = \dfrac{1}{24} \Rightarrow v = 24$ cm **[2]**

(ii) Real, inverted and magnified. **[2]**

37. An object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. If the distances of the object is 30 cm from the lens, find the position nature and magnification of the image.

Sol. Given, $f = 20$ cm, $u = 30$ cm

$v = ?$, $m = ?$

Now by using lens formula, $-\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$

We have, $-\dfrac{1}{(-30)} + \dfrac{1}{v} = \dfrac{1}{20}$

or $\dfrac{1}{v} = \dfrac{1}{20} - \dfrac{1}{30}$

or $\dfrac{1}{v} = \dfrac{1}{60}$ or $v = 60$ cm

Thus, the image is formed at 60 cm on other side (i.e., right side) of the lens. **[2]**

Magnification, $m = \dfrac{v}{u} = \dfrac{60}{20} = 3$

Thus, magnification is 3. **[1]**

38. An object is placed 25 cm away from a converging lens of focal length 10 cm. Draw the ray diagram and find position and nature of image formed.

Sol. Object distance, $u = -25$ cm

Image distance, $v = ?$

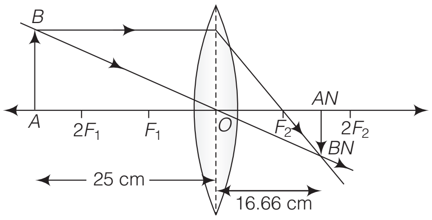
Focal length, $f = 10$ cm

From lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ or $\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$

$$= \frac{1}{10} + \frac{1}{(-25)} = \frac{3}{50}$$

or $v = \frac{50}{3} = 16.66$ cm from the lens **[1]**

Ray diagram



[1]

The image is real, diminished and inverted. **[1]**

39. A 6 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 25 cm. The distance of the object from the lens is 40 cm.

By calculation determine

(i) the position and

(ii) the size of the image formed.

Sol. Given, height of object, $h_o = 6$ cm

Focal length of lens, $f = 25$ cm

Distance of object, $u = -40$ cm

(i) Using lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{25} + \frac{1}{(-40)}$$

$$= \frac{8-5}{200} = \frac{3}{200}$$

$$v = \frac{200}{3} = 66.67 \text{ cm}$$

[1½]

(ii) $\therefore$ Magnification, $m = \frac{h_i}{h_o} = \frac{v}{u}$

$$\Rightarrow \quad h_i = \frac{v}{u} \times h_o = \frac{200}{3 \times (-40)} \times 6 = -10 \text{ cm}$$

[1½]

40. A concave lens of focal length 20 cm forms an image at a distance of 10 cm from the lens. What is the distance of the object from the lens? Also draw ray diagram.

Sol. Given, $f = -20$ cm (sign convention), $v = -10$ cm

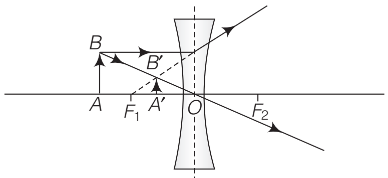
($\because$ image formed by concave lens is virtual)

By using lens formula, $\frac{1}{u} - \frac{1}{v} = \frac{1}{f}$

We have, $-\frac{1}{u} - \frac{1}{10} = -\frac{1}{20}$

or $\frac{1}{u} = -\frac{1}{20} + \frac{1}{10} = \frac{1}{20}$ or $u = -20$ cm **[1]**

Ray diagram



[1]

Thus, the object is placed at 30 cm from the concave lens.

41. An object of height 5 cm is placed perpendicular to the principal axis of a concave lens of focal length 10 cm. If the distance of the object from the optical centre of the lens is 20 cm, determine the position, nature and size of the image formed using the lens formula.

Sol. Given, height of object, $h_o = 5$ cm,

focal length, $f = -10$ cm,

distance of object, $u = -20$ cm, $v = ?$

Using lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{(-10)} + \frac{1}{(-20)} = \frac{-1}{10} - \frac{1}{20}$$

$$= \frac{-2-1}{20} = \frac{-3}{20}$$

$$\Rightarrow \quad v = -6.67 \text{ cm}$$

Image is at 6.67 cm from concave lens. **[1½]**

As, magnification, $m = \frac{h_i}{h_o} = \frac{v}{u}$

$$\Rightarrow \quad h_i = h_o \times \frac{v}{u} = 5 \times \frac{-20}{3} \times \frac{1}{-20}$$

$$= \frac{5}{3} = 1.67 \text{ cm}$$

The image is virtual, erect and diminished. **[1½]**

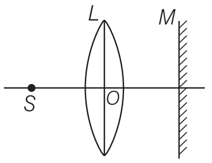
CHAPTER EXERCISE

2 Marks Questions

1. Copy and complete the following table. ***[2009]***

Type of Lens	Position of Object	Nature of Image	Size of Image
Convex	At F		
Concave	At infinity		

2. The diagram shows a point source of light S, a convex lens L and a plane mirror M. These are placed such that rays of light from S return to it after reflection from M.



(i) What is the distance OS called?

(ii) To which point (left of S or right of S) will the rays return, if M is moved to the left and brought in contact with L?

3. Distinguish between a real and a virtual image.

4. An object is placed in front of a concave lens. Is it possible that the image formed has the same size as that of the object? If yes, then draw the ray diagram.

3 Marks Questions

5. The diagram shows an object (OA) and its image ($O'A'$) formed by a lens. Complete the ray diagram and locate the focus of the lens. State whether the lens is concave or convex?

6. (i) Where should an object be placed so that, a real and inverted image of the same size as the object is obtained using a convex lens?

(ii) Draw a ray diagram to show the formation of the image as specified in the part a (i). ***[2015]***

7. Explain the action of a simple microscope as a magnifier. Draw the ray diagram for the image formation.

8. State three characteristics of the image of an extended source, formed by a concave lens.

4 Marks Questions

9. (i) Where should an object be placed so that, a real and inverted image of double the size of the object is obtained using a convex lens?

(ii) Draw a ray diagram to show the formation of the image as specified in the part (i).

(iii) Ramesh claims to have obtained an image thrice the size of the object with a concave lens. Is he correct? Give reason for your answer.

10. An object is placed in front of a lens between its optical centre and the focus and forms a virtual, erect and diminished image.

(i) Name the lens which forms this image.

(ii) Draw a ray diagram to show the formation of the image with the above stated characteristics. ***[2011]***

Numerical Based Questions

11. Find the focal length of a lens of power + 4.0 D. What type of lens is this? ***Ans.*** 0.25 m

12. A lens produce an erect and magnified image of an object when the object is placed at 20 cm from its optical centre.

(i) Identify the nature of lens.

(ii) What is the position of the object if the focal length of the lens is 25 cm? ***Ans.*** 100 cm

13. An object is placed at a distance of 10 cm from a lens of power 4D. Find the position and nature of image so formed. ***Ans.*** –7.14 cm, diminished virtual and erect

14. An object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the position of the image. What is the nature of the image formed? ***Ans.*** 30 cm, real and inverted

15. A convex lens has focal length equal to 25 cm. An object is placed at a distance 12.5 cm from the lens. Draw the diagram to find the position of image. ***Ans.*** 25 cm on the object side

ARCHIVES* *(Last 7 Years)*

Collection of Questions Asked in Last 7 Years' (2018-2012) ICSE Class 10th Examinations

2018

1. State the position of the object in front of a converging lens if

(i) it produces a real and same size image of the object.

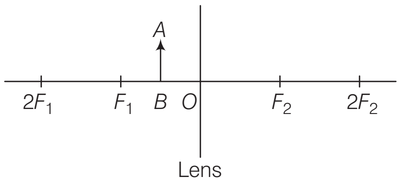
(ii) it is used as a magnifying lens. ***[2]***

2. The power of a lens is – 5D.

(i) Find its focal length.

(ii) Name the type of lens. ***[2]***

3. An object *AB* is placed between *O* and F_1 on the principal axis of a converging lens as shown in the diagram.



Copy the diagram and by using three standard rays starting from point *A*, obtain an image of the object *AB*. ***[3]***

4. An object is placed at a distance of 12 cm from a convex lens of focal length 8 cm. Find

(i) the position of the image

(ii) nature of the image. ***[4]***

2017

5. A lens forms an upright and diminished image of an object when the object is placed at the focal point of the given lens.

(i) Name the lens.

(ii) Draw a ray diagram to show the image formation. ***[3]***

2016

6. A lens produced a virtual image between the object and the lens.

(i) Name the lens.

(ii) Draw a ray diagram to show the formation of this image. ***[3]***

2015

7. (i) Where should an object be placed so that a real and inverted image of the same size as the object is obtained using a convex lens?

(ii) Draw a ray diagram to show the formation of the image as specified in the part a (i). ***[3]***

2014

8. Ranbir claims to have obtained an image twice the size of the object with a concave lens. Is he correct? Give reason for your answer. ***[2]***

9. A lens forms an erect, magnified and virtual image of an object.

(i) Name the lens.

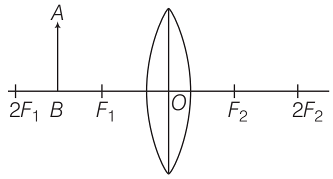
(ii) Draw a labelled ray diagram to show the image formation. ***[3]***

10. (i) Define the power of a lens.

(ii) The lens mentioned in Q. 3 above is of focal length 25 cm. Calculate the power of the lens. ***[3]***

2013

11. An object *AB* is placed between $2F_1$ and F_1 on the principal axis of a convex lens as shown in the diagram.



Copy the diagram and using these rays starting from point *A*, obtain the image of the object formed by the lens. ***[4]***

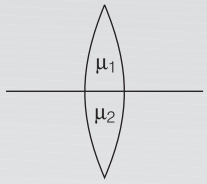
2012

12. You are provided with the printed piece of paper using this paper, how will you differentiate between a convex and concave lens? ***[2]***

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 Which of the following is true for rays coming from infinity?



(a) Two images are formed
(b) Continuous image is formed between focal points of upper and lower lens
(c) One image is formed
(d) None of the above

2 Two lenses of power – 3.5 D and + 1.0 D one placed in contact with each other. What is the focal length of this combination?

(a) 10 cm (b) 20 cm
(c) 30 cm (d) 40 cm

3 The image when obtained from a concave lens of focal length f is magnified up to n times the size of the object. What is the distance of the object from the lens?

(a) $\left(\frac{1-n}{n}\right)f$ (b) $\left(\frac{1+n}{n}\right)f$
(c) $\left(1-\frac{1}{n}\right)f$ (d) $\left(1+\frac{1}{n}\right)f$

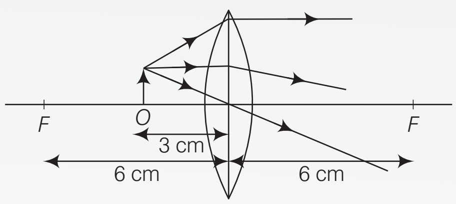
4 When the object is at infinity, what is the nature of image formed by concave lens?

(a) Real, inverted, enlarged
(b) Real, inverted, same size
(c) Virtual, erect, enlarged
(d) Virtual, erect, diminished

5 A convex lens of focal length 40 cm, a concave lens of focal length 40 cm and a concave lens of focal length 15 cm are placed in contact. The power of the combination in dioptre is

(a) + 1.5 (b) – 1.5
(c) + 6.67 (d) – 6.67

6 The diagram shows an object O placed 3 cm away from a converging lens of focal length 6 cm.



What type of image is produced?

(a) Real, upright and diminished
(b) Real, inverted and magnified
(c) Virtual, upright and magnified
(d) Virtual, inverted and diminished

7 A needle placed 45 cm from a lens forms an image on a screen placed 90 cm on the other side of the lens. What is the power of the lens?

(a) +10 D (b) –10 D
(c) +3.33 D (d) –3.33 D

8 Consider the following statements in context with the sign conventions for spherical lens and choose the incorrect one.

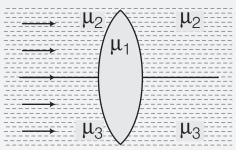
I. All the distances are measured from the pole of the lens.
II. The distances measured against the direction of incident light are taken as negative.
III. The distances measured downward and perpendicular to the principal axis are taken as negative.

(a) Only I (b) Only II
(c) III only (d) All are incorrect

9 If two convex lenses are in contact with each other,

(a) the diverging power increases
(b) the converging power increases
(c) the diverging power decreases
(d) the converging power decreases

10 A double convex lens, made of a material of refractive index μ_1, is placed inside two liquids of refractive indices μ_2 and μ_3 as shown $\mu_2 > \mu_1 > \mu_3$. A wide, parallel beam of light is incident on the lens from the left. The lens will give rise to



(a) a single convergent beam
(b) two different convergent beams
(c) two different divergent beams
(d) a convergent and a divergent beam

Answers

1. (a)	**2.** (d)	**3.** (a)	**4.** (d)	**5.** (d)	**6.** (c)	**7.** (c)	**8.** (a)	**9.** (b)	**10.** (d)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 241.

CHAPTER

6

Spectrum of Light

In the previous chapters, we have learnt that when a ray of light travels from one medium to another, it gets deviated from its path. It is because of the difference in the speeds of light in two media. This deviation will not occur if the angle of incidence becomes zero.

Since, the deviation always occurs at the boundary of the two media. Therefore, the magnitude of the deviation depends on the angle of incidence at the interface of two media and the refractive index of the second medium with respect to the first medium. In this chapter, we will study about the refraction of light through prism, which constitutes the phenomenon of dispersion.

Chapter Objectives

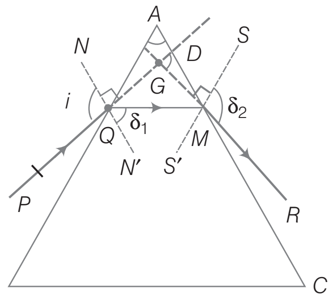
- Deviation Produced by a Triangular Prism
- Dispersion of White Light by a Glass Prism
- Scattering of Light
- Electromagnetic Spectrum

Prism

Prism is a transparent refracting medium bounded by at least two lateral surfaces, inclined to each other at a certain angle. It has two triangular bases and three rectangular lateral surfaces. The angle between two lateral surfaces is called **angle of prism** (A).

Deviation Produced by a Triangular Prism

In the figure given alongside, a ray of light PQ is entering from air to glass at the first surface AB. The light ray on refraction get bent toward the normal by an angle δ_1. At the second surface AC, the light ray enters from glass to air, so it bent away from the normal by an angle δ_2. The diagram shows refraction through a prism.



Deviation of light ray through a triangular glass prism

where,

$PQ =$ incident ray, $QM =$ refracted ray, $MR =$ emergent ray, $\angle A =$ angle of prism, $\angle i =$ angle of incidence and $\angle D =$ angle of deviation.

This represents the deviation of light rays produced by a prism.

Note When a ray of light passes through a prism, it bends towards the thicker part of the prism.

Therefore, the net deviation produced in the emergent ray *MR* w.r.t. the incident ray *PQ* can be given as,

$$D = \delta_1 + \delta_2$$

In chapter 4, we have already discussed the dependence of angle of deviation on various factors in details.

Dependence of Angle of Deviation on the Colour (or Wavelength) of Light

As, for light of different colours, the refractive index of a given transparent medium is different, it decreases with increase in the wavelength of the light. Therefore, the refractive index of the material of prism is maximum for the violet colour and least for red light. As a result, a given prism deviates the violet light most and the red light least.

Also, from the definition of refractive index,

i.e., $$\mu = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

As, speed of violet light is minimum and red is maximum in a medium, so

$$\mu_{\text{violet}} > \mu_{\text{red}}$$

As, $$\mu = \frac{\sin i}{\sin r}$$

where, r is the angle of refraction.

$\Rightarrow$ $$\sin r = \frac{\sin i}{\mu}$$

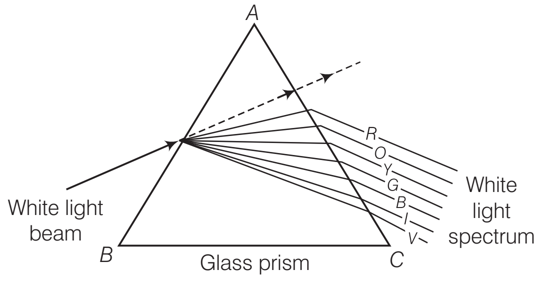
So, for a particular value of i, $r_{\text{violet}} < r_{\text{red}}$.

Hence, $\delta_{\text{violet}} > \delta_{\text{red}}$

Dispersion of White Light by a Glass Prism

The phenomenon of splitting of white light into its constituent colours, when it passes through a prism is called **dispersion.** This band of seven colours so obtained, the VIBGYOR (V = violet, I = indigo, B = blue, G = green, Y = yellow, O = orange and R = red) is called **spectrum**.

Isaac Newton was the first one to use a glass prism to obtain the spectrum of light.



Dispersion of white light by a glass prism

White light gets dispersed only at one surface of prism *AB*. But the deviation occurs at both the surfaces of prism i.e., *AB* and *AC*. Also, prism never produce any colour, rather it just helps in splitting the components of white light.

Note A similar band of seven colours is produced when a beam of white light from an electric bulb falls on a triangular glass prism.

Cause of Dispersion

Light rays of different colours, travel with the same speed in vacuum and air but in any other medium, they travel with different speeds and bend through different angles, which leads to the dispersion of light.

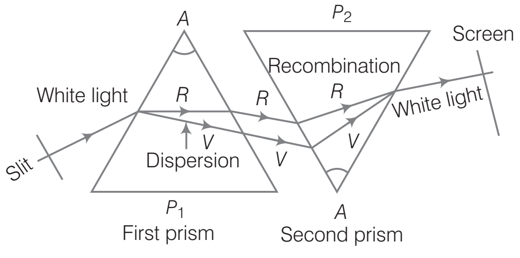
Red light has the maximum wavelength and **violet light** has the minimum wavelength. So in any medium, red light travels fastest and deviates least, while violet light travels slowest and deviates maximum, i.e.,

$$\text{Wavelength} \propto \text{Velocity} \propto \frac{1}{\text{Deviation}}$$

Note
- If δ_r, δ_y and δ_v are the deviations for red, yellow and violet components, then mean deviation is measured by δ_y as yellow light falls in between red and violet, $\delta_v - \delta_r$ is called angular dispersion.
- The dispersive power of a material is defined as the ratio of **angular dispersion** to the mean deviation when a white beam of light is passed through it. It is given by, $\omega = \frac{\delta_v - \delta_r}{\delta_y}$.

Recombination of White Light

Newton showed that the reverse of dispersion of light is also possible. He kept two prisms close to each other one in erect position and the other in an inverted position. The light gets dispersed when passes through the first prism. The second prism receives all the seven coloured rays from first prism and recombines them into original white light. This observation shows that sunlight is made up of seven colours. Any light that gives spectrum similar to that of sunlight is called **white light**.



Recombination of the spectrum of white light

Rainbow

A natural spectrum appearing in the sky after a rain shower is called rainbow. It is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere. It is always formed in a direction opposite to that of the Sun.

The water droplets act like small prisms. They refract and disperse the incident sunlight, then reflect it internally and finally, refract it again when it comes out of the raindrop. Due to the dispersion of light and internal reflection, different colours reach the observer's eye. It can also be seen on a sunny day by looking at the sky through a waterfall or through a water fountain, with the Sun behind you.

Note Red colour appears on the upper side of the rainbow and violet on the lower side, in case of primary rainbow.

CHECK POINT 01

1. When a monochromatic beam of light undergoes minimum deviation through equilateral glass prism, state how does the beam pass through the prism with respect to the base?
2. Among seven constituents colours of white light, which colour travels
   (i) fastest (ii) slowest in glass?
3. What do you understand by the term of dispersion of light?
4. Name the subjective property of light related its wavelength.
5. Name the phenomenon which is responsible for the formation of rainbow.

Scattering of Light

The reflection of light from an object in all directions is called scattering of light. The colour of scattered light depends on the size of scattering particles and wavelength of light. Very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelength (red light). If the size of the scattering particles is large enough, then the scattered light may even appear white.

Note
- The blue light present in sunlight is scattered 10 times more than the red light.
- Scattering $\propto d^6$ (where, d = diameter of particle)
- According to Rayleigh, amount of scattering $\propto \frac{1}{\lambda^4}$ (where, λ = wavelength of light)

Some Phenomena Based on Scattering of Light

Some phenomena based on scattering of light are

Tyndall Effect

The path of a beam of light passing through a true solution is not visible. However, its path becomes visible when it passes through a colloidal solution, where the size of the particles is relatively larger.

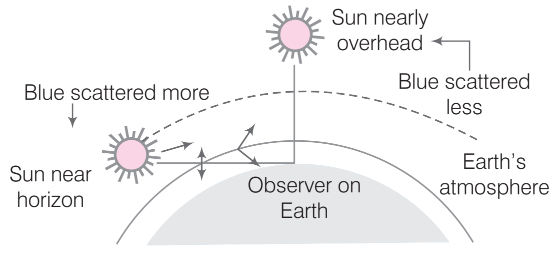
This scattering of light when it passes through a colloidal solution is called Tyndall effect. The Earth's atmosphere is a heterogeneous mixture of minute particles of smoke, tiny water droplets, suspended particles of dust and molecules of air which becomes visible due to scattering of light.

Blue Colour of Sky

During the day time, sky appears blue. This is because the size of the particles in the atmosphere is smaller than the wavelength of visible light. So, they are more effective in scattering the light of shorter wavelengths (blue end of spectrum). Hence, when sunlight passes through the atmosphere, the fine particles scatter the blue colour more strongly than red. This scattered blue light enters our eye. Hence, during the day time, the sky appears blue. It should be noted that the sky appears black to the passengers flying at higher altitudes because scattering of light is not prominent at such height due to the absence of particles.

Colour of Sun at Sunrise and Sunset

Light from the Sun near the horizon passes through thicker layers of air and covers larger distance in the atmosphere before reaching our eyes. Due to this, most of the blue light and shorter wavelengths are scattered away by the particles near the horizon. Therefore, the light that reaches our eyes is of longer wavelengths. This gives rise to the reddish appearance of the Sun and the sky. However at the noon, the light from the Sun overhead would travel relatively shorter distance. So, it appears white as only a little of the blue and violet colours are scattered.



Reddening of the Sun at sunrise and sunset

Note If the Earth had no atmosphere, then sky would have looked dark and black.

Electromagnetic Spectrum

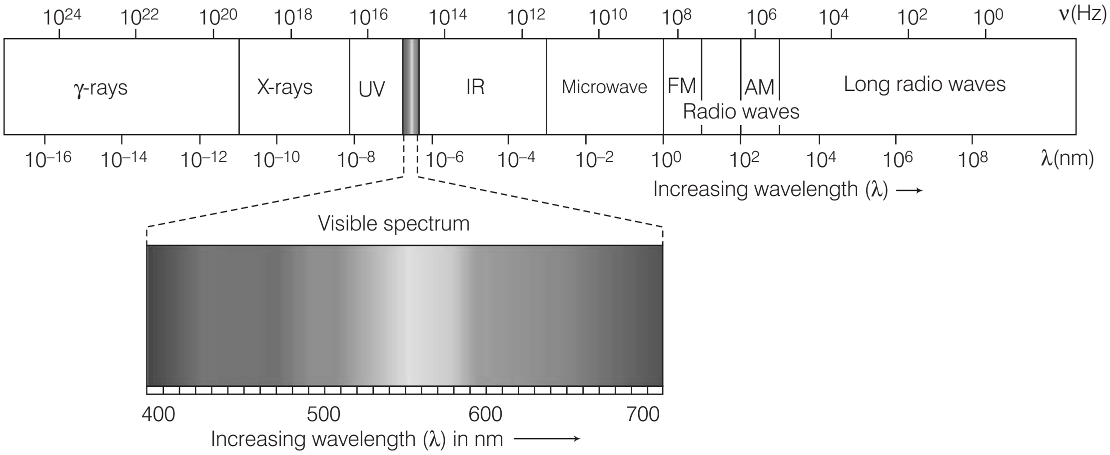
The orderly arrangement of electromagnetic waves in increasing or decreasing order of wavelength λ or frequency ν is called electromagnetic spectrum. The range varies from 10^{-12} m to 10^4 m, i.e., from γ-rays to radio waves.

Note
- A spectrum which has defined boundaries i.e., various bands of colours do not overlap with each other is called pure spectrum whereas the spectrum which do not have defined boundaries is called **impure spectrum**.

- The region in the spectrum beyond red and before violet is called **invisible spectrum**.

Broad Classification of Spectrum in the Increasing Order of Wavelength

The figure shown below shows the various parts of the electromagnetic spectrum with approximate wavelength range.



Properties of Different Electromagnetic Waves

Type	Wavelength range	Production	Detection	Effect on photographic plate	Penetrating power	Applications	Discover
Radio wave	> 0.1 m	Rapid acceleration and decelerations of electrons in aerials	Receiver's aerials	Do not affects	High	In amplitude modulation, ground wave propagation, TV waves and cellular phones	Marconi
Microwave	0.1 m to 1 mm	Klystron valve or magnetron valve	Point contact diodes	Do not affects	High	In RADAR's, microwave oven, study of atomic and molecular structures	Hertz
Infrared wave	1 mm to 700 nm	Vibration of atoms and molecules	Thermopiles bolometer, infrared photographic film	Do not affects	Passes through rock salt but absorbed by prism	In physical theraphy and weather forecasting	William Hershell
Visible light	700 nm to 400 nm	Electrons in atoms emit visible light when they move from higher energy level to a lower energy level	The eye, photocells, photographic film	Affects	Reflects by human body, but passes through glass prism	To see things	Newton
Ultraviolet rays	400 nm to 1 nm	Inner shell electrons in atoms moving from higher energy level to a lower energy level	Photocells, photographic film	Strongly affect	Only passes through quartz	In burglar alarms, sterlise surgical instruments	Prof. J. Ritter
X-rays	1 nm to 10^{-3} nm	X-ray tubes or inner shell electrons	Photographic film, strongly affect Geiger tubes, ionisation chamber	Strongly affect	High	To detect the fracture, diseased organs, stones in body, etc, for scientific research	Rontgen
Gamma rays	$< 10^{-3}$ nm	Radioactive decay of the nucleus	Geiger tubes, films	Affects	High	In nuclear reaction, treatment of tumour and cancer, kill pathogenic microorganisms	Rutherford

General Properties of Electromagnetic Spectrum

The properties common to all electromagnetic spectrum are as follows

(i) The electromagnetic waves of entire wavelength range do not require any material medium for their propagation.

(ii) They all travel with the same speed in vacuum which is same as the speed of light in vacuum, i.e., 3×10^8 m/s.

(iii) They exhibit the properties of reflection and refraction.

(iv) These waves are not deflected by the electric and magnetic fields.

(v) These waves are transverse waves.

Properties and Uses of Infrared Waves

These waves were discovered by **Herschell**. These waves are also called **heat waves**. These waves are produced from the heat radiating bodies and molecules.

They have high penetration power. Its frequency range is from 3×10^{11} Hz to 4×10^{14} Hz.

Uses of infrared waves are given below

(i) These are used in physical therapy.

(ii) These are used in satellite for army purpose.

(iii) These are used in weather forecasting.

(iv) These are used for producing dehydrated fruits.

(v) These are used in solar water heater, solar cells and cooker.

Properties and Uses of Ultraviolet Rays

These rays were discovered by **Ritter** in 1801. These are produced by special lamps and very hot bodies. The sun is an important source of UV-rays but fortunately absorbed by ozone layer. Its frequency range is from 10^{14} Hz to 10^{16} Hz.

Uses of ultraviolet rays are given below

(i) These are used in burglar alarm.

(ii) These are used in checking mineral sample.

(iii) These are used to study molecular structure.

(iv) To kill germs in water.

(v) To sterilise surgical instruments.

Relation between Frequency, Speed and Wavelength of Electromagnetic Waves

All electromagnetic waves move with same velocity (v) $(3 \times 10^{-8}$ m/s) in vacuum but their frequencies (ν) and wavelength (λ) are different.

The relation between frequency (ν), speed (v) and wavelength (λ) of electromagnetic waves is

$$\boxed{\text{Frequency}\,(\nu) = \frac{\text{Speed of elecromagnetic wave}\,(v)}{\text{Wavelength}\,(\lambda)}}$$

Example 1. **An electromagnetic wave of frequency 40 MHz travel in free space in the x-direction. Determine the wavelength of the wave.**

Sol. Given, frequency, $\nu = 40$ MHz

Speed of wave, $v = 3 \times 10^8$ m/s

Using the relation,

wavelength of wave, $\lambda = \dfrac{\text{speed of wave}\,(v)}{\text{frequency}\,(\nu)}$

Substituting the given values, we get

$$\lambda = \frac{3 \times 10^8}{40 \times 10^6} = 7.5 \text{ m}$$

Example 2. **What is the wavelength of an electromagnetic wave whose frequency is 10^{15} Hz? Name this electromagnetic wave.**

Sol. Given, frequency, $\nu = 10^{15}$ Hz,

speed of wave, $v = 3 \times 10^8 \text{ ms}^{-1}$

Using the relation,

wavelength of wave, $\lambda = \dfrac{\text{speed of wave}\,(v)}{\text{frequency}\,(\nu)}$

Substituting the given values, we get

$$\lambda = \frac{3 \times 10^8}{10^{15}} = 3 \times 10^{-7} \text{ m} = 300 \text{ nm}$$

Such a wave is infrared wave, whose wavelength varies from 10 nm to 400 nm.

Note This EM spectrum and its properties have been frequently asked in previous years 2014, 2013, 2012, 2011, 2010.

CHECK POINT 02

1 Which characteristic property of light is responsible for the blue colour of the sky?

2 The backlight of a motor is red, why?

3 Arrange the electromagnetic waves in the descending order of their wavelength.

(a) Microwaves (b) Infrared rays

(c) Ultravoilet (d) γ- rays

4 Write the equation for the relation between the frequency and wavelength of light in vacuum.

5 Name the region beyond the violet end of the spectrum.

6 Calculate speed of EM wave in a glass slab in which frequency of EM wave is 4×10^{14} Hz and wavelength is 500 nm. ***Ans.*** 2×10^{14} m/s

SUMMARY

- Prism is a portion of a transparent refracting medium bounded by two plane surfaces inclined each other at a certain angle.
- Angle of Deviation It is the angle between incident and emergent ray. It depends on angle of prism, angle of incidence and angle of emergence, refractive index of the material of the prism.
- Deviation of light caused by a prism is inversely proportional to its wavelength.
- Dispersion It is a phenomenon of splitting of light into its constituents colours. It is caused because of the different velocities of light in same medium.
- Red light deviates the least whereas violet light deviates maximum.
- Spectrum It is the band of colours obtained on the screen when a white light splits into component colours by the prism. It is of two type, pure spectrum and empure spectrum.
- Rainbow It is a natural phenomenon due to the dispersion of light formed by the rain drop, when sunlight falls on it. It is formed due to refraction, dispersion and total internal reflection of light.
- Scattering of Light It is the reflection of light from an object in all directions. It only takes place when the size of the scattering object is very small as compared to the wavelength of the light.
- Blue colour of the sky, reddish appearence of sun at sunrise and sunset, etc are due to scattering of light.
- Electromagnetic Spectrum It is the orderly distribution of electromagnetic radiations according to their wavelength or frequency.
- All the electromagnetic radiations travel with the same speed in vacuum which is same as the speed of light in vacuum, i.e., 3×10^8 m/s.
- Ultraviolet radiations wavelength range varies from 1 nm to 400 nm and infrared radiations wavelength range varies from 700 nm to 1 mm.

EXAM PRACTICE

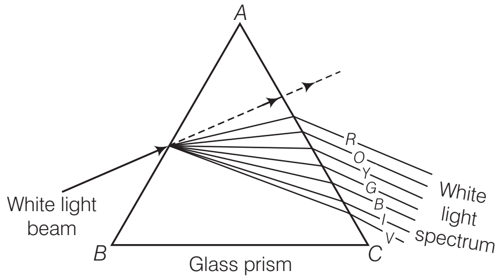
a 2 Marks Questions

1. Briefly mention, how does the deviation produced by a triangular prism depend on the colours (or wavelengths) of light incident on it?

Sol. Since, the refractive index of glass increases with decrease in wavelength of light. So, the deviation caused by a prism also increases with decrease in the wavelength of light, e.g., as λ of violet less than λ of red, hence $\delta_{\text{red}} < \delta_{\text{violet}}$. ***[2]***

2. Draw a ray diagram showing the dispersion through a prism when a narrow beam of white light is incident on one of its refracting surfaces. Also indicate the order of the colours of the spectrum obtained.

Sol. Ray diagram showing the dispersion of white light through a prism is shown below,



[1]

The order of the colours of the spectrum are given below

V = violet, I = indigo, B = blue,

G = green, Y = yellow, O = orange and R = red. ***[1]***

3. Explain the cause of dispersion of white light through a prism.

Sol. The speed of light for different colours is same in air but it is different for different colours in any other transparent medium. The speed of light in a transparent medium decreases with the decrease in the wavelength of light. ***[1]***

Since, the refractive index of the medium depends on the wavelength of the light. So, different colours of different wavelengths are deviated through different angles of deviation through a glass prism. This causes the dispersion of white light. ***[1]***

4. Is it possible that a glass slab disperse the light? If not, why?

Sol. No, it is not possible that a glass slab disperse the light, because it has parallel rectangular faces. ***[1]***

When a white light is incident on the glass slab, it gets dispersed into different colours but these different colours combine to form white light on emerging from the other parallel face. ***[1]***

5. Name the four colours of the spectrum of white light which have wavelength longer than the blue light. Also, name the light amongst the given, which shows maximum deviation.

Sol. The four colours of the spectrum of white light which have wavelength longer than the blue light are green, yellow, orange, red. ***[1]***

Green shows the maximum displacement amongst the given lights. ***[1]***

6. If the wavelengths for the light of red and blue colours are approximately 7.8×10^{-7} m and 4.8×10^{-7} m respectively, mention

(i) which colour has a greater speed in vacuum?

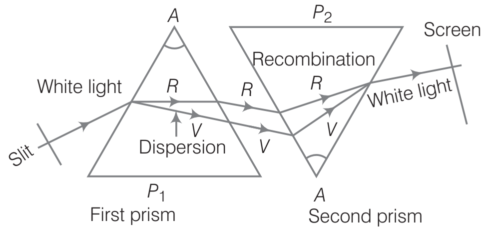
(ii) which colour has a greater speed in glass?

Sol. (i) In vacuum, both the colours (i.e., red and blue) will have the same speed. ***[1]***

(ii) In glass, red light has a greater speed because its deviation is least. ***[1]***

7. How will you use two identical prisms so that a narrow beam of white light incident on one prism emerges out of the second prism as white light? Draw the diagram.

Sol. A narrow beam of white light incident on one of the prisms emerges out of the identical prism placed in an inverted position with respect to the first prims, as shown in the figure given below. ***[1]***



[1]

8. What do you understand by term "spectrum of light"? Name one natural spectrum formed by sunlight after rain.

Sol. The band of seven colours formed on the screen when a white light passes through a glass prism, is known as spectrum of light. ***[1]***

Rainbow is a natural spectrum formed by the sunlight after rain. ***[1]***

9. (i) Define scattering.

(ii) The smoke from a fire looks white. Which of the following statements is true?

1. Molecules of the smoke are bigger than the wavelength of light.
2. Molecules of the smoke are smaller than the wavelength of light. ***[2018]***

Sol. (i) The process of absorption and then reemission of light energy is called scattering of light. When sunlight passes through the Earth's atmosphere, much of the light gets scattered (i.e., the light spreads in all directions) by the fine dust particles and air molecule in it ***[1]***

(ii) As molecules of the smoke are bigger than the wavelength of light, as a result they scatter all wavelengths which overlaps to give white colour. ***[1]***

10. Why is it difficult to drive on a foggy day?

Sol. On a foggy day, most of the light gets scattered by the particles in the fog. Due to this visibility reduces. Hence, it becomes difficult to see and is difficult to drive also on a foggy day. ***[2]***

11. Briefly mention, why does the sky at noon appear white?

Sol. During the time of noon, the sun is directly above our head. Due to which the sunlight travels relatively shorter distance as compare to the time when sun is at the horizon. So, we get light rays directly from the sun without much scattering. Therefore, the sky at noon appears white. ***[2]***

12. (i) Why is white light considered to be polychromatic in nature?

(ii) Give the range of wavelength of these electromagnetic waves which are visible to us. ***[2009]***

Sol. (i) Since, polychromatic light consists of many colours each having its characteristic wavelength.
Therefore, white light is also a polychromatic light because it is made up of seven colours, containing different wavelengths. ***[1]***

(ii) 400 nm to 700 nm is the range of visible spectrum. ***[1]***

13. Mention two properties of infrared radiations that are not true for visible light.

Sol. *Two properties are*

(i) they are absorbed by glass. ***[1]***

(ii) they do not affect the ordinary photographic film. ***[1]***

14. Why are infrared radiations preferred over ordinary visible light for taking photographs in fog?

Sol. For taking photographs in fog, infrared radiations are preferred over ordinary visible light

(i) because of their long wavelengths, they are scattered less by the earth's atmosphere. As, intensity of scattered radiation $\propto \frac{1}{\lambda^4}$. ***[1]***

(ii) also, they can penetrate deep inside the atmosphere even in fog. ***[1]***

15. Explain the following statement.

"The photographic dark rooms are provided with infrared lamps". Write any other use of infrared radiations.

Sol. Since, infrared lamps do not affect the photographic film due to this reason, the dark rooms are provided with infrared lamps. ***[1]***
Infrared radiations are used for producing dehydrated fruits. ***[1]***

16. (i) Name the radiations which are absorbed by green house gases in earth's atmosphere.

(ii) A radiation X is focussed by a particular device on the bulb of a thermometer and mercury in the it shows a rapid increase. Name the radiation.

Sol. (i) Infrared radiations are low energy radiations, which are absorbed by CO_2, present in Earth's atmosphere. ***[1]***

(ii) Infrared radiations trapped by the bulb of the thermometer increases the mercury level. ***[1]***

b 3 Marks Questions

17. It is seen that the white light splits into bands of seven colours when passed through the glass prism. With reference to this observation, answer the following questions.

(i) State the conclusion that you draw about the white light.

(ii) Name the sequence of colours from the base of the prism.

(iii) Do all the bands are of same width? If not, then why?

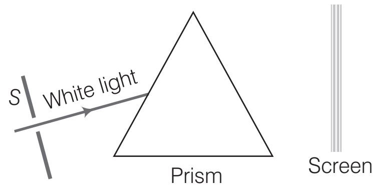
Sol. (i) After reading the given observation, it is concluded that white light is polychromatic due to which refraction and dispersion of white light takes place.

(ii) The sequence of colours from the base of prism is violet, indigo, blue, green, yellow, orange and red.

(iii) Bands of colours will be of different width. As, their widths are depends on the range of frequency or wavelength of a colour.

As, the range of colour increases, its bandwidth also increases. So, red colour has maximum and yellow has minimum bandwidth. ***[1 + 1 + 1]***

18. The figure given below shows a thin beam of white light from a source *S* striking on one face of prism.

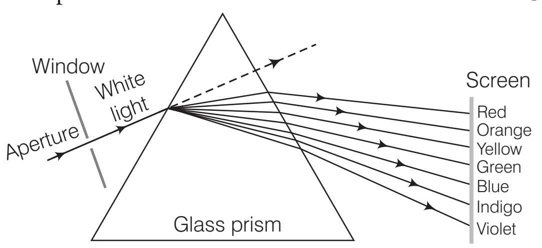


(i) In order to show the effect of the prism on the beam, complete the diagram so that, it can represent what is seen on the screen.

(ii) Assume if a slit is placed between the prism and the screen to pass only the light of green colour, then what observation will you get on the screen.

(iii) State the conclusion that you draw from the observation in part (ii) above?

Sol. (i) As we can see in the figure (below), a pattern of seven colours is formed on the screen with red on the top and violet at the bottom. ***[1]***



(ii) Since, a green filter transmits only green light. Therefore, it is placed between the prism and the screen, the spectrum on the screen will appear dark except for the region near the green part in the original spectrum. ***[1]***

(iii) It proves that the prism by itself produces no colour. ***[1]***

19. (i) A glass slab is placed over a page on which the word VIBGYOR is printed with each letter in its corresponding colour.

(a) Will the image of all the letters be in the same place?

(b) If not, state which letter will be raised to the maximum. Give a reason for your answer.

(ii) What will be the colour of an object which appears green in white light and black in red light?

Sol. (i) (a) No, the image of all the letters are not in the same place, because the letter of each colour have different frequency or wavelength. ***[1]***

(b) The letter V for violet is raised more because λ is least for violet colour, hence deviation is most. ***[1]***

(ii) The colour of an object which appears green in white light and black in red light will be green. ***[1]***

20. Why do we see a rainbow in the sky only after rainfall?

Sol. We see a rainbow in the sky only after rainfall due to dispersion of sunlight by tiny water droplets, present in the atmosphere. These droplets act like small prism. They refract and disperse the incident sunlight, then reflect it internally and finally refract it again when it comes out of the raindrop. Hence, due to dispersion of light and internal reflection, different colours are seen by the observer's eye. ***[3]***

21. Explain how scattering of light depends upon particle size.

Sol. Since, scattering of the light is proportional to diameter of particle and inversly proportional to the wavelength of light. So, very fine particles scatter mainly blue light while particles of larger size scatter light of longer wavelength. If the size of the scattering particles is very large, the scattered light may appear white. ***[3]***

22. State three properties common to all type of electromagnetic radiations.

Sol. *Three properties common to all electromagnetic radiations are*

(i) they do not require any material medium for their propagation. ***[1]***

(ii) they all travel with the same speed in vacuum, which is same as the speed of light in vacuum, i.e., 3×10^8 ms^{-1}. ***[1]***

(iii) they exihibit the properties of reflection and refraction. ***[1]***

23. Which type of rays exist beyond visible red end of the electromagnetic spectrum? State one property and one use of these rays.

Sol. Beyond visible red end of electromagnetic spectrum, infrared rays exist. They have frequency less than and wavelength greater than that of red light. ***[1]***

Property They are detected by their heating property. ***[1]***

Use They are used in photography at night and also in mist and fog. ***[1]***

24. (i) Suggest one way in each case by which we can detect the presence of
(a) infrared radiations and
(b) ultraviolet radiations.
(ii) Give one use of infrared radiations.

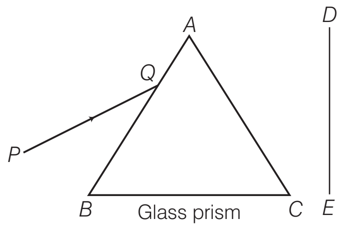
Sol. (i) (a) We can detect infrared radiation by using a thermopile or a blackened bulb thermometer. ***[1]***

(b) We can detect the presence of ultraviolet radiation by using silver chloride solution. ***[1]***

(ii) Infrared radiations are used in muscular therapy and for taking photographs in fog. ***[1]***

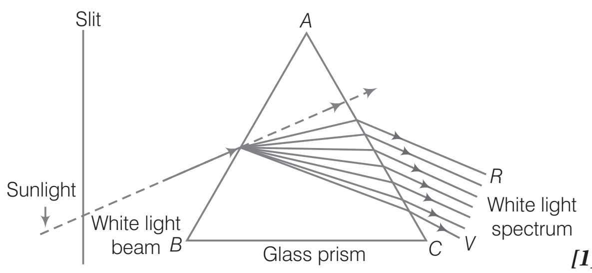
C 4 Marks Questions

25. A narrow beam of white light is passing through a glass prism *ABC* as shown in the diagram.



Trace it on your answer sheet and show the path of the emergent beam as observed on the screen *DE*.
(i) Write the name and cause of the phenomenon observed.
(ii) Where else in nature is this phenomenon observed?
(iii) Based on this observation state the conclusion which can be drawn about the constituents of white light.

Sol. *The path of the light incident on the prism is shown below*



[1]

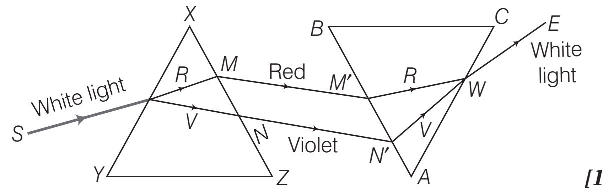
(i) The phenomenon of splitting of white light into its constituent colours is called dispersion of light. It is caused because different constituent colours of light travel with different speeds in the medium other than air/vacuum and bend through different angles. ***[1]***

(ii) This phenomenon is observed as formation of rainbow. ***[1]***

(iii) Based on phenomenon of dispersion, we can conclude that
(a) white light consists of seven colour and ***[½]***
(b) violet light suffers maximum deviation and red light suffers minimum deviation. ***[½]***

26. Explain, how can you produce deviation with dispersion?

Sol. First of all, take two prisms *XYZ* and *ABC* of same material and same refracting angles (here, we can also take different material and different refracting angles prisms).



[1½]

Both prisms are placed inverted as shown in the figure above. When a ray of white light passes through prism *XYZ*, the emergent rays *MM′* and *NN′* bends towards the base *YZ* of prism *XYZ* with colour red or violet respectively and form the band of seven colours between red and violet rays. The seven colours enter into prism *ABC* and bends towards base *BC* of prism. ***[1½]***

Since, $\mu_V > \mu_R$, so violet $N'W$ ray bends the most and $M'W$ (red) bends the least and overall colours meet at *W* and emerges out as a white light *WE* as shown in the figure. ***[1]***

27. What is meant by scattering of light? Mention the factor on which it depends. Explain why
(i) the colour of the clear sky is blue and
(ii) for astronauts sky appears darker?

Sol. The reflection of light from an object in all directions is called scattering of light.

The colour of scattered light depends on the size of scattering articles and wavelength of light.

i.e., Scattering $\propto d^6$ (where, d = diameter of particle)

and scattering $\propto \dfrac{1}{\lambda^4}$ (where, λ = wavelength of particle) ***[2]***

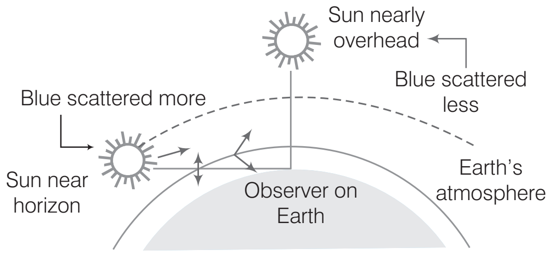
(i) During the day time sky appears blue. This is because the size of particles in the atmosphere is smaller than the wavelength of visible light. So, they are more effective in scattering the light of shorter wavelengths i.e., blue light. ***[1]***

(ii) Since, at such a height there is no atmosphere i.e., no particles. Therefore, no scattering of light takes places. Hence, for astronauts the sky appears dark. *[1]*

28. How can we explain the reddish appearance of the sun at sunrise or sunset? Why does it not appear red at noon?

Sol. The reddish appearance of the sun at sunrise or sunset is due to the scattering of light by the molecules of air and other fine particles in the atmosphere having size smaller than the wavelength of visible light. A light from the sun near the horizon passes through thicker layers of air and covers larger distance in the Earth's atmosphere before reaching our eyes.

Hence, most of the blue light and shorter wavelengths are scattered away by the particles. So, only red light being of higher wavelength reaches us which gives reddish appearance of the sun at sunrise or sunset. *[2]*



[1]

At noon, the sun appears white, not red, as only a little of the blue and violet colours are scattered as light from the sun overhead would travel relatively shorter distance. *[1]*

Numerical Based Questions

29. An electromagnetic wave has a frequency of 500MHz and a wavelength of 60 cm. Calculate velocity.

Sol. Given, frequency, $\nu = 500 \text{ MHz} = 500 \times 10^6 \text{ Hz}$,

wavelength, $\lambda = 60$ cm

$$\text{Velocity, } v = \nu\lambda = 500 \times 10^6 \times \frac{60}{100} = 3 \times 10^8 \text{ ms}^{-1}$$ *[2]*

30. The wavelength of electromagnetic radiation is 900 nm. Find its frequency. (Take, speed of radiation = $3 \times 10^8 \text{ ms}^{-1}$)

Sol. Given, wavelength, $\lambda = 900\text{nm}$

$$= 900 \times 10^{-9} \text{ m}$$
$$= 9 \times 10^{-7} \text{ m}$$

Speed of radiation, $v = 3 \times 10^8 \text{ ms}^{-1}$

As we know,

$$\text{Frequency, } \nu = \frac{\text{Speed of electromagnetic radiation}}{\text{Wavelength}}$$

Substituting the given values, we get

$$\nu = \frac{3 \times 10^8}{9 \times 10^{-7}} = 0.34 \times 10^{15}$$
$$= 3.4 \times 10^{14} \text{ Hz}$$ *[2]*

31. A radio can tune into any station in 7.5 MHz to 12 MHz band, what is the corresponding wavelength band?

Sol. Given, frequency range = 7.5 MHz to 12 MHz

$$= 7.5 \times 10^6 \text{ Hz to } 12 \times 10^6 \text{ Hz}$$

Speed of radio waves, $v = 3 \times 10^8 \text{ ms}^{-1}$

From the relation,

speed of wave (v) = wavelength (λ) × frequency (ν)

$$\Rightarrow \quad \lambda = \frac{v}{\nu}$$

$$\therefore \quad \lambda_1 = \frac{3 \times 10^8}{7.5 \times 10^6} = 40 \text{ m}$$

$$\text{and} \quad \lambda_2 = \frac{3 \times 10^8}{12 \times 10^6} = 25 \text{ m}$$

∴ The corresponding wavelength band is 40 m – 25 m. *[2]*

32. An enemy plane is at a distance of 300 km from a radar. In how much time, the radar will be able to detect the plane? (Take, velocity of radiowaves as $3 \times 10^8 \text{ ms}^{-1}$). *[2017]*

Sol. As we know, speed $= \dfrac{\text{distance}}{\text{time}}$

Given, distance from the radar to the plane,

$$d = 300 \text{ km} = 300000 \text{ m}$$

Velocity of radar, $v = 3 \times 10^8 \text{ ms}^{-1}$

According to the formula, $d = \dfrac{v \times t}{2}$

$$t = \frac{2 \times d}{v} = \frac{2 \times 300{,}000}{3 \times 100000000} = \frac{2}{1000} = 0.002\text{s}$$ *[2]*

CHAPTER EXERCISE

2 Marks Questions

1. What are the necessary conditions that are to be followed to obtain a pure spectrum on a screen?
2. Explain the reason for the given statement. "Light of different colours is deviated through different angles by a prism".
3. Write a note on the following terms:
   (i) Monochromatic light
   (ii) Polychromatic light
4. When a ray of light is passed through a hollow glass prism, it does not give spectrum. Explain why?
5. "Do the ratio of speed of red and blue radiation in glass is smaller than one, greater than one or equal to one"? Give reason.
6. State one harmful effect each of ultraviolet and infrared radiations.
7. Give reasons for the following:
   (i) Smoke out of a chimney sometimes appears blue.
   (ii) Infrared radiations are used to detect diseases in crops.
8. Briefly tell, how do the sky appears when seen from the moon (or outer space)? Give reason in support of your answer.

3 Marks Questions

9. Explain any three factors on which the deviation produced by a prism depends.
10. If a player is wearing a uniform consisting of a red shirt and a white short as seen in a white light, so state what will be the appearance of shirt and the short in
    (i) red light and (ii) blue light?
11. Briefly mention the name and wavelength of electromagnetic wave whose frequency is 10^{12} Hz. Can you produce and use it in the kitchen?

4 Marks Questions

12. What do you mean by electromagnetic spectrum? Give the complete electromagnetic spectrum.
13. (i) "The sunlight appears yellow". Justify this statement along with a reason.
    (ii) Name the extreme colours in pure spectrum of light.

Numerical Based Questions

14. An electromagnetic wave travels in vacuum along z-direction. If the frequency of the wave is 30 MHz, what is its wavelength? ***Ans.*** 10 m
15. A certain electromagnetic wave has a wavelength of 625 nm.
    (i) What is the frequency of the wave ?
    (ii) What region of the electromagnetic spectrum is it found?
    Ans. (i) 4.8×10^{14} Hz, (ii) Visible region

ARCHIVES* *(Last 8 Years)*

Collection of Questions Asked in Last 8 Years' (2018-2011) ICSE Class 10th Examinations

2018

1. (i) Define scattering.

(ii) The smoke from a fire looks white.

Which of the following statements is true?

1. Molecules of the smoke are bigger than the wavelength of light.
2. Molecules of the smoke are smaller than the wavelength of light. ***[2]***

2017

2. An enemy plane is at a distance of 300 km from a radar. In how much time, the radar will be able to detect the plane? (Take, velocity of radiowaves as $3 \times 10^8 \text{ms}^{-1}$) ***Ans.*** 0.002 s ***[2]***

2016

3. What do you understand by the term scattering of light? Which colour of white light is scattered the light and why? ***[4]***

2015

4. (i) Name the high energetic invisible electromagnetic waves, which help in the study of the structure of crystals.

(ii) State an addition use of the waves mentioned in part (i). ***[2]***

2014

5. (i) Name a prism required for obtaining a spectrum of ultraviolet light.

(ii) Name the radiations which can be detected by a thermopile. ***[2]***

6. Why is the red colour used as a sign of danger? ***[2]***

7. A type of electromagnetic wave has a wavelength of 50 Å.

(i) Name the wave.

(ii) What is the speed of wave in vacuum?

(iii) State one use of this type of wave. ***[3]***

2013

8. Name the radiations

(i) that are used for photography at night.

(ii) are used for detection of fracture in bones.

(iii) whose wavelength range is from 10 nm to 400 nm? ***[3]***

2012

9. (i) What is meant by "dispersion of light"?

(ii) In the atmosphere, which colour of light gets scattered the least? ***[2]***

2011

10. Which characteristic property of light is responsible for the blue colour of the sky? ***[2]***

11. (i) Suggest one way in each case by which we can detect the presence of

(a) infrared radiations and

(b) ultraviolet radiations.

(ii) Give one use of infrared radiations. ***[3]***

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

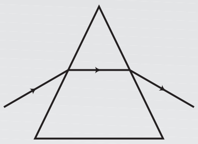
CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 A passenger in an aeroplane will
(a) never see a rainbow
(b) may see a rainbow as concentric circles
(c) may see a rainbow as concentric arcs
(d) may see a rainbow as straight bands

2 Violet has the smallest wavelength, but colour of sky is blue. Why?
(a) Most of the violet rays are absorbed by the atmosphere
(b) Our eyes are less sensitive to violet colour
(c) Both (a) and (b)
(d) Neither (a) nor (b)

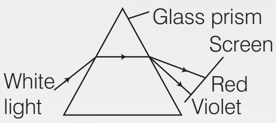
3 If a ray of light enters glass prism (as shown in figure) of refractive index 1.5, then the speed of light inside the prism will be

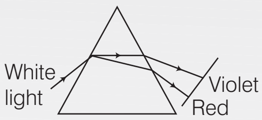


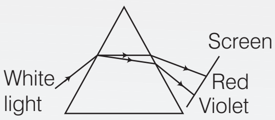
(a) $0.2\times10^{8}ms^{-1}$ (b) $2\times10^{9}ms^{-1}$
(c) $2\times10^{7}ms^{-1}$ (d) $2\times10^{8}ms^{-1}$

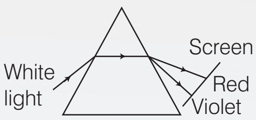
4 When white light is dispersed by a prism, compared with blue light, the red light is
(a) slowed down less and refracted less
(b) slowed down less and refracted more
(c) slowed down more and refracted less
(d) slowed down more and refracted more

5 Which amongst the given figures below correctly depicts the dispersion of white light by a glass prism?

(a)


(b)


(c)


(d)


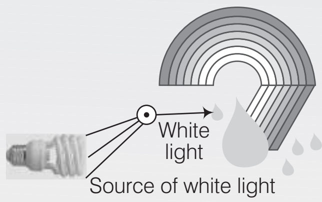
6 Consider the following statement and choose the incorrect one (s).
I. The blue colour of clear sky is due to the presence of atmosphere on the earth.
II. The greyish appearance of sky is due to the presence of smoke and dust particles in the atmosphere.
III. Emergency signals and danger signals are red because red light can travel long distance without being scattered.
IV. When electromagnetic waves strike a matter, then scattering takes place.

(a) I, IV (b) I, II, IV (c) II, IV (d) None of these

7 If a swimmer inside water looks at an aeroplance in the sky, then which of the following conditions are fulfilled?


(a) For the swimmer, the aeroplane will appear to be lower than it actually is
(b) For the swimmer, the aeroplane will appear to be higher than it actually is
(c) For the swimmer, the aeroplane will appear at its actual height
(d) For the pilot, the swimmer will appear to be at greater depth than it actually is

8 In a science project, a student tried to show rainbow formation using artificial rain and strong source of white light as shown in figure below. What should be the position of observer to observe the rainbow?



(a) Looking towards the source
(b) Looking towards the raindrops with the source behind him
(c) Looking anywhere in the room
(d) Looking towards the raindrop such that he is equally inclined towards the source of raindrops

9 State T for true and F for false.
I. To recombine the spectrum to obtain white light, the dispersive prism and recombination prism should be in same position.
II. If a glass prism is dipped in water, its dispersive power decreases.
III. When sunlight comes down through the clouds, tyndall effect is observed.
IV. Headlights are made of yellow colour because of its long wavelength and low scattering.

	I	II	III	IV		I	II	III	IV
(a)	T	T	T	T	(b)	F	T	T	T
(c)	F	F	T	T	(d)	F	T	F	T

Answers

1. (b) 2. (c) 3. (d) 4. (a) 5. (c) 6. (d) 7. (b) 8. (b) 9. (b)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 242.

CHAPTER

7

Sound

Sound is a form of energy which produces a sensation of hearing in our ears. It is produced by vibrating objects. Vibration means a kind of rapid to and fro motion of an object. We can produce sound by striking the tuning fork, by plucking, scratching, rubbing, blowing or shaking different objects. They all produce sound due to vibrations.

Basically sound require a material medium (solid, liquid or gas) for their propagation, so they are called mechanical waves.

Chapter Objectives

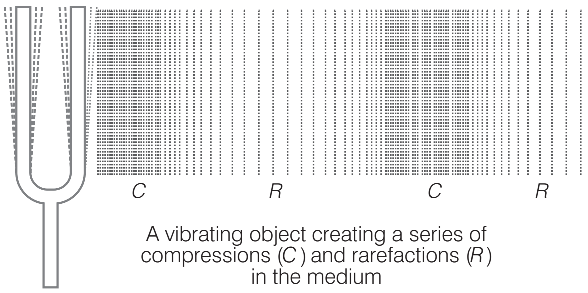
- Range of Hearing
- Reflection of Sound Waves
- Echo
- Characteristics of Sound
- Free (or Natural), Forced and Damped Vibrations
- Resonance

Propagation of Sound in Air

When a vibrating object moves forward in air, it pushes and compresses the air in front of it, creating a compression which starts to move away from the vibrating object. When the vibrating object moves backwards, then it creates rarefaction.

Compression is the part of a longitudinal wave in which the particles of the medium are closer to one another than they normally are and it is the region of high pressure. It is denoted by C.

Rarefaction is the part of a longitudinal wave in which the particles of the medium are farther apart than they normally are and it is the region of low pressure. It is denoted by *R*.



A vibrating object creating a series of compressions (*C*) and rarefactions (*R*) in the medium

As the object moves back and forth rapidly, a series of compressions and rarefactions is created in air. These make the sound wave that propagates through the medium.

Terms Related with Sound Waves

Sound waves can be described by following terms

Wavelength

The distance between the two consecutive compressions or two consecutive rarefactions, is called the wavelength. Wavelength is the minimum distance in which sound wave repeats itself. It is represented by a Greek letter lambda (λ). Its SI unit is metre (m).

Frequency

It tells us how frequently an event occurs. The number of complete waves (or oscillations) produced in one second is called frequency of the wave/sound. It is the number of vibrations that occur per second.

If we can count the number of the compressions or rarefactions that crosses per unit time, we will get the frequency of sound wave.

It is denoted by ν (Greek letter, nu). Its SI unit is hertz (Hz). 1 hertz is equal to 1 vibration per second.

1 kHz = 1000 Hz

Note The frequency of a wave is fixed and does not change even when it passes through different substances.

Time Period

The time taken by two consecutive compressions or rarefactions to cross a fixed point is called the time period of the sound wave. It is denoted by symbol T. Its SI unit is second (s). The time period of a wave is the reciprocal of its frequency i.e.,

$$\text{Time period } (T) = \frac{1}{\text{Frequency } (\nu)}$$

or

$$\boxed{\text{Frequency } (\nu) = \frac{1}{\text{Time period } (T)}}$$

Amplitude

The maximum displacement of the particles of the medium from their original mean positions on passing a wave through the medium, is called amplitude of the wave. It is usually denoted by the letter A. Its SI unit is metre (m).

Speed

The distance travelled by a wave in one second is called speed of the wave or velocity of the wave. Under the same physical conditions, the speed of sound remains same for all frequencies. It is represented by letter v.

$$\boxed{\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}}$$

Its SI unit is metre per second (m/s or ms^{-1}).

Relationship between Speed, Frequency and Wavelength of a Sound Wave

Suppose distance travelled by a wave is λ (wavelength), in time T, then the speed is given by

$$v = \frac{\lambda}{T}$$

We know that, $f = \nu = \frac{1}{T}$

Therefore, $v = \lambda \times \nu$

or $v = \nu\lambda$

or $\boxed{\text{Speed (velocity)} = \text{Frequency} \times \text{Wavelength}}$

Example 1. **A sound travels at a speed of 330 ms^{-1}. If its wavelength is 1.5 cm, then calculate the frequency of sound wave.**

Sol. Given, speed of sound, $v = 330$ m/s

Wavelength, $\lambda = 1.5$ cm $= 0.015$ m

Frequency, $\nu = ?$

We know that, $v = \nu\lambda$

So, $\nu = \frac{v}{\lambda} = \frac{330}{0.015} = 22000$ Hz or 22 kHz

Range of Hearing

The average frequency range over which the human ear is sensitive is called **audible range**. The audible range of sound for human beings is from 20 Hz to 20000 Hz.

Infrasonic Sound

The sound of frequencies lower than 20 Hz are known as infrasonic sounds or infrasound, which cannot be heard by human beings.

Ultrasonic Sound

The sounds of frequencies higher than 20000 Hz are called as ultrasonic sounds or ultrasound which cannot be heard by human beings. Bats can hear ultrasonic sounds having frequencies upto 120000 Hz. Bats, dolphins, tortoise and rats can also produce ultrasonic sounds as well as hear ultrasonic sound.

Reflection of Sound Waves

Like light, sound can also be made to change its direction and bounce back when it falls on a hard surface. This bouncing back of sound when it strikes a hard surface is known as reflection of sound.

It does not require a smooth and shining surface like that of mirror, it can be reflected from any surface whether it is smooth or rough. Sound is reflected in the same way as light and follows the same laws of reflection.

Echo

When a person shouts in a big empty hall or near a hillside, we first hear his original sound, after that we hear the reflected sound of that shout. This reflected sound is echo. So, **the phenomena of repetition of sound caused by reflection of sound waves is called an echo.**

As the sensation of sound persists in our brain for about 0.1 s. So, to hear a distinct echo, the time interval between the original sound and the reflected one must be atleast 0.1 s.

The speed of sound in air is 344 m/s. So, the distance travelled by the sound in 0.1 s is

$$= \text{speed} \times \text{time} = 344 \times 0.1 = 34.4 \text{ m}$$

So, echo will be heard, if the minimum distance between the source of sound and the obstacle is

$$= \frac{34.4}{2} \text{ m} = 17.2 \text{ m}$$

This distance will change with the change in temperature. Echoes may be heard more than once due to successive multiple reflections.

The rolling of thunder is due to successive reflections of sound from a number of reflecting surfaces, such as clouds and the land.

Note The persistance of sound in a big hall due to repeated reflections from the walls, ceiling and floor of the wall is known as reverberation.

Conditions for Formation of Echoes

The conditions for formation of echoes are as follows

(i) The size of the obstacle/reflector must be large as compared to the wavelength of the incident sound (for reflection of sound to take place).

(ii) The minimum distance between the source of sound and the reflector should be atleast 17 m (so that the echo is heard distinctly after the original sound is over).

(iii) The intensity or loudness of the sound should be sufficient enough, so that the reflected sound can be heard clearly. The original sound should be of short duration.

Determination of Speed of Sound by the Method of Echo

The phenomenon of echo can be used to determine the speed of sound in air.

Let d be the distance between the observer and the obstacle and v be the speed of sound. Then, the total distance travelled by the sound to reach the obstacle and then to come back is $2d$ and the time taken is given by

$$t = \frac{\text{Total distance travelled by the sound}}{\text{Speed of sound}}$$

$$= \frac{2d}{v} \quad \text{or} \quad d = \frac{vt}{2} \Rightarrow \boxed{v = \frac{2d}{t} \text{ ms}^{-1}}$$

Example 2. **A boy is standing in the middle of a big square field. There is a tall building on one side of the field. He explodes a cracker and hears its echo 0.4 s later. What is the size of the square field? (Given, speed of sound in air is 330 m/s)**

Sol. Given, speed of sound in air, $v = 330 \text{ ms}^{-1}$

Time taken for hearing the echo, $t = 0.4 \text{ s}$

As we know, distance travelled by the sound,

$$2d = v \times t = 330 \text{ ms}^{-1} \times 0.4 \text{ s} = 132 \text{ m}$$

As in 0.4 s, sound has to travel twice the distance between the boy and the building.

Hence, the distance between the boy and the building is

$$= \frac{d}{2} = \frac{132}{2} = 66 \text{ m}$$

Side of the square field

$= $ Twice the distance between the boy and the building

$= 2 \times 66 \text{ m} = 132 \text{ m}$

So, size of the square field $= (\text{side of the square field})^2$

$$= (132 \text{ m})^2 = 132 \text{ m} \times 132 \text{ m} = 17424 \text{ m}^2$$

Example 3. **If boy fires a gun and hears its echo after 5s. The boy then moves 310 m towards the hill and fires the gun again. This time, he hears the echo after 3s. Calculate the speed of the sound.**

Sol. Given, time, $t_1 = 5 \text{ s}$

Let d be the distance of the hill from the boy and v be the velocity of sound which is to be determined.

Using the formula, $t = \frac{2d}{v}$.

Substitute the given values, we get

$$\Rightarrow \quad 5 = \frac{2d}{v}$$

$$\Rightarrow \quad d = \frac{5v}{2} \quad \text{...(i)}$$

When the boy moves through a distance 310 m towards the wall, then $d' = d - 310$ and $t' = 3 \text{ s}$.

$$\Rightarrow \quad 3 = \frac{2(d - 310)}{v}$$

$$\Rightarrow \quad d - 310 = \frac{3v}{2} \quad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$v = 310 \text{ ms}^{-1}$$

Uses of Echoes

Uses of echoes by bats, dolphins, fishermen, medical field and in SONAR are given below

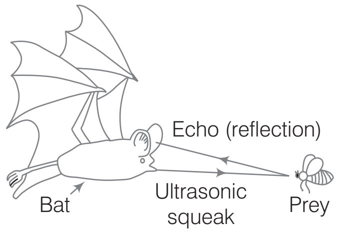
The method used by some animals like bats, tortoises and dolphins to locate the objects by hearing the echoes of their ultrasonic squeaks is known as **echolocation**. They search out prey and fly in dark night by **emitting** and **detecting reflections** of **ultrasonic waves.**

Bats

Bats emit high frequency or high pitched ultrasonic squeaks while flying and listen to the echoes produced by reflection of their squeaks from the obstacles or prey in their path.

From the time taken by the echo to be heard, bats can determine the distance of the obstacle or prey and can avoid the obstacle by changing the direction or catch the prey.

However, certain prey's mother can hear the high frequency ultrasonic squeaks of a bat and can know, where the bat is flying nearby and are able to escape.



Bats can search their prey in the darkness of night by the method of echolocation

Dolphins

Dolphins uses the same method as used by bats, in order to locate the obstacles or prey. They also emit the ultrasonic waves and hear their echoes to detect their enemy and obstacles or for hunting their prey.

Fishermen or Trawlermen

Initially, they send ultrasonic waves from a source. These waves are then received and reflected by the fish.

After that, the receiver of the fisherman receive the echo and the total time t of the to and fro journey of the wave is recorded. The distance of fish is then calculated by using the relation $d = \frac{vt}{2}$.

where, v is speed of ultrasonic waves (near 1400 m/s in water). This helps them to catch the fishes easily.

Medical Field

In the medical field, echoes of the ultrasound is used to investigate the internal organs of human body such as liver, gall bladder, pancreas, kidneys, uterus, heart, etc.

These waves can penetrate through the human body and different type of tissues and get reflected in different ways from a region, where there is a change of tissue density. In this way, ultrasound helps us to investigate internal organs of human body and to give pictures of these organs by converting the reflected waves into electrical signals. These pictures or images are then displayed on a monitor or printed on a film. This technique is called ultrasonography. Similarly, ultrasound is also used for diagnosing heart diseases by scanning the heart from inside. This technique is **echocardiography**.

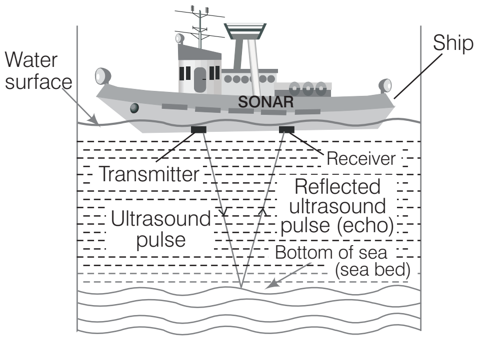
SONAR

The word **SONAR** stands for **Sound Navigation And Ranging**. It is an apparatus used to find the depth of a sea or to locate the under water things like shoals of fish, shipwrecks, hills, ice bergs, sunken ships, enemy submarines, etc. It uses ultrasonic waves to measure the distance, direction and speed of underwater objects.

SONAR consists of two parts

(i) A transmitter (for emitting ultrasonic waves)

(ii) A receiver (for detecting ultrasonic waves), as shown in figure.



To measure the depth of a sea by using SONAR

The **transmitter** produces and transmits ultrasonic waves. These waves travel down the sea-water towards the bottom of the sea. When these sound pulse strikes the bottom of the sea, then it is reflected back in the form of echo and are sensed by the detector.

The **detector** converts the ultrasonic waves into electrical signals which are appropriately interpreted. The distance of the object that reflects the sound wave can be calculated by knowing the speed of sound wave in water and the time interval between transmission and reception of the ultrasound.

This will give us the depth of the sea.

Let the time interval between transmission and reception of ultrasound signal be t and the speed of sound through sea-water be v.

The total distance $2d$ travelled by the ultrasound is, then

$$2d = v \times t$$

This method is called **echo-ranging**.

Ultrasonic sound waves are used in SONAR, because these waves have very high frequency and very short wavelength, due to which they can penetrate into sea-water to a large extent to locate the underwater objects or to determine the depth of the sea. These waves cannot be confused with engine noises or other sounds made by the ship as they cannot be heard by human beings.

Example 4. Using the SONAR, sound waves are emitted at the surface of water, which after being reflected from bottom of water, are detected. If the time interval from the emission to the detection of the sound waves is 4 s. Calculate the depth of the water. (Take, speed of sound in water is 1450 m/s)

Sol. Time taken by sound waves to travel from surface to bottom, $t = \frac{4}{2} = 2\text{ s}$

and speed of sound waves, $v = 1450\text{ m/s}$

$\therefore$ Depth of water $= vt = 1450 \times 2 = 2900\text{ m}$

Example 5. A submarine produces a ultrasonic waves of velocity 1500 m/s in water. The officer receives signal after 50s of emission of ultrasonic waves. Find the distance of object which is present in the bottom of sea.

Sol. Given, velocity of ultrasonic waves in water, $v = 1500$ m/s

Time taken $= 50\text{ s}$

Distance between object and submarine, $s = ?$

Using the formula, $d = v \times t$

Substituting the given values, we get

$$= 1500 \times 50 = 75000\text{ m}$$

As, ultrasonic wave travels twice the distance between object and submarine, so $d = 2s$

As, $2s = 75000$ m, $s = \frac{75000}{2} = 37500\text{ m} = 37.5\text{ km}$

CHECK POINT 01

1. Reflection of sound can also takes place at rough surface. Explain, why?
2. Calculate the minimum distance in air required between the source of sound and obstacle to hear echo. (Take, speed of sound in air = 350 ms^{-1}.) ***Ans.*** 17.5 m
3. How do bats use echo to detect prey?
4. How ultrasound is used to investigate the interval organs of human body?
5. Which type of apparatus is used to find the objects in the sea?

Characteristics of Sound

A sound has four characteristics such as **loudness, pitch, quality (or timbre)** and **intensity** by which two sound waves can be distinguished from one another.

1. Loudness

It is the measure of the sound energy reaching the ear per second. Greater the sound energy reaching our ear per second, louder the sound will appear to be.

If the sound waves have a small amplitude, then sound will be faint or soft but, if waves have a large amplitude, then the sound will be loud. Also, the amplitude of the sound waves depends upon the force with which an object is made to vibrate.

Sound Level in Decibel (dB)

The unit of loudness is phons and the level of sound is expressed in decibel (dB). Thus, the loudness of a sound in phons is equivalent the loudness in decibel of an equally loud pure sound of frequency 1 kHz. This means, 60 phons is as loud as a 60 dB.

The loudness of the sound wave is proportional

(i) directly to the square of its amplitude $(A)^2$.

(ii) inversely to the square of the distance from the source.

Factor Affecting the Loudness of Sound

Following are the factors affecting the loudness of the sound

(i) Larger is the surface area of the vibrating object, greater would be the amount of energy transferred. Hence, louder will be the sound heard.

(ii) More the density of the medium, louder will be the sound heard.

(iii) In the presence of resonating body near the vibrating object, a louder sound is heard.

2. Intensity

The amount of sound energy passing each second through unit area is known as the **intensity of sound**.

Subjective Nature of Loudness and the Objective Nature of Intensity

Loudness and intensity are not the same terms. **Loudness** is a measure of the response of the ear to the sound. Even when two sounds are of equal intensity, we may hear one as louder than the other, simply because our ear detects it in better way. The SI unit of intensity is **watt per square metre** (W/m^2).

The intensity of sound wave in air is proportional to

(i) the square of the amplitude of vibration $(A)^2$.

(ii) the square of the frequency of vibration $(\nu)^2$.

(iii) the density of air.

Hence, it can be said that for a sound wave loudness has a subjective as it depends on the listener, whereas intensity has an objective nature as it a measurable quantity.

3. Pitch (or Shrillness) and Frequency

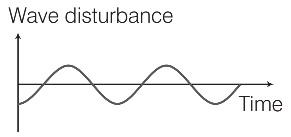
Pitch is that characteristic of sound by which we can distinguish between different sounds of the same loudness. Due to this characteristic, we can distinguish between a man's voice and woman's voice of the same loudness without seeing them.

Pitch of a sound depends on the frequency of vibration. Greater the frequency of a sound, the higher will be its pitch.

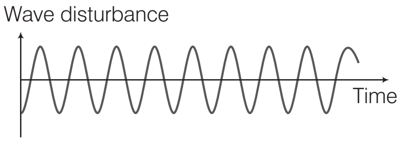
In other words, the faster the vibration of the source, the higher is the frequency and hence higher is the pitch.

Objects of different sizes and conditions vibrates at different frequencies to produce sounds of different pitches.

Figure given below shows wave shape for low and high pitched sound



Wave shape for a low pitched sound



Wave shape for a high pitched sound

Example 6. Two waves of the same pitch have their amplitude in the ratio 2 : 3.

(i) What will be the ratio of their loudness?

(ii) What will be the ratio of their frequencies?

Sol. (i) As, loudness $\propto$ (amplitude)^2

$\therefore$ Its ratio $\left(\frac{2}{3}\right)^2$ becomes $\frac{4}{9}$.

(ii) The ratio of frequencies is 1 : 1, as pitch depends upon the frequency.

4. Quality and Waveforms

The quality (or timbre) of sound is that characteristic of sound which enables us to distinguish one sound from another having the same pitch and loudness.

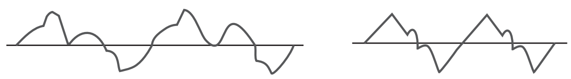
The pleasant sound is said to be of a rich quality. A sound of single frequency is called **a tone**.

The sound produced due to a mixture of several frequencies is called **a note** and is pleasant in listening too.

The sound produced by different musical instruments like flute, violin, sitar, tanpura, etc., and similarly, sound produced by different singers, can be distinguished from one another on the basis of their quality.

The quality of musical instrument depends on

(i) the shape of the sound wave produced as shown in figure.



(a) Shape of sound waves produced by a note played on flute

(b) Shape of sound waves when the same note is played on violin

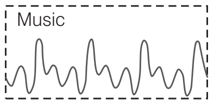
(ii) mixture of frequencies present.

5. Noise and Music

All types of sounds which produces sensation of hearing are of two types basically

(i) music (ii) noise

Differences between Musical Sound and Noise

Musical Sound	Noise
It is a sound which produces a pleasing effect on the listener.	It is a sound which produces an unpleasing effect on the listener.
It's waveform is periodic and regular with no abrupt change in amplitude.	It's waveform is irregular or haphazed with sudden change in its amplitude.
e.g., Any musical instrument.	e.g., Traffic on the road.
	

Noise Pollution

The disturbance caused in the environment due to undesirable loud and harsh sound of level above 120 dB from different sources such as loudspeaker, siren, moving vehicles, etc., is known as noise pollution. It causes headache and permanent damage to the ears of listener.

Free (or Natural), Forced and Damped Vibrations

Free Vibrations

If a body vibrates with its natural frequency without the help of any external periodic forces, then it is said to be natural (or free) vibrations.

The amplitude and frequency of a freely vibrating body remains constant with respect to time. In ideal condition, once a body starts vibrating, if continues its vibrations with the same amplitude and frequency forever.

Some examples of natural vibrations are given below

(i) If a tuning fork is struck against a hard rubber pad, then it vibrates with its natural frequency.
(ii) A free suspended pendulum vibrating about its mean position.
(iii) A metal blade clamped at one end is gently disturbed. The blade is then vibrates with its natural frequency about the mean position.
(iv) Strings of various musical instruments on being plucked vibrates about the mean position with its natural frequency.

Forced Vibrations

When a body vibrates under the influence of an external periodic force with a frequency equal to that of the external periodic force, then its vibrations are called forced vibrations.

Some examples of forced vibrations are given below

(i) The vibrations produced in the diaphragm of a microphones sound box with frequencies corresponding to the speech of the speaker are the forced vibrations.
(ii) While playing a guitar, the artist forces the strings of the guitar to execute forced vibrations.
(iii) Swing pushed at regular intervals.

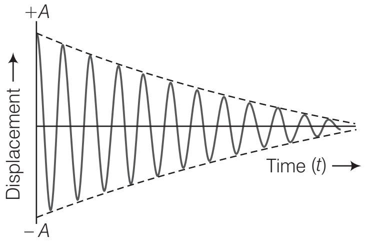
Differences between the Free and Forced Vibrations

Free Vibrations	Forced Vibrations
The vibrations of a body in the absence of any resistive forces are called free vibrations.	The vibrations of a body in the presence of external periodic forces are called forced vibrations.
The frequency of the vibrations depends on the shape and size of the body.	The frequency of the forced vibrations is equal to the frequency of the applied external force.
The frequency of vibrations is always a constant quantity.	The frequency of forced vibrations changes with the change in frequency of applied force.
The amplitude of vibrations does not change with respect to time.	The amplitude of forced vibrations is very small, if the frequency of applied force differs widely from the natural frequency of the body.

Damped Vibrations

The periodic vibrations of a body of decreasing amplitude in presence of some resistive force are called the damped vibrations.

The displacement-time graph for the damped vibrations is shown in the figure given below.



Displacement-time graph for damped vibrations

The amplitude/displacement decreases exponentially with time.

Some examples of a damped vibrations are given below

(i) Vibrations of a tuning in air.
(ii) Vibrations of stringed instrument in air.
(iii) Vibrations of a simple pendulum in air.

Differences between the Free and Damped Vibrations

Free Vibrations	Damped Vibrations
The amplitude of free vibrations is constant and theoretically the vibrations continues forever.	The amplitude of damped vibrations gradually decreases with respect to time and in the end, the vibrations ceases.
There is no loss of energy.	In each vibrations, there is some loss of energy.
The vibrations are only under the restoring force and hence no external force acts on the vibrating body.	The opposing force e.g., Friction, etc., acts in the direction opposite to the direction of vibrations.
The frequency of vibrations remains constant and is unaltered and is equal to the natural frequency.	The frequency of vibrations becomes less than the natural frequency.

Resonance

It is a special case of forced vibrations. When the frequency of an externally applied periodic force on a body is equal to its natural frequency, then the body readily begins to vibrate with an increased amplitude. This phenomenon is known as resonance. The vibrations of large amplitude are called the **resonant vibrations** e.g.,

(i) Sympathetic vibrations of pendulums.
(ii) Resonance in radio and TV receiver.
(iii) Resonance in bridge.
(iv) Frequency heard by tuning fork due to resonance with air.

Example 7. A vibrating tuning fork is placed over the mouth of a burette filled with water. The top of the burette is opened and the water level gradually starts falling. It is found that the sound from the tuning fork becomes very loud for a particular length of the water column. *[2013]*

(i) Name the phenomenon taking place when this happens.

(ii) Why does the sound become very loud for this length of the water column?

Sol. (i) In the above process, the phenomenon taking place is resonance.

(ii) The sound becomes very loud for this length of the water column, because the frequency of the air column becomes equal to the frequency of the tuning fork

i.e., $f_a = f_v$

where, f_v = frequency of tuning fork

and f_a = frequency of air column.

CHECK POINT 02

1. Is the loudness of sound depends on the amplitude of vibrations of the source? Explain, why?
2. Define decibel and on what factor does it depend?
3. If the amplitude of a wave is doubled, then what will be the effect on its loudness?
4. Low pitch sound has low frequency and high pitch of sound has high frequency. Explain, why?
5. What is range of sound above which noise pollution take place?
6. What is the difference between free vibration and damped vibration on the basis of amplitude?
7. How does the free vibration depend on the frequency?
8. Name one factor which affects the frequency of sound emitted due to vibrations in an air column.

SUMMARY

- Sound is produced by vibrating objects.
- The bouncing back of sound when it strikes a hard surface is known as reflection of sound.
- The repitition of sound caused by reflection of sound waves is called an echo.
- The minimum distance between the source of sound and the reflector should be atleast 17 m (so that the echo is heard distinctly after the original sound is over).
- Some animals like bats, dolphins, etc., locate their prey by hearing the echoes of their ultrasonic squeaks.
- In the medical field, echoes of the ultrasound is used to investigate the internal organs of human body such as liver, gall bladder, heart, etc.
- SONAR stands for sound navigation and ranging.
- SONAR is an apparatus used to find the depth of a sea or to locate the under water things like shoals of fish, shipwrecks, hills, ice bergs, sunken ships and enemy submarines, etc.
- SONAR consists of two parts (i) a transmitter and (ii) a receiver.
- The transmitter produces and transmits ultrasonic waves.
- The detector converts the ultrasonic waves into electrical signals.
- The measure of a sound energy reaching the ear per second is known as loudness.
- The loudness of a sound is measured in decibel (dB). It depends on the sensitivity or the response of our ears.
- The amount of sound energy passing each second through unit area is known as the intensity of sound.
- The SI unit of intensity is watt per square metre (W/m^2).
- Pitch is that characteristic of sound by which we can distinguish between the different sounds of the same loudness.
- The quality (or timbre) of sound is that characteristic of sound which enables us to distinguish one sound from another having the same pitch and loudness.
- Vibration means a kind of rapid to and fro motion of an object. When an object vibrates, it sets the particles of medium around it in vibration.
- If a body vibrates with its natural frequency without the help of any external periodic forces, then it is said to be natural (or free) vibrations.
- The amplitude and frequency of a freely vibrating body remains constant with respect to time.
- When a body vibrates under the influence of an external periodic force with a frequency equal to that of the external periodic force, then its vibrations are called forced vibrations.
- The periodic vibrations of a body of decreasing amplitude in presence of some resistive force are called the damped vibrations.
- When the frequency of an externally applied periodic force on a body is equal to its natural frequency, then the body readily begins to vibrate with an increased amplitude, this is known as resonance.

EXAM PRACTICE

a 2 Marks Questions

1. Explain why, echoes cannot be heard in a small room?

Sol. For hearing echo, there should be atleast a distance of 17 m between source of sound and body from which sound is reflected. Since, in small rooms, distance is usually less than 17 m, hence echoes cannot be heard. ***[2]***

2. A student went to a hill station early in the morning, he could hear the echo of his clap after 0.1 s.

When he went to the same place in the afternoon he could not hear the echo at all, then explain the reason for his changed observation.

Sol. There is a rise in temperature in the afternoon, so the speed of sound increases with increase in temperature. As speed increases, time taken by reflected sound will be less, may be less than 0.1 s in afternoon. That is why the student could not hear the echo at all in the afternoon. ***[2]***

3. State the conditions required to hear an echo.

Sol. *The conditions to hear an echo are*

(i) The time interval between source sound and reflected sound must be atleast 0.1 s. ***[1]***

(ii) The minimum distance between the obstacle and source of sound should be atleast 17.2 m. ***[1]***

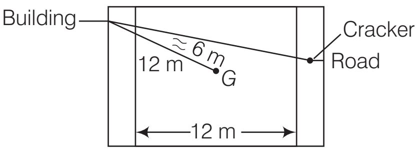
4. When can we distinctly hear the echo of a sharp sound? Why cannot we hear an echo in a small hall?

Sol. As we know that, to listen echo for a sound wave whose speed in air is 344 ms^{-1} and persistance of sound is 0.1 s, a minimum distance of 17.2 m between observer and reflecting surface is required. As the condition of minimum distance between the source and reflecting surface is not satisfied, so in a small hall we do not hear echoes. ***[2]***

5. A girl is sitting in the middle of a park of dimension $12 \text{ m} \times 12 \text{ m}$. On the left side of it there is a building adjoining the park and on right side of the park, there is a road adjoining the park.

A sound is produced on the road by a cracker. Is it possible for the girl to hear the echo of this sound? Explain your answer.

Sol. No, it is not possible for the girl to hear the echo of this sound, because the distance between girl and obstacle (building) is only 6 m approx but echo is heard only, if the minimum distance between the observer at the source of sound and the obstacle is 11.3 m.



[2]

6. Mention two practical uses of echo.

Sol. *Two practical uses of echo are*

(i) The method of echolocation, in which some animals like bats, tortoises and dolphins to locate the object by hearing the echoes of their ultrasonic squeaks. ***[1]***

(ii) In the medical field, echoes of the ultrasound is used to investigate the internal organs of human body such as liver, gall bladder, pancreas, kidneys, etc. ***[1]***

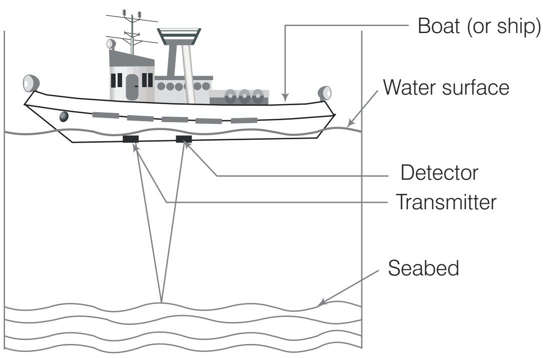
7. What is a SONAR? For what it is used?

Sol. Full form of SONAR is Sound Navigation And Ranging. It is used to measure depth of sea and ocean or to locate under water things i.e., shoals of fish shipwrecks and enemy submarines.

It uses ultrasonic waves to measure the distance, direction and speed of under water objects. ***[1+1]***

8. Can SONAR be used to determine the depth of a sea? Draw a well labelled diagram showing the procedure.

Sol. Yes, SONAR technique can be used to determine the depth of the sea. ***[1]***



[1]

9. Distinguish between loudness and intensity of sound.

Sol. Difference between loudness and intensity

Loudness	Intensity
It is a subjective quantity. A sound may be loud for one person but may be feeble for another person.	It is an objective physical quantity which does not change for person to person.
It cannot be measured as it is just a sensation which can be felt only.	It can be measured as a physical quantity.
Loudness of sound is measured in the unit of decibel (dB).	Intensity of sound is measured in the unit of watt per square metre (W/m^2).
It depends on the sensitivity of ears.	It does not depend on the sensitivity of ears.

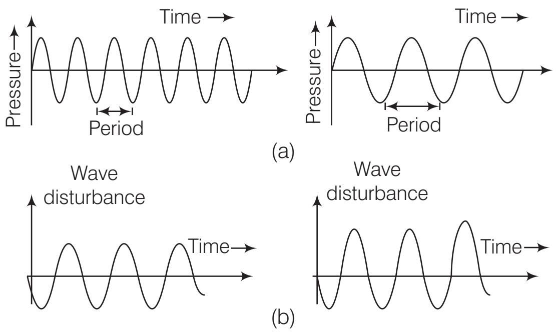
[2]

10. What is meant by intensity of sound? How is it different from loudness?

Sol. **Intensity of Sound** It is the amount of sound energy passing each second through unit area. ***[1]***

Loudness is a measure of the response of the ear to the sound. Even when two sounds are of equal intensity, we may hear one as louder than the other, as our ear detects it better. Therefore, loudness depends both on the intensity of sound and the response of the ear to that sound. ***[1]***

11. Compare the following in Figs. (a) and (b) and name them.



Sol. In the Fig. (a), there is a sound wave with same amplitude but different frequencies. First one high pitched, second graph low pitched. ***[1]***

In the Fig. (b), there is a soft sound wave and a loud sound wave of same frequencies, because number of waves are same in both graphs but has different amplitude. ***[1]***

12. Which wave property determines
(i) loudness (ii) pitch?

Sol. (i) Loudness of wave is determined by its amplitude. ***[1]***

(ii) Pitch of the wave is determined by its frequency. ***[1]***

13. Fig. (A) shows a trace of a sound wave which is produced by a particular tuning fork.

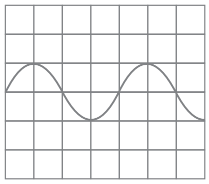
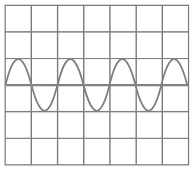
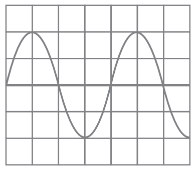


Fig. (A)

(i) Draw a trace of the sound wave which has a higher pitch than that shown in Fig. A.
(ii) Draw a trace of the sound wave which louder than that shown in Fig. A.

Sol. (i)  (ii) 

[3]

14. How does the change in frequency and amplitude affect a musical sound?

Sol. *For a musical sound*

(i) increase in frequency means increase in its pitch.
(ii) increase in its amplitude means increase in intensity or loudness. ***[2]***

15. The ratio of amplitude of two waves is 3 : 4. What is the ratio of their
(i) loudness (ii) frequencies?

Sol. (i) Ratio of loudness will be 9 : 16 as loudness depends upon intensity which is directly proportional to the square of amplitude. ***[1]***

(ii) Ratio of frequencies will be 1 : 1 as frequency remains same for the two waves. ***[1]***

16. (i) Why is the ratio of the velocities of light of wavelengths 4000 Å and 8000 Å in vacuum 1 : 1?
(ii) Which of the above wavelengths has a higher frequency? ***[2018]***

Sol. (i) The speed of light in vacuum is always constant (3×10^8 m / s) and it does not depends on wavelength or frequency. ***[1]***

(ii) As we know that, $v = n\lambda$

$$n = \frac{v}{\lambda} \Rightarrow n \propto \frac{1}{\lambda}$$

where, n = frequency,

v = velocity and λ = wavelength.

Therefore, frequency is inversely proportional to wavelength, therefore wavelength of 4000Å will have more frequency. ***[1]***

17. Name the subjective property of sound related to its frequency and of light related to its wavelength.

Sol. Property of sound related to frequency is pitch and property of light related to its wavelength is colour. **[2]**

18. What is meant by noise pollution? Name one source of sound causing noise pollution. **[2016]**

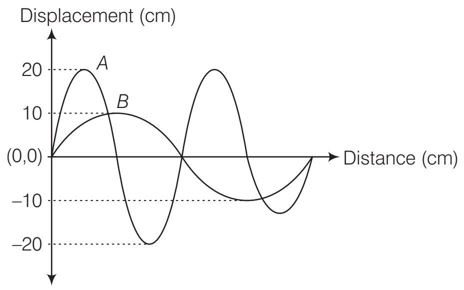
Sol. Noise pollution is the disturbance or unpleasant sound that may harm the activity or balance of human or animal life. **[1]**

The noise pollution is mainly caused by machines, transportation system, etc. **[1]**

19. Will the sound be audible, if the string is set into vibration on the surface of the moon? Give reason.

Sol. No, we will not hear any audible sound on the surface because sound needs a medium to propagate. Moon has no atmosphere, so sound will not be heard. **[2]**

20. Displacement-distance graph of two sound waves A and B, travelling in a medium are as shown in the diagram below.



Study the two sound waves and compare their

(i) Amplitudes (ii) Wavelengths **[2018]**

Sol. (i) Amplitude of sound wave, $A = 20$ cm

Amplitude of sound wave, $B = 10$ cm

$\therefore$ Amplitude of sound wave A is twice than that of sound wave B. **[1]**

(ii) From the graph, it can be seen that wavelength of sound wave A is half of the wavelength of sound wave B. **[1]**

21. How is the frequency of a stretched string related to

(i) its length (ii) its tension? **[2017]**

Sol. (i) Frequency of stretched string related with its length as

$$\nu \propto \frac{1}{\text{length}}$$ **[1]**

(ii) Frequency of stretched string is related to tension in string as $\nu \propto \text{tension}$

This means, frequency is inversely proportional to the length of the string and directly proportional to its tension. **[1]**

22. State two ways by which the frequency of transverse vibrations of a stretched string can be decreased. **[2016]**

Sol. The two ways by which the frequency of transverse vibrations of a stretched string can be decreased are

(i) by increasing the length (l), when tension (T) and mass (m) are kept constant. **[1]**

(ii) by decreasing the tension (T), when length (l) and mass (m) are kept constant. **[1]**

23. (i) What do you understand by the free vibrations of a body?

(ii) Why does the amplitude of a vibrating body continuously decrease during damped vibrations? **[2018]**

Sol. (i) Free vibration are the periodic vibrations of a body in the absence of any external force on it. **[1]**

(ii) A body continuously losses its energy due to the presence of frictional force by the surrounding medium in damped oscillations, therefore amplitude of body continuously decreases. **[1]**

24. (i) Three musical instrument give out notes at the frequencies listed below.

Flute 400 Hz, **Guitar** 200 Hz, **Trumpet** 500 Hz.

Which one of these has the highest pitch?

(ii) With which of the following frequencies does a tuning fork of 256 Hz resonate?

288 Hz, 341 Hz, 333 Hz, 512 Hz

Sol. (i) Trumpet having highest frequency of 500 Hz have highest pitch, because pitch is directly proportional to the frequency. **[1]**

(ii) The frequency 512 Hz will resonate a tuning fork of 256 Hz as 512 Hz is an integral multiple of the natural frequency of the tuning fork. **[1]**

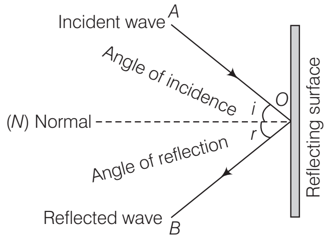
25. Explain, why stringed musical instruments like the guitar, are provided with a hollow box.

Sol. The musical instrument like guitar is provide with a hollow box, because vibrating strings of the instrument produce a very weak sound which cannot be heard. Hence, they are provided with a sound box. This box is a hollow chamber and is so constructed that the column of air inside it has a natural frequency which is same as that of the string stretched on it. Hence, due to resonance, helps in producing a loud sound. **[2]**

b 3 Marks Questions

26. Does sound follow the same laws of reflection as light does? Explain.

Sol. Yes, sound wave follows the same laws as in case of laws of reflection of light.



[1]

The laws of reflection of sound are as follows

(i) The incident sound wave (AO), the reflected sound wave (OB) and the normal (ON) at the point of incidence, all lie in the same plane. *[1]*

(ii) The angle of incidence ($\angle AON$) of sound is equal to the angle of reflection ($\angle NOB$) of sound. *[1]*

27. (i) What is an echo?

(ii) State two conditions for an echo to take place. *[2016]*

Sol. (i) Echo is the sound heard after it gets reflected from a rigid surface. *[1]*

(ii) *Two conditions for an echo to take place are given below*

(a) There should be a minimum distance of 17.2 m between the listener and the reflecting body. *[1]*

(b) Reflecting body should be as big as compared to the wavelength of sound. *[1]*

28. (i) What is meant by an echo? Mention one important condition i.e., necessary for an echo to be heard distinctly.

(ii) Mention one important use of echo. *[2008]*

Sol. (i) **Echo** The sound heard after reflection from a distant obstacle after the original sound is ceased is known as echo. To hear echo distinctly, the reflecting surface in air should be at a minimum distance of 17 m from the listener. *[2]*

(ii) In the medical field, echoes of the ultrasound is used to investigate the internal organs of human body such as liver, gall bladder, pancreas, kidneys, uterus, heart, etc. *[1]*

29. When a sound is reflected from a distant object, an echo is produced. Let the distance between the reflecting surface and the source of sound production remains the same. Do you hear echo sound on a hotter day?

Sol. The time taken by echo to be heard,

$$t = \frac{2d}{v}$$ *[1]*

where, d = distance between the reflecting surface and source of sound and v = speed of sound in air. *[1]*

As we know that speed of sound increases with increase in temperature, so on a hotter day, speed of sound will be higher, so the time after which echo is heard will decrease.

If time taken by the reflected sound is less than 0.1 s after the production of original sound, then echo is not heard. *[1]*

30. (i) Name the waves used for echo depth sounding.

(ii) Give one reason for their use for the above purpose.

(iii) Why are the waves mentioned by you not audible to us? *[2016]*

Sol. (i) Ultrasonic waves are used for echo depth sounding. *[1]*

(ii) These waves can be confined into a narrow beam and are not easily absorbed in the medium and can travel a long distance. *[1]*

(iii) The frequency of ultrasonic waves is above 20000 Hz which is beyond the audibility range of human. *[1]*

31. How is it that, bats are able to fly at night without colliding with other objects?

Sol. Bats search out prey and fly at night by emitting and detecting reflections of ultrasonic waves. *[1]*

They emit high frequency ultrasonic squeaks while flying and listen to the echoes produced by reflection of their squeaks from the obstacle, prey or object in their path. From the time taken by the echo to be heard, bats can determine the distance of the object and can avoid the object by changing the direction without colliding with it. *[2]*

32. Name the factor that determines

(i) loudness of the sound heard

(ii) quality of the note

(iii) pitch of the note *[2017]*

Sol. (i) Loudness-amplitude *[1]*

(ii) Quality (or timbre) nature of wave form *[1]*

(iii) Pitch of note-frequency *[1]*

33. (i) Name the characteristic of sound which enables a person to differentiate between two sounds with equal loudness but having different frequencies.

(ii) Define the characteristic named by you in (i).

(iii) Name the characteristic of sound which enables a person to differentiate between two sounds of the same loudness and frequency but produced by different instruments.

Sol. (i) Pitch or shrillness is that characteristic of sound which enables a person to differentiate between two sounds with equal loudness but having different frequencies. ***[1]***

(ii) Pitch is that characteristic of sound by which an acute (or shrill) note can be distinguished from a grave or flat note. ***[1]***

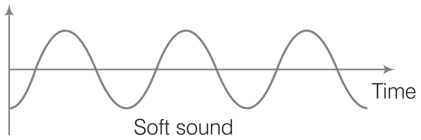
(iii) Quality is that characteristic of sound which enables a person to differentiate between two sounds of the same loudness and frequency but produced by different instruments. ***[1]***

34. What is meant by loudness of sound? State the factor on which it depends. Draw figures to illustrate

(i) soft sound and (ii) loud sound.

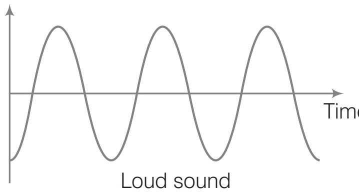
Sol. **Loudness** Refer to theory (Page 127). ***[1]***

(i) Wave disturbance



[1]

(ii) Wave disturbance



[1]

35. A nail was gently touched by the hammer and then was hit harder.

(i) When will be the sound created louder?

(ii) Which characteristic of sound here is responsible for change in sound?

(iii) Give the SI unit of loudness.

Sol. (i) Sound will be produced when we beat hammer hard on the nails. ***[1]***

(ii) Amplitude of vibrating body is responsible for change in sound. ***[1]***

(iii) The SI unit of loudness is decibel (dB). ***[1]***

36. (i) What are the factors on which the following characteristics of a musical note depend?

(a) Intensity

(b) Timbre

(ii) How does a trawlerman catch fish in deep water?

Sol. (i) *Factors on which the given characteristics of musical note depends are*

(a) Intensity depends upon

1. frequency 2. amplitude. ***[1]***

(b) Timbre depends upon

1. waveform of sound 2. frequency

3. resonance and sound pressure. ***[1]***

(ii) A trawlerman sends ultrasonic waves in deep water, which on striking the shoal of fish, return back to him. He notes the time t taken by the waves in going and coming back, then he calculates the depth of water d by using the relation

$$d = \frac{vt}{2}$$

where, v is the velocity of ultrasonic waves in water.

This helps them to catch the fishes easily. ***[1]***

37. Distinguish between the terms

(i) music and noise (ii) tone and note.

Sol. (i) **Music** The sound which is pleasant to the ears, is called music. It is produced by regular periodic vibrations. There is no sudden change in its amplitude.

e.g., Sound produced from a tabla. ***[1]***

Noise The sound which is unpleasant to the ears, is called noise. It is produced at an irregular intervals. There is sudden change in its amplitude.
e.g., Sound produced in a market and the sound produced by an explosion. ***[1]***

(ii) **Tone** The sound of single frequency is called a tone. ***[1/2]***

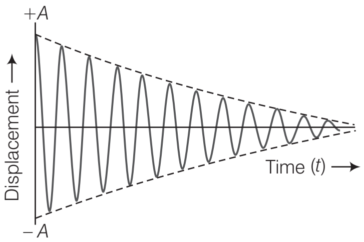
Note The sound which is a mixture of several frequencies is called a note. ***[1/2]***

38. (i) What are damped vibrations?

(ii) Give one example of damped vibration.

(iii) Name the phenomenon that causes a loud sound when the stem of a vibrating tuning fork is kept pressed on the surface of a table. ***[2017]***

Sol. (i) The periodic vibrations of body of decreasing amplitude in presence of resistive force are called the damped vibrations. The displacement-time graph for the damped vibrations shown in the diagram below.



The amplitude, displacement decreases exponentially with time ***[1]***

(ii) Simple pendulum's oscillation. ***[1]***

(iii) **Resonance** Refer to theory (Page 129). ***[1]***

39. (i) What is meant by resonance?

(ii) State two ways in which resonance differs from forced vibrations.

Sol. (i) The phenomenon in which body vibrates under the influence of periodic force, where frequency of the applied periodic force is equal to the natural frequency of the vibrating body. Then, the body begins to vibrate with increased amplitude. **[1]**

(ii) *The two ways in which resonance differs from forced vibrations are as*

Resonance	Forced Vibrations
This is the phenomenon of setting a body (*A*) into vibrations with the help of another body (*B*), where frequency of (*B*) is equal to the natural frequency of (*A*).	In this, a body (*A*) is set into vibrations under the influence of periodic force of body (*B*). Frequency of vibrations of body (*B*) is different from the natural frequency of the body (*A*).
Vibrations are of larger amplitude.	Vibrations are of smaller amplitude.

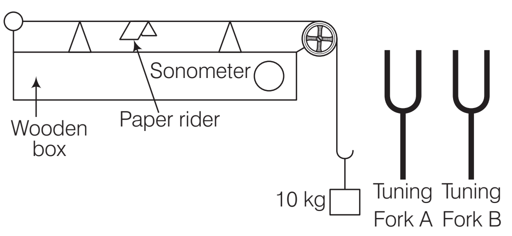
[1 × 2]

40. (i) Sound made in front of a tall building 18 m away, is repeated. Name the phenomenon and briefly explain it.

(ii) A tuning fork, held over an air column of a given length, produces a distinct audible sound. What do you call this phenomenon? How does it occur?

Sol. (i) As, we know the minimum distance between source and reflector is 17 m and here the distance is 18 m, so the phenomenon due to which sound is repeated is echo. Basically, the phenomenon of repetition of sound caused by reflection of sound waves is called an echo. **[1½]**

(ii) We call the phenomenon as resonance. This occurs when the frequency of forced vibrations produced by the tuning fork becomes equal to the natural frequency of the air column. **[1½]**

41. 

The diagram above shows a wire stretched over a sonometer. Stems of two vibrating tuning forks *A* and *B* are touched to the wooden box of the sonometer. It is observed that the paper rider (a small piece of paper folded at the centre) present on the wire flies off when the stem of vibrating tuning fork *B* is touched to the wooden box but the paper just vibrates when the stem of vibrating tuning fork *A* is touched to the wooden box.

(i) Name the phenomenon when the paper rider just vibrates.

(ii) Name the phenomenon when the paper rider flies off.

(iii) Why does the paper rider fly off when the stem of tuning fork *B* is touched to the box? **[2018]**

Sol. (i) Forced vibration **[1]**

(ii) Resonance **[1]**

(iii) The paper rider flies off because the natural frequency of vibration of wire matches the frequency of the tuning fork. This results in increase in magnitude of amplitude of vibrations. **[1]**

42. A rear view mirror of motorbike starts vibrating violently at some particular speed of motorbike.

(i) Why does this happen?

(ii) What is the name of the phenomenon taking place?

(iii) What could be done to stop the violent vibrations?

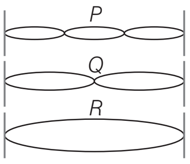
Sol. (i) This happens when the frequency with which piston of the engine is vibrating becomes equal to the natural frequency with which the body of the motorbike is vibrating. **[1]**

(ii) The phenomenon is resonance. **[1]**

(iii) The speed of the vehicle should be changed in order to control this types of violent vibrations. **[1]**

C 4 Marks Questions

43. The adjacent diagram shows three different modes of vibrations *P*, *Q* and *R* of the same string.



(i) Which vibrations will produce a louder sound and why?

(ii) The sound of which string will have maximum shrillness?

(iii) State the ratio of wavelengths of *P* and *R*. **[2014]**

Sol. (i) The mode of vibration *R* will produce a louder sound, because its amplitude is more than that of *P* and *Q*. **[1]**

(ii) The sound of *P* string will have maximum shrillness because its frequency is more than that of *R* and *Q*. **[1]**

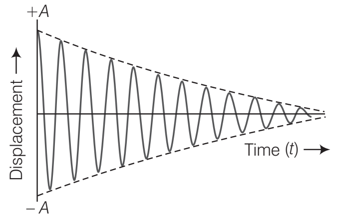
(iii) Frequency, $f_P = 3f$, frequency, $f_R = f$

As, $\lambda = \dfrac{v}{f}$ **[1]**

$\therefore$ The ratio of wavelengths of P and R is given by

$$\frac{\lambda_P}{\lambda_R} = \frac{v/f_P}{v/f_R} = \frac{f_R}{f_P} = \frac{f}{3f} = \frac{1}{3}$$ **[1]**

44. The diagram below shows the displacement-time graph for a vibrating body.



(i) Name the type of vibrations produced by the vibrating body.

(ii) Give one example of a body producing such vibrations.

(iii) Why is the amplitude of the wave gradually decreasing?

(iv) What will happen to the vibrations of the body after sometime?

Sol. (i) Damped vibrations are produced by the vibrating body. **[1]**

(ii) A simple pendulum oscillating in air, tuning fork vibrating in air are examples of a body producing such vibrations. **[1]**

(iii) The amplitude of the wave gradually decreasing, because of friction due to which energy is decreased continuously. **[1]**

(iv) As its amplitude decreases, so the vibrations of the body finally stops. **[1]**

45. (i) Give one example each of natural vibration, forced vibration and resonance.

(ii) Mention one practical use of echoes.

Sol. (i) **For Natural Vibration** A tuning fork struck against a hard rubber pad. **[1]**

For Forced Vibration Vibration produced in the board of a guitar when its string is made to vibrate. **[1]**

For Resonance While tuning a wireless receiver, we adjust its natural frequency equal to that of the incoming wireless carries waves, so that a loud sound of incoming signal is heard. **[1]**

(ii) In medical field, echoes of the ultrasound is used to investigate the internal organs of human body such as liver, gall bladder, uterus, etc. **[1]**

46. (i) Name the phenomenon involved in tuning a radio set to a particular station.

(ii) Define the phenomenon named by you in part (i) above.

(iii) What do you understand by loudness of sound?

(iv) In which units is the loudness of sound measured? **[2016]**

Sol. (i) Resonance is the phenomenon involved in tuning a radio set to a particular station. **[1]**

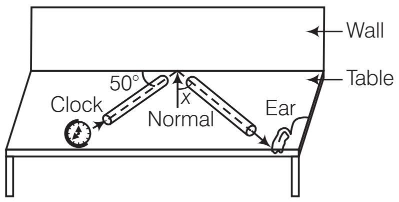
(ii) Resonance is the phenomenon in which vibration takes place under the influence of periodic force, where frequency of the applied force is equal to the natural frequency of the vibrating body. **[1]**

(iii) Loudness is the sensation produced in the ear which enables to distinguish between a loud and a faint sound. **[1]**

(vi) Loudness of sound is measured in units called decibels (dB). **[1]**

Numerical Based Questions

47. For hearing the loudest ticking sound heard by the ear, find the angle x in the given figure.



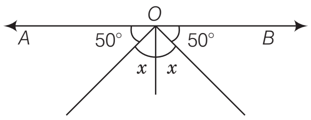
Firstly, we use the law of reflection i.e., angle of incidence = angle of reflection and use the property of linear pair axiom, then find the value of x.

Sol. We know that in laws of reflection, the angle of incidence (x) is always equal to the angle of reflection (x).

Since, AOB is a straight line.

$\therefore$ $\angle AOB = 180°$

$\therefore$ $50° + x + x + 50° = 180°$



($\because$ sum of all angles lies on the same side of a line is 180°)

$2x + 100° = 180°$

$\Rightarrow$ $2x = 180° - 100° \Rightarrow 2x = 80°$

$\Rightarrow$ $x = \dfrac{80°}{2} \Rightarrow x = 40°$

Hence, the value of x is 40°. **[3]**

48. An observer stands at a distance of 850 m from a cliff and fires a gun. After what time gap will he hear the echo, if sound travels at a speed of 350 ms^{-1} in air?

Sol. Given, distance between sound source and cliff, $d = 850$ m

Total distance travelled by the sound $= 2d$ **[1]**

Speed, $v = 350$ m/s

Time, $t = ?$

$$\therefore \quad v = \frac{2d}{t} \Rightarrow t = \frac{2d}{v} = \frac{2 \times 850}{350} = 4.86\text{s}$$ **[1]**

49. A ship on the surface of water sends a signal and receives it back after 4s from a submarine inside the water. Calculate the distance of the submarine from the ship. (Take, the speed of sound in water is 1450 ms^{-1}.)

Sol. Given, time, $t = 4$s, $v = 1450$ m/s

For an echo, total distance $= 2d$ **[1]**

$$\therefore \; 2d = v \times t \Rightarrow d = \frac{v \times t}{2} = \frac{1450 \times 4}{2} = 2900 \text{ m}$$ **[1]**

50. Aditi clapped her hands near a cliff and heard the echo after 4 s. What is the distance of the cliff from her, if the speed of sound is taken as 346 ms^{-1}?

Sol. Given, speed of sound, $v = 346\ ms^{-1}$

Time taken for hearing the echo, $t = 4$ s

$\therefore$ Distance travelled by the sound $= v \times t$

$$= 346 \times 4 = 1384 \text{ m}$$ **[1]**

In 4 s, sound has to travel twice the distance between the cliff and Aditi. Therefore, the distance between the cliff and Aditi is $\frac{1384}{2} = 692$ m. **[1]**

51. On a cloudy day, a thunder sound was heard 14s after the flash of lighting. How far was the cloud? (Take, the speed of sound is 340 ms^{-1})

Sol. Given, speed of sound, $v = 340\ ms^{-1}$

Time taken by thunder to be heard, $t = \frac{2d}{v} = 14$ s

$$2d = v \times t = 340 \times 14 = 4760 \text{ m}$$

$$\therefore \quad d = \frac{4760}{2} = 2380 \text{ m}$$

Therefore, the distance of the cloud is 2380m. **[2]**

52. An ultrasonic wave is sent from a ship towards the bottom of the sea. It is found that the time interval between the sending and the receiving of the wave is 1.5 s. Calculate the depth of the sea, if the velocity of sound in sea water is 1400 ms^{-1}.

Sol. Given, time interval, $t = 1.5$ s

Distance travelled by the ultrasonic waves during $d = 1.5$ s, velocity, $v = 1400$ m/s

$$\therefore \quad 2d = v \times t$$

$$= 1400 \times 1.5 = 2100 \text{ m}$$ **[1]**

As the depth of the sea will be given by

$$= \frac{d}{2} = \frac{2100}{2} = 1050 \text{ m}$$ **[1]**

53. A boy stands 60 m in front of a fall wall and claps. The body continues to clap every time an echo is heard. Another boy finds that the time taken between the first and forty-first clap is 16 s. Calculate the speed of sound.

Sol. Distance of boy from the wall, $d = 60$ m

Total distance travelled by the sound

$$= 2d = 2 \times 60 = 120 \text{ m}$$

Time interval between first and forty-first clap = 16 s

$\therefore$ Time interval between two successive claps $= \frac{16}{40}$ s.

$\therefore$ Speed of sound, $v = \frac{2d}{t} = \frac{120}{(16/40)} = 300$ m/s **[2]**

54. A man standing 25 m away from a wall produces a sound and receives the reflected sound.

(i) Calculate the time after which he receives the reflected sound, if the speed of sound in air is 350 ms^{-1}.

(ii) Will the man be able to hear a distinct echo? Give a reason for your answer. **[2011]**

Sol. Given, distance between man and wall, $d = 25$ m

(i) Velocity of sound, $v = 350$ m/s, $t = ?$

$$\therefore \quad v = \frac{2d}{t}$$

$$\Rightarrow \quad t = \frac{2d}{v} = \frac{2 \times 25}{350} = 0.14 \text{ s}$$ **[1]**

(ii) Yes, the man will be able to hear a distinct echo, because the least time for distinct echo to be heard is 0.1 s as

$$0.14 \text{ s} > 0.1 \text{ s}$$

As the distance travelled by the sound wave is twice the distance between man and wall, so take distance as $2d$. **[1]**

55. The human ear can detect continuous sounds in the frequency range from 20 Hz to 20000 Hz. Assuming that the speed of sound in air is 330 ms^{-1} for all frequencies, calculate the wavelengths corresponding to the given extreme frequencies of the audible range. **[2017]**

Sol. Applying the formula, $v = \lambda \times \nu$

where, v = speed of sound $= 330\ \text{ms}^{-1}$

ν = frequency and λ = wavelength of sound.

We have range of frequencies from 20 Hz-20000 Hz.

Hence, for frequency $\nu = 20$ Hz, we have

$$330 = \lambda \times 20 \quad \Rightarrow \lambda = \frac{330}{20} = 16.5\ \text{m}$$ **[1]**

For frequency $\nu = 20000$ Hz, we have

$$330 = \lambda \times 20000 \Rightarrow \lambda = \frac{330}{20000} = 16.5 \times 10^{-3}\ \text{m}$$ **[1]**

56. A sound made on the surface of a lake takes 3 s to reach a boatman. How much time will it take to reach a diver inside the water at the same depth? (Take, velocity of sound in air = 300 ms^{-1} and velocity of sound in water = 1440 ms^{-1})

Sol. First calculate the distance between boatman and source, then by using this, calculate the time taken to reach the sound to the diver. **[1]**

Given, time of sound to reach at boatman, $t = 3$ s

Velocity of sound in air, $v_a = 300$ m/s

Velocity of sound in water, $v_w = 1440$ m/s

Time taken by diver, $t_d = ?$

Depth of lake, $d_l = v_a \times t$ (as given in question)

$= 300 \times 3 = 900$ m

Time taken by sound in water to reach a diver,

$$t_w = \frac{d_l}{v_w} = \frac{900}{1440} = 0.625\,\text{s}$$ **[1]**

57. A man standing between two cliffs produces a sound and hears two successive echoes at intervals of 3 s and 4 s, respectively. Calculate the distance between the two cliffs. The speed of sound in the air is 330 ms^{-1}. *[2012]*

Sol. Calculate the distance between first and second cliff, then by adding both, get the total distance between the cliffs.

Given, time taken from nearer cliff, $t_1 = 3$ s

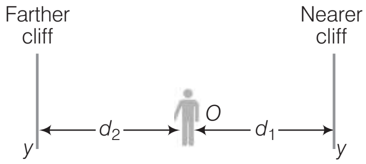
Time taken from farther cliff, $t_2 = 4$ s

Speed of sound in air, $v_a = 330$ m/s **[1]**

Total distance, $d = ?$

Distance of man from nearer cliff,

$$d_1 = \frac{v_a \times t_1}{2} = \frac{330 \times 3}{2} = 495\ \text{m}$$ **[1]**



Distance of man from farther cliff,

$$d_2 = \frac{v_a \times t_2}{2} = \frac{330 \times 4}{2} = 660\ \text{m}$$

Total distance between two cliffs,

$$d = d_1 + d_2 = 495 + 660 = 1155\ \text{m}$$ **[1]**

58. (i) A man stands at a distance of 68 m from a cliff and fires a gun. After what time interval will he hear the echo, if the speed of sound in air is 340 ms^{-1}?

(ii) If the man had been standing at a distance of 12 m from the cliff, then would he have heard a clear echo? *[2010]*

Sol. (i) Given, distance between man and cliff, $d = 68$ m

Total distance travelled by the sound $= 2d$

Velocity of sound, $v = 340$ m/s and time, $t = ?$

$$\therefore \quad t = \frac{2d}{v} = \frac{2 \times 68}{340} = 0.4\,\text{s}$$ **[1½]**

(ii) No, he has not heard a clear echo, because to hear a clear echo distinctly, the reflecting surface in air should be at a minimum distance of 17 m from the listener. **[1½]**

59. A boy standing in front of a wall at a distance of 85 m produces 2 claps per second. He notices that the sound of his clapping coincides with the echo. The echo is heard only once when clapping is stopped. Calculate the speed of sound.

Sol. Let d be the distance of wall from the boy.

Given, $d = 85$ m

To hear the echo, sound has to travel a total distance

$= 2d = 2 \times 85 = 170$ m **[1]**

Since, 2 claps are produced in one second, therefore each clap is produced after $\frac{1}{2}$ s which is equal to the time taken for the echo to be heard **[1]**

i.e., $t = \frac{1}{2}\ \text{s} = 0.5$ s

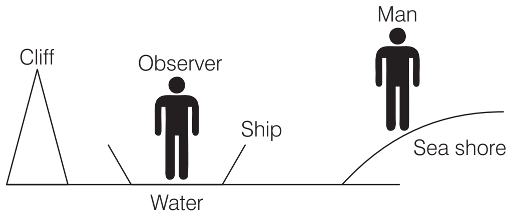
Now, the speed of sound, $v = \dfrac{\text{total distance travelled}}{\text{time taken}}$

$$= \frac{170\ \text{m}}{0.5\,\text{s}} = 340\ \text{ms}^{-1}$$ **[1]**

60. A person is standing at the sea shore. An observer on the ship which is anchored in between a vertical cliff and the person on the shore fires a gun. The person on the shore hears two sounds, 2 seconds and 3 seconds after seeing the smoke of the fired gun. If the speed of sound in the air is 320 ms^{-1}, then calculate

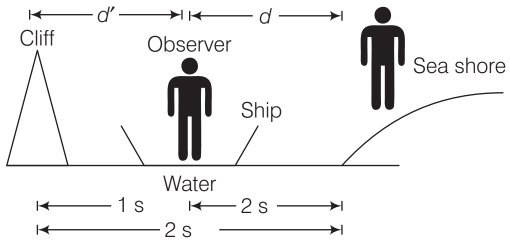
(i) the distance between the observer on the ship and the person on the shore.

(ii) the distance between the cliff and the observer on the ship.



[2018]

Sol.



(i) Observer hears direct sound in 2s.

As, velocity $= \dfrac{\text{distance}}{\text{time}}$

$$320 = \frac{d}{2} \Rightarrow d = 320 \times 2 = 640 \text{ m}$$

∴ Distance between person and observer $= 640$ m. **[2]**

(ii) Observer hears reflected sound in 3s. This means sound goes to cliff and reflect back in remaining one second.

i.e. $\quad t = 1\text{ s} \Rightarrow v = \dfrac{2d'}{t} \Rightarrow 320 = \dfrac{2d'}{1}$

$\Rightarrow \dfrac{320}{2} = d' \Rightarrow d' = 160$ m **[2]**

61. (i) The ratio of the amplitudes of two waves is 9 : 16. What is the ratio of their intensities?

(ii) A pendulum has a frequency of 4 vibrations per second. An observer starts the pendulum and fires a gun simultaneously. He hears the echo from a cliff after 8 vibrations of the pendulum. If the velocity of sound in air is 340 ms^{-1}, then what is the distance between the cliff and the observer?

Sol. As intensity is directly proportional to the square of amplitude, so putting the value of amplitude you get the ratio of intensities.

(i) Ratio of amplitudes of two waves $\dfrac{A_1}{A_2} = \dfrac{9}{16}$

As, intensity $(I) \propto$ amplitude $(A)^2$.

So, ratio of intensities, $\dfrac{I_1}{I_2} = \dfrac{A_1^{\,2}}{A_2^{\,2}} = \dfrac{81}{256}$ **[1]**

(ii) Given, $f = 4 \dfrac{\text{vibration}}{\text{second}} = 4$ Hz

Velocity of sound = 340 m/s

Distance between observer and cliff, d = ?

4 vibrations take 1 s.

∴ 8 vibrations will require $= \dfrac{1}{4} \times 8 = 2$ s **[1]**

Now, $\quad d = \dfrac{v \times t}{2} = \dfrac{340 \times 2}{2} = 340$ m

(∵ sound waves have to travel twice the distance between the observer and cliff) **[1]**

62. (i) A wire of length 80 cm has a frequency of 256 Hz. Calculate the length of a similar wire under similar tension, which will have frequency of 1024 Hz.

(ii) A certain sound has a frequency of 256 Hz and a wavelength of 1.3 m.

(a) Calculate the speed with which this sound travels.

(b) What difference would be felt by a listener between the above sound and another sound travelling at the same speed, but of wavelength 2.6 m? **[2017]**

Sol. (i) As, the frequency (ν) of wire is inversely proportional to its length (l)

i.e., $\qquad \nu \propto \dfrac{1}{l}$

So, for the same tension, we have

$$\nu_1 l_1 = \nu_2 l_2$$

Given, $\nu_1 = 256$ Hz, $\nu_2 = 1024$ Hz

and $\quad l_1 = 80 \text{ cm} \Rightarrow \dfrac{256 \times 80}{1024} = l_2 \Rightarrow l_2 = 20$ cm **[2]**

(ii) Given, $\nu = 256$ Hz, $\lambda = 1.3$ m

(a) Using the formula,

$$v = \nu\lambda = 256 \times 1.3 = 332.8 \text{ m/s} \approx 333 \text{ m/s}$$

(b) Now, new wavelength = 2.6 m

$$v = \nu \times \lambda \Rightarrow 333 = \nu \times 2.6$$

$$\Rightarrow \quad \nu = \frac{333}{2.6} = 128.07 \text{ Hz}$$

Frequency of above sound is 256 Hz, whereas frequency of this calculated sound is 12.8 Hz, because speed of sound is same. **[2]**

CHAPTER EXERCISE

2 Marks Questions

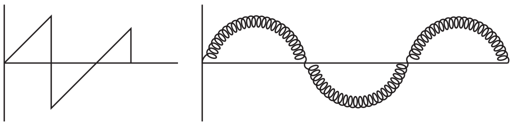
1. Draw waves of different pitch (low and high).
2. Write two characteristics of noise.
3. Write two uses of SONAR technique.
4. Write a short note on noise pollution.

3 Marks Questions

5. State three characteristics of a musical sound.
6. (i) On what factors does the natural frequency of a body depend?
   (ii) State condition for a body to execute free vibrations.
7. (i) Explain natural and forced vibrations with example.
   (ii) Explain how do the phenomena of resonance play an important role in machine parts?

4 Marks Questions

8. (i) Two friends were playing on their identical guitars whose string were adjusted to give notes of the same pitch. Will the quality of the two notes be the same? Give a reason for your answer.
   (ii) Give the relation among wavelength, time period and wave velocity of a wave motion.
9. (i) Sometimes when a vehicle is driven at a particular speed, a rattling sound is heard. Explain briefly, why this happens and give the name of the phenomenon taking place?
   (ii) Suggest one way be which the rattling sound could be stopped.
10. Two musical notes of same pitch and loudness are played on a violin and a piano. The waveforms are as shown in figures below.



Violin Piano

Explain, why the wave patterns are different?

Numerical Based Questions

11. A child hears an echo from a cliff, 4s after the sound from a powerful cracker is produced. How far away is the cliff from the child? (Take, velocity of the sound in air is 330 m/s) ***Ans.*** 660 m
12. A radar is able to detect the reflected waves from an enemy aeroplane, after a time interval of 0.02 ms. If the velocity of the waves is 3×10^8 ms^{-1}, then calculate the distance of the plane from the radar. ***Ans.*** 3 km
13. A student standing at one end of a closed corridor 86 m long blows a short blast on a whistle and notes a series of echoes. If the time from the blast to the fifth echo is 2.5 s, then calculate the speed of sound. ***Ans.*** 344 m/s
14. Two waves of the same pitch have their amplitudes in the ratio 3 : 4.
    (i) What will be the ratio of their loudness?
    (ii) What will be the ratio of their intensities?
    (iii) What will be the ratio of their frequencies?
    Ans. (i) 9 : 16, (ii) 9 : 16, (iii) 1 : 1
15. A boy has wooden blocks in his both hands. He claps block together with a regular gap between the claps, so that each clap coincides with the echo of the last clap returning from the wall.
    Distance between person and wall is 100m. Time noted for 50 claps is 29s. Calculate the speed of sound. ***Ans.*** 344.82 ms^{-1}
16. A pendulum has a frequency of 5 vibrations per second. An observer starts the pandulum and fires a gun simultaneously. He hears the echo from a cliff after 8 vibrations of the pendulum. If the velocity of sound in air is 340s^{-1}, then what is the distance between the cliff and the observer? ***Ans.*** 272 m
17. Two men 1.02 km apart stand at the same distance from a vertical hillock. One of them fires a shot and other hears the echo 2s after hearing the direct sound. Find the distance of the man from the hillock assuming the velocity of sound to be 340 m/s. ***Ans.*** 850 m

ARCHIVES* *(Last 6 Years)*

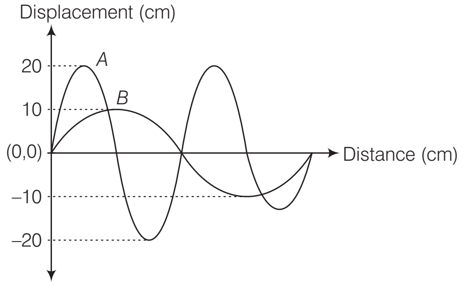
Collection of Questions Asked in Last 6 Years' (2018-2013) ICSE Class 10th Examinations

2018

1. (i) Why is the ratio of the velocities of light of wavelengths 4000 Å and 8000 Å in vacuum 1 : 1?

(ii) Which of the above wavelengths has a higher frequency? ***[2]***

2. Displacement-distance graph of two sound waves *A* and *B*, travelling in a medium are as shown in the diagram below.



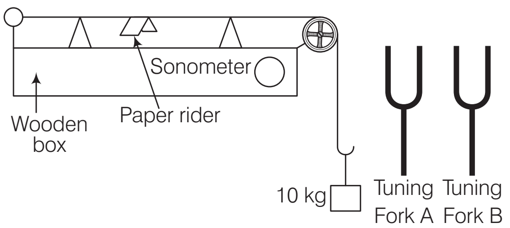
Study the two sound waves and compare their

(i) Amplitudes (ii) Wavelengths ***[2]***

3. (i) What do you understand by the free vibrations of a body?

(ii) Why does the amplitude of a vibrating body continuously decrease during damped vibrations? ***[2]***

4.



The diagram above shows a wire stretched over a sonometer. Stems of two vibrating tuning forks *A* and *B* are touched to the wooden box of the sonometer. It is observed that the paper rider (a small piece of paper folded at the centre) present on the wire flies off when the stem of vibrating tuning fork *B* is touched to the wooden box but the paper just vibrates when the stem of vibrating tuning fork *A* is touched to the wooden box.

(i) Name the phenomenon when the paper rider just vibrates.

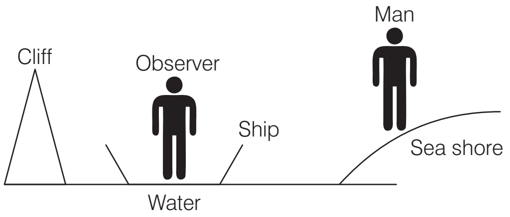
(ii) Name the phenomenon when the paper rider flies off.

(iii) Why does the paper rider fly off when the stem of tuning fork *B* is touched to the box? ***[3]***

5. A person is standing at the sea shore. An observer on the ship which is anchored in between a vertical cliff and the person on the shore fires a gun. The person on the shore hears two sounds, 2 seconds and 3 seconds after seeing the smoke of the fired gun. If the speed of sound in the air is 320 ms^{-1}, then calculate

(i) the distance between the observer on the ship and the person on the shore.

(ii) the distance between the cliff and the observer on the ship.



[4]

2017

6. Name the factor that determines

(i) loudness of the sound heard.

(ii) quality of the note.

(iii) pitch of the note. ***[3]***

7. How is the frequency of a stretched string related to

(i) its length

(ii) its tension? ***[2]***

8. (i) A wire of length 80 cm has a frequency of 256 Hz. Calculate the length of a similar wire under similar tension, which will have frequency of 1023 Hz. ***[2]***

(ii) A certain sound has a frequency of 256 Hz and a wavelength of 1.3 m.

(a) Calculate the speed with which this sound travels. ***[1]***

(b) What difference would be felt by a listener between the above sound and another sound travelling at the same speed, but of wavelength 2.6 m?

9. (i) What are damped vibrations?

(ii) Give one example of damped vibration.

(iii) Name the phenomenon that causes a loud sound when the stem of a vibrating tuning fork is kept pressed on the surface of a table. ***[3]***

10. The human ear can detect continuous sounds in the frequency range from 20 Hz to 20000 Hz. Assuming that the speed of sound in air is 330 ms^{-1} for all frequencies of the audible range. Calculate the wavelengths corresponding to the given extreme frequencies of the audible range. ***[2]***

2016

11. The ratio of amplitude of two waves is 3 : 4. What is the ratio of their

(i) loudness (ii) frequencies? *[3]*

12. (i) Name the waves used for echo depth sounding.

(ii) Give one reason for their use for the above purpose.

(iii) Why are the waves mentioned by you not audible to us? *[3]*

13. (i) What is an echo?

(ii) State two conditions for an echo to take place. *[3]*

14. State two ways by which the frequency of transverse vibrations of a stretched string can be increased. *[2]*

15. What is meant by noise pollution? Name one source of sound causing noise pollution. *[2]*

16. (i) Name the phenomenon involved in tuning a radio set to a particular station. *[1]*

(ii) Define the phenomenon named by you in part (i) above. *[1]*

(iii) What do you understand by loudness of sound? *[1]*

(iv) In which units is the loudness of sound measured? *[1]*

2015

17. (i) Draw a graph between displacement and the time for a body executing free vibrations. *[1]*

(ii) Where can a body execute free vibrations? *[1]*

18. (i) (a) State the safe limit of sound level in terms of decibel for human hearing. *[1]*

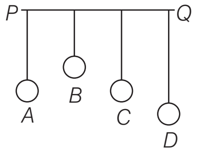
(b) Name the characteristic of sound in relation to its waveform. *[1]*

(ii) A person standing between two vertical cliffs and 480 m from the nearest cliff shouts. He hears the first echo after 3s and the second echo 2s later. Calculate

(a) the speed of sound *[1]*

(b) the distance of the other cliff from the person. *[1]*

19. In the diagram, A, B, C, D are four pendulums suspended from the same elastic string PQ. The length of A and C are equal to each other while the length of pendulum B is smaller than that of D. Pendulum A is set into a mode of vibrations.



(i) Name the type of vibrations taking place in pendulums B and D. *[1]*

(ii) What is the state of pendulum C? *[1]*

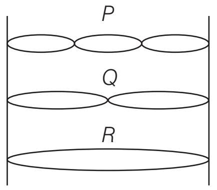
(iii) State the reason for the type of vibrations in pendulums B and C. *[1]*

2014

20. (i) What are mechanical waves? *[1]*

(ii) Name one property of waves that do not change when the wave passes from one medium to another. *[1]*

21. The adjacent diagram shows three different modes of vibrations P, Q and R of the same string.



(i) Which vibrations will produce a louder sound and why? *[1]*

(ii) The sound of which string will have maximum shrillness? *[1]*

(iii) State the ratio of wavelengths of P and R. *[1]*

2013

22. A bucket kept under a running tap is getting filled with water. A person sitting at a distance is able to get an idea when the bucket is about to be filled.

(i) What change takes place in the sound to give this idea? *[1]*

(ii) What causes the change in the sound? *[1]*

23. A sound made on the surface of a lake takes 3s to reach a boatman. How much time will it take to reach a diver inside the water at the same depth?

(Take, velocity of sound in air = $300\,ms^{-1}$ and velocity of sound in water = $1440\,ms^{-1}$) *[2]*

24. (i) What is the principle on which SONAR is based? *[1]*

(ii) An observer stands at a certain distance away from a cliff and produces a loud sound. He hears an echo of the sound after 1.8 s. Calculate the distance between the cliff and the observer, if the velocity of sound in air is $340\,ms^{-1}$. *[2]*

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 Which of the following does not produce a sound wave?
(a) A bell ringing under water
(b) A gun fired in a room with no echoes
(c) A hammer hitting a block of rubber
(d) An explosion in outer space

2 The frequency of a source is 20 kHz. The frequency of sound wave produced by it in water and air will be
(a) same as that of source (b) > 20 kHz
(c) < 20 kHz (d) depend upon velocity

3 During night, distant sounds such as that of the traffic and the loudspeakers become louder than during day. This is due to
(a) reflection of sound waves
(b) refraction of sound waves
(c) absence of other sounds
(d) clear perception of hearing

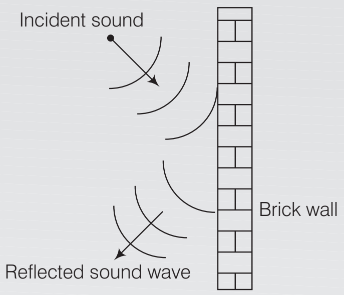
4 The sound level at a point is increased by 30 dB. By what factor is the pressure amplitude increased?
(a) 16 times (b) 10 times (c) 8 times (d) 32 times

5 The frequency of a note with high pitch is greater than the frequency of a note with low pitch. Which statement about the note with the high pitch is not correct?
I. It has larger wavelength.
II. It has smaller wavelength.
III. It has greater speed in air.
IV. It has lower speed in air.
(a) Both I and II (b) Both III and IV
(c) I, II and IV (d) I, III and IV

6 Given below is a diagram showing a set of percussion instruments (i.e., producing sound on being struck).

Which of the following statements is not true about the percussion instrument?
(a) The surface of the instrument vibrates when struck, thus producing sound.
(b) Louder sound can be produced, if hit with greater force.
(c) When the vibrating surface is touched, then sound will stop.
(d) These instruments can produce only loud sounds.

7 A sound wave is reflected from a brick wall. Compared with the incident wave, the reflected wave has



(a) a greater amplitude (b) a shorter wavelength
(c) the same speed (d) the same velocity

8 Sound waves of wavelength λ travelling in a medium with a speed of v m/s enter another medium, where its speed is $2v$ m/s. What will be the wavelength sound waves in the second medium?
(a) λ (b) 4λ (c) 2λ (d) 3λ

9 State 'T' for true or 'F' for false.
I. Wave creates disturbance and transmits matter from one place to another.
II. Progressive waves are waves originating from a source such that they never return to the source.
III. In a longitudinal wave, the density of particles is more at a compression.
IV. During a tsunami, the shock waves originating in the ocean bed propagates as both transverse and longitudinal wave.
V. The ripples in water waves are created by the oscillatory movement of water particles.

Codes

	I	II	III	IV	V
(a)	F	F	F	T	T
(b)	F	T	T	F	T
(c)	T	F	T	F	T
(d)	F	T	F	T	F

10 The pressure amplitude in sound wave from a radio receiver is 2.0×10^{-2} N/m^2 and the intensity at a point is 5.0×10^{-7} N/m^2. If by turning the volume knob, then the pressure amplitude increased to 2.5×10^{-2} N/m^2. Evaluate the intensity.
(a) 7.8×10^{-6} W/m^2 (b) 7.8×10^{-7} W/m^2
(c) 7.8×10^{-8} W/m^2 (d) 7.8 W/m^2

Answers

1. (d) **2.** (a) **3.** (b) **4.** (d) **5.** (d) **6.** (d) **7.** (c) **8.** (c) **9.** (b) **10.** (b)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 243.

CHAPTER

8

Electricity

Chapter Objectives

- Electric Charge and Electric Current
- Electric Potential and Potential Difference
- Ohm's Law
- Resistance
- Specific Resistance (Resistivity)
- Electromotive Force (emf) of a Cell (e)
- Combination of Resistors
- Electrical Energy
- Heating Effect of Electric Current
- Electric Power
- House Wiring (Ring System)
- Power Distribution

Electricity is an essential part of life in today's world. It is a controllable and convenient form of energy. It is being used in almost every sector of modern society like households, commercial, transport and industry, etc., to make life faster and easier.

Electric Charge and Electric Current

Electric Charge

It is a physical entity which is defined by excess or deficiency of electrons on a body. A body is said to be **negatively charged**, if it **gains** electrons. e.g., An ebonite rod rubbed with fur acquires negative charge.A body is said to be **positively charged**, if it **loses** electrons.e.g., A glass rod rubbed with a silk cloth acquires positive charge.

The SI unit of electric charge is **coulomb** (C).

The total charge acquired by a body is an integral multiple of magnitude of charge on a single electron. This principle is called **quantisation of charge.**

The possible value of charge on a body can be $\pm ne$.

where, n = number of electrons lost or gained by the body

and e = charge on one electron (1.6×10^{-19} coulomb).

Electric Current

It is defined as the rate of flow of electric charge through any cross-section of a conductor in unit time.

If q amount of charges flows through a conductor in t time, then

$$\boxed{\text{Electric current, } I = \frac{\text{Charge }(q)}{\text{Time }(t)} = \frac{ne}{t}} \qquad (\because q = ne)$$

where, n = number of electrons flowing through the conductor.

The SI unit of electric current is **ampere** (A). It is a scalar quantity. When 1 coulomb of charge flows through any cross-section of a conductor in 1 second, then the electric current flowing through it is said to be 1 ampere.

i.e., $$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}} \Rightarrow 1\text{ A} = \frac{1\text{C}}{1\text{s}}$$

Smaller units of current are **milliampere** ($1 \text{ mA} = 10^{-3}$ A) and **microampere** ($1\ \mu\text{A} = 10^{-6}$ A).

Note Charge is 1 coulomb if 6.25×10^{18} electrons move or 1 ampere current flows in 1 second.

Direction of Electric Current

The direction of electric current is taken as opposite to the direction of the flow of electrons (negative charges). In an electric circuit, the current flows from positive terminal of the cell to the negative terminal.

Example 1. **A current of 150 mA flows through a circuit for 2 min. Find the amount of charge that flows through the circuit.**

Sol. Given, current, $I = 150\,\text{mA} = 150 \times 10^{-3}$ A

Time, $t = 2$ min $= 2 \times 60 = 120$ s

Amount of charge, $q = ?$

We know that, $q = I \times t$

$\Rightarrow \quad q = 150 \times 10^{-3} \times 120$

$\Rightarrow \quad q = 18$ C

So, 18 C of charge flows around the circuit.

Example 2. **A total of 6×10^{46} electrons flow through a current carrying conductor when connected through an external power supply for 20 s. Find the value of current in the conductor.**

Sol. Given, total number of electrons, $n = 6 \times 10^{46}$ electrons, time, $t = 20$ s, current, $I = ?$

We know that, $q = ne$ ...(i)

(from the principle of quantisation of electric charge)

and $I = \frac{q}{t}$ ...(ii)

From Eqs. (i) and (ii), we get

$$I = \frac{ne}{t} = \frac{6 \times 10^{46} \times 1.6 \times 10^{-19}}{20} \quad (\because e = 1.6 \times 10^{-19}\,\text{C})$$

$$= 0.48 \times 10^{27}\,\text{A}$$

$$= 4.8 \times 10^{26}\,\text{A}$$

Thus, the current through the conductor is 4.8×10^{26} A.

Electric Potential and Potential Difference

Electric Potential

Electric potential at a point in region of some charge or charges is defined as the amount of work done when a unit positive charge is moved from infinity to that a point.

If work done in moving a positive charge q from infinity to the point is W, then electric potential V of that point is

$$\boxed{V = \frac{W}{q}}$$

The SI unit of electric potential is volt (V).
It is a scalar quantity.

Electric Potential Difference (ΔV)

It is defined as work done in moving a unit positive charge from one point to another in region of charges.

Let W be the work done in moving a charge q from point B to point A, then the potential difference $(V_B - V_A)$ between these two points is given by

$$\Delta V = V_B - V_A = \frac{W}{q}$$

The electric potential difference between two points is said to be 1 volt, if 1 joule of work is done in moving 1 coulomb of electric charge from one point to other point.

Thus, $$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

$$\Rightarrow \quad 1\text{ V} = \frac{1\text{ J}}{1\text{ C}} \Rightarrow 1\text{ V} = 1\text{ J/C} = 1\text{ JC}^{-1}$$

Smaller units of electric potential,

$$1 \text{ mV} = 10^{-3}\text{V}, \quad 1\,\mu\text{V} = 10^{-6}\text{ V}$$

Larger units of electric potential,

$$1 \text{ kV} = 10^{3}\text{ V}, \quad 1 \text{ MV} = 10^{6}\text{ V}$$

Example 3. **Calculate the potential difference between two terminals of a battery, if 100 J of work is required to transfer the charge of 20 C from one terminal of the battery to the other.**

Sol. Given, work done, $W = 100$ J, charge, $q = 20$ C

Potential difference, $\Delta V = ?$

We know that, $\Delta V = \frac{W}{q} = \frac{100}{20} = 5$ V

The potential difference between two points is 5 V.

Example 4. **How much work is done in moving a charge of 2 C from a point of 118 V to a point at 128 V?**

Sol. Given, charge, $q = 2$ C

Potential at point A, $V_A = 118$V

Potential at point B, $V_B = 128$ V

Work done, $W = ?$

We know that, potential difference, $\Delta V = V_B - V_A$
$= 128 - 118 = 10$ V

$\therefore$ Work done, $W = \Delta V \times q = 10 \times 2 = 20$ J

So, the work done in moving the charge is 20 J.

CHECK POINT 01

1. If a body has positive charge, then what does it mean?
2. What is the nature of charged acquired by an ebonite rod when rubbed with a fur?
3. In which direction does current flow in an electric circuit?
4. Is current scalar or vector?
5. The charge on an electron is 1.6×10^{-19}C. Find the number of electrons that will flow per second to constitute a current of 2A. ***Ans.*** 1.25×10^{19} electrons
6. If work done in moving a charge of 20 mC from infinity to a point in an electric field is 15 J, then what is the electric potential at this point? ***Ans.*** 7.5×10^{2} V

Ohm's Law

According to this law, the electric current flowing through a conductor is directly proportional to the potential difference applied across its ends, providing the physical conditions (such as temperature) remain unchanged.

If V is the potential difference applied across the ends of a conductor through which current I flows, then according to Ohm's law,

$$V \propto I \quad \text{(at constant temperature)}$$

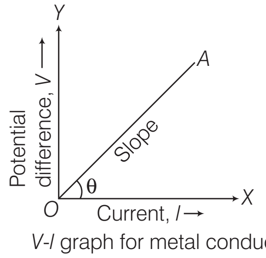
or $$V = IR$$

or $$I = \frac{V}{R}$$

where, R is the constant of proportionality called resistance of the conductor at a given temperature. From the above formula, it is clear that current is inversely proportional to resistance.

V-I Graph

The graph between the potential difference V and the corresponding current I is found to be a straight line passing through the origin for metallic conductors.



V-I graph for metal conductor

Slope of *V-I* graph, gives resistance,

i.e., $$\text{slope} = \tan\theta = \frac{\Delta V}{\Delta I} = \frac{V}{I} = \text{resistance}$$

Resistance

It is that property of a conductor by virtue of which it opposes/resists the flow of charges through it. Its SI unit is **ohm**, it is represented by the Greek letter **Ω**.

Resistance of a conductor is given by $R = \frac{V}{I}$.

It is said to be 1 ohm, if a potential difference of 1 volt across the ends of the conductor makes a current of 1 ampere to flow through it.

i.e., $$1\ \text{ohm} = \frac{1\ \text{volt}}{1\ \text{ampere}} \Rightarrow 1\ \Omega = \frac{1\ V}{1\ A} = 1\ VA^{-1}$$

Example 5. The potential difference between the terminals of an electric heater is 75 V when it draws a current of 5A from the source. What current will the heater draw, if the potential difference is increased to 150 V?

Sol. Given, potential difference, $V = 75$ V

Current, $I = 5$ A

We know that, $R = \frac{V}{I}$

$$\Rightarrow \quad R = \frac{75}{5} = 15\ \Omega$$

When potential difference is increased to 150V, then current is

$$I' = \frac{V'}{R} = \frac{150}{15} = 10\ A$$

So, the current through the heater becomes 10 A.

Some Important Terms Related to Resistance

Some important terms related to resistance are as follow

(i) **Resistor** A component in an electric circuit which offers resistance to the flow of electrons constituting electric current is known as resistor. These are used to make those electrical devices, where high resistance is required. It reduces current in a circuit, e.g., Alloys like nichrome, manganin and constantan.

(ii) **Rheostat/Variable Resistance** It is a variable resistor, which is used to control the flow of electric current by manually increasing or decreasing the resistance.

(iii) **Good Conductor** A material which offers low resistance to the flow of electrons or electric current in an electric circuit is known as a good conductor, e.g., Silver, copper, aluminium are good conductors, among these, silver is the best conductor of electricity.

(iv) **Poor Conductor** A material which offers higher resistance to the flow of electrons or electric current in an electric circuit is known as poor conductor, e.g., Mercury, lead, stainless steel, alloys of iron and chromium.

(v) **Insulator** A material which offers very high resistance to the flow of electrons or electric current in an electric circuit is known as insulator, e.g., Rubber, dry wood and plastic. Electric current does not flow through it.

(vi) **Semiconductor** A material which offers intermediate resistance (more than conductor and less than insulator) to the flow of electrons or electric current in an electric circuit is known as semiconductor, e.g., Germanium, silicon, etc.

Factors on which the Resistance of a Conductor Depends

The electrical resistance of a conductor depends on the following factors

(i) **Length of the Conductor** The resistance of a conductor R is directly proportional to its length l.

i.e., $$R \propto l \qquad \text{...(i)}$$

Due to this, when the length of a wire is doubled/halved, then its resistance also gets doubled/halved.

(ii) **Area of Cross-section of the Conductor** The resistance of a conductor R is inversely proportional to its area of cross-section A.

i.e., $$R \propto \frac{1}{A} \qquad \text{...(ii)}$$

Due to this, when the area of cross-section of wire is doubled, then its resistance gets halved and if area of cross-section of wire is halved, then its resistance will get doubled.

Note When a conductor is stretched (increased its length), then its area of cross-section decreases accordingly but the volume (i.e., area × length) of the conductor remains the same.

(iii) **Nature of the Material of the Conductor** The resistance of a conductor depends on the nature of the material of which it is made.

Some materials have low resistance, whereas others have high resistance.

Hence, from Eqs. (i) and (ii), we can write

$$R \propto \frac{l}{A} \text{ or } R = \rho\frac{l}{A}$$

where, ρ is the constant of proportionality called **resistivity** or **specific resistance** (discussed in later section) of the conductor.

(iv) **Effects of Temperature** With the increases in the temperature of a conductor, the random motion of the electrons also increases. Due to this, the collisions between the electrons and the positive ions also increases. Therefore, the resistance of a conductor also increases with the increases in its temperature.

Note With rise in temperature resistance of semiconductors and electrolytes decreases and for alloys it increases.

Example 6. **A wire of given material having length l and area of cross-section A has a resistance of $10\,\Omega$. What would be the resistance of another wire of the same material having length $l/4$ and area of cross-section $2.5A$?**

Sol. For first wire, length = l, area of cross-section = A

and resistance, $R_1 = 10\,\Omega$

i.e., $$R_1 = \frac{\rho l}{A} = 10\,\Omega \Rightarrow \rho = \frac{10A}{l} \qquad \text{...(i)}$$

For second wire, length = $l/4$, area of cross-section = $2.5A$ and resistance,

$$R_2 = \rho\frac{l/4}{2.5A} = \frac{10A}{l}\cdot\frac{l}{4 \times 2.5A} = 1\Omega \qquad \text{(from Eq. (i))}$$

So, the resistance of that wire is $1\,\Omega$.

Ohmic and Non-Ohmic Resistors

The conductor which obeys Ohm's law is called ohmic resistor (or linear resistance). e.g., Silver, nichrome, copper, iron, etc. The *V-I* graph for these resistor is a straight line passing through the origin (refer to the graph on page 03). Whereas those conductor which does not obey Ohm's law is known as non-ohmic resistor (or non-linear resistance). e.g., Triode valve, junction diode, transistor, etc. The *V-I* graph for these resistors is a curve line.

Also, it is not necessary for the graph of non-ohmic resistors to pass through the origin.

Specific Resistance (Resistivity)

It is defined as the resistance of a conductor of unit length and unit area of cross-section. Its SI unit is ohm-metre (Ω-m).

The resistivity of a material does not depend on its length or thickness but depends on the nature of the substance and temperature. It is a characteristic property of the material of the conductor and varies only, if its temperature changes. Insulators such as glass, rubber, ebonite, etc., have very high resistivity (10^{12} to 10^{17} Ω-m), while conductors have very low resistivity (10^{-8} to 10^{-6} Ω-m).

Alloys have higher resistivity than that of their constituent metals. They are used to make heating elements of devices such as electric iron, heaters, etc. This is because they do not oxidise easily at high temperatures. The high resistivity of alloys also allow dissipation of electrical energy in the form of heat. Tungsten is used almost exclusively for filaments of electric bulbs, whereas copper and aluminium are generally used for electrical transmission lines.

Conductivity

It is defined as the reciprocal of resistivity of a conductor. It's SI unit is mho per metre ($\Omega^{-1}\text{m}^{-1}$) or siemen per metre (S/m). It is expressed as

$$\sigma = \frac{1}{\rho}$$

Example 7. Resistance of a metal wire of length 2 m is 30 Ω at temperature 25°C. If the diameter of the wire is 0.6 mm, then what will be the resistivity of the metal at that temperature?

Sol. Given, length of wire, $l = 2$ m

Resistance, $R = 30\,\Omega$

Temperature, $T = 25°\text{C}$

Diameter of wire, $d = 0.6\text{ mm} = 6 \times 10^{-4}$ m

Resistivity of the wire, $\rho = ?$

We know that, $\rho = \frac{RA}{l} = \frac{R\pi d^2}{4l}$ $\left(\because A = \frac{\pi d^2}{4}\right)$

$$= \frac{30 \times \pi \times (6 \times 10^{-4})^2}{4 \times 2} = 4.24 \times 10^{-6}\ \Omega\text{-m}$$

The resistivity of the metal at 25°C is $4.24 \times 10^{-6}\ \Omega$-m.

Superconductors

The resistance of certain metal or alloy e.g., mercury, lead, niobium, etc., drop to zero, when they are cooled below a certain temperature. These conductors are known as superconductors. In these types of conductors, once a current starts flowing through them, they persist it even when there is no potential difference across them.

CHECK POINT 02

1. Keeping the potential difference constant, the resistance of a circuit is halved. By how much does the current change?
2. The potential difference across a wire is 75 V and its electric resistance is 30 Ω. Find out the electric current through the wire. ***Ans.*** 2.5 A
3. Define the electric resistance of a wire and also write its SI unit.
4. What is the difference between a good conductor and a poor conductor? Give two examples of each.
5. If the length of a wire is halved and its cross-sectional area is doubled, then what would be the resistance of the wire? (Given, initially the resistance of the wire is R) ***Ans.*** $R/4$
6. What is the difference between Ohmic and non-Ohmic resistors?
7. Define the resistivity of a material and also write its SI unit.

Electromotive Force (emf) of a Cell (ε)

Electric cell has to do some work in maintaining the current through a circuit. The work done by the cell in moving unit positive charge through the whole circuit (including the cell) is called the electromotive force (emf) of the cell. If during the flow of q coulomb of charge in an electric circuit, the work done by the cell is W, then

$$\text{emf of the cell, } \varepsilon = \frac{W}{q}$$

Its unit is joule/coulomb or volt.

If $W = 1$ joule and $q = 1$ coulomb, then $\varepsilon = 1$ volt, i.e., if in the flow of 1 coulomb of charge, the work done by the cell is 1 joule, then the emf of the cell is 1 volt.

Internal Resistance (r)

It is defined as the resistance offered by the electrolyte of the cell to the flow of current through it. It is denoted by r. Its unit is also ohm.

Internal resistance of a cell depends on the following factors

(i) It is directly proportional to the separation between the two plates of the cell.

(ii) It is inversely proportional to the plate area dipped into the electrolyte.

(iii) It depends on the nature, concentration and temperature of the electrolyte and increases with increase in concentration.

Terminal Potential Difference (V)

Terminal potential difference of a cell is defined as the potential difference between the two terminals of the cell in a closed circuit (i.e., when current is drawn from the cell). It is represented by V and its unit is volt. It is always less than the emf of the cell.

Combination of Resistors

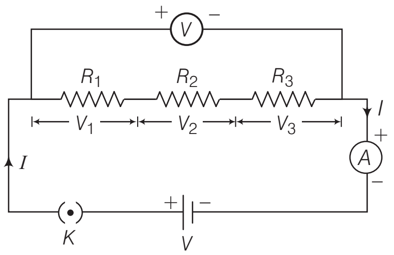
Two or more resistors can be connected with each other by different combination methods in order to achieve the desired equivalent resistance in a particular circuit.

There are two methods of joining the resistors together which are as given below

Series Combination of Resistors

When two or more resistors are connected end to end, then they are said to be connected in series.

The following figure shows the connection of resistors in series



Series combination of resistors

This figure has been drawn because it matches with the matter mentioned below. But the figure already needs an explaination where in we had to write, the voltage drop is been calculate by the voltmeter V_1, V_2 and V_3.

Because the symbol —(V)— is of the voltmeter, rather than first signifying the potential drop in the circuit. An applied potential V produces current I in the resistors and R_1, R_2 and R_3causing a potential drop V_1, V_2 and V_3 respectively, through each resistor.

Total potential, $V = V_1 + V_2 + V_3$

By Ohm's law, $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$

Thus, $\quad V = V_1 + V_2 + V_3 = IR_1 + IR_2 + IR_3$

$\Rightarrow \quad V = I(R_1 + R_2 + R_3)$

If R is the equivalent resistance and $V = IR$

Hence, $\quad IR = I(R_1 + R_2 + R_3)$

$$\Rightarrow \quad \boxed{R = R_1 + R_2 + R_3}$$

Some important points regarding series combination of resistors are as follow

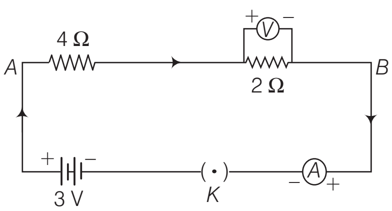
(i) The equivalent resistance is equal to the sum of the individual resistances.

(ii) The equivalent resistance is thus greater than the resistance of either resistor. This is also known as **maximum effective resistance**.

(iii) The current through each resistor is same.

(iv) The potential difference across each resistor is different.

Example 8. Study the following electric circuit. Find the readings of (i) the ammeter and (ii) the voltmeter.



Sol. In the given circuit, the resistance of 4Ω and a bulb of resistance 2Ω are connected in series, so equivalent resistance of the circuit,

$$R = R_1 + R_2 = 4\ \Omega + 2\ \Omega = 6\ \Omega$$

(i) Total current flowing in the circuit,

$$(I) = \frac{\text{Potential difference } (V)}{\text{Total resistance } (R)} = \frac{3}{6} = 0.5\text{A}$$

In series combination, current flowing through each component of the circuit is same and is equal to the total current flowing in the circuit. So, 0.5 A current will flow through the ammeter, therefore its reading will be 0.5 A.

(ii) Reading of voltmeter = Potential difference across 2Ω bulb

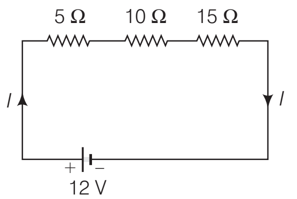
$$\therefore \qquad V = IR = 0.5 \times 2 = 1\text{ V}$$

($\because$ current flowing through the bulb is 0.5 A)

Example 9. Three resistors of 5 Ω, 10 Ω and 15 Ω are connected in series with a 12 V power supply. Calculate their combined resistance, the current that flows in the circuit and in each resistor and the potential difference across each resistor.

Sol. Given, $R_1 = 5\Omega$, $R_2 = 10\Omega$, $R_3 = 15\Omega$, $V = 12\text{V}$, $R = ?$, $I = ?$ and $V_1, V_2, V_3 = ?$

According to question, the three resistors are connected in series combination, then equivalent resistance,



$$R = R_1 + R_2 + R_3 = 5 + 10 + 15 = 30\ \Omega$$

$\therefore$ The current flowing through the circuit

$$(I) = \frac{\text{Potential of power supply } (V)}{\text{Total resistance of the circuit} (R)}$$

$$= \frac{12}{30} = \frac{2}{5} = 0.4\text{ A}$$

In series combination, the current flowing through each resistor is equal to total current flowing through the circuit. Therefore, current flowing through each resistor is 0.4 A.

$\therefore$ Potential difference across first resistor,

$$V_1 = IR_1 = 0.4 \times 5 = 2\text{ V}$$

Potential difference across second resistor,

$$V_2 = IR_2 = 0.4 \times 10 = 4\text{ V}$$

and potential difference across third resistor,

$$V_3 = 0.4 \times 15 = 6\text{ V}$$

Disadvantages of Series Combination

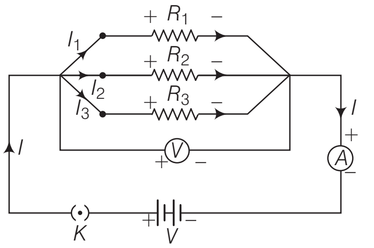
(i) In series combination, if any of the components fail to work, the circuit will break and then none of the components will be able to operate.

(ii) It is not possible to connect a bulb and a heater in series because they need different values of current to operate properly. Due to this, we do not use series circuit.

Parallel Combination of Resistors

When two or more resistors are connected simultaneously between two points, then they form a parallel combination.

The following figure shows the connection of resistors in parallel



Parallel combination of resistors

An applied potential V produces current I_1 in R_1, I_2 in R_2 and I_3 in R_3.

Total current, $I = I_1 + I_2 + I_3$ ...(i)

By Ohm's law, $I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}$ and $I_3 = \frac{V}{R_3}$

If R is the equivalent resistance, then $I = \frac{V}{R}$

Thus, $$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$ [from Eq. (i)]

$$\Rightarrow \quad \frac{V}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\Rightarrow \quad \boxed{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

Some important points regarding parallel combination of resistors are as follow

(i) The reciprocal of equivalent resistance is equal to the sum of the reciprocal of individual resistances.

(ii) The equivalent resistance is less than the resistance of either resistor. This is also known as **minimum effective resistance**.

(iii) The current from the source is greater than the current through either resistor.

(iv) The potential difference across each resistor is same.

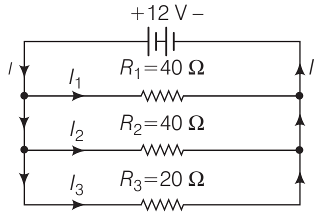
Note For n equal resistances combined in series (equivalent resistance R_s) and in parallel (equivalent resistance R_p), then

$$\frac{R_s}{R_p} = n^2$$

Example 10. **Two 40 Ω resistors and a 20 Ω resistor are all connected in parallel with a 12 V power supply. Calculate their effective resistance and the current through each resistor. What is the current flowing through the supply?**

Sol. Given, $R_1 = 40\ \Omega,\ R_2 = 40\ \Omega,\ R_3 = 20\ \Omega,\ V = 12\text{V}, R = ?,$
$I, I_1, I_2, I_3 = ?$

According to circuit, the three resistors are connected in parallel combination, then effective resistance,



$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{40} + \frac{1}{40} + \frac{1}{20}$$

$$= \frac{1+1+2}{40} = \frac{4}{40} = \frac{1}{10}$$

$$\Rightarrow \quad R = 10\ \Omega$$

So, the three resistors together have an effective resistance of 10 Ω.

Each resistor has a potential difference of 12 V across it.

As in parallel combination, the potential difference across each resistance is equal to the total potential difference applied on the combination.

Also, current, $I = \frac{\text{potential difference } (V)}{\text{resistance } (R)}$

Current through 40 Ω resistor, $I_1 = \frac{12}{40} = 0.3\text{ A}$

Also, $I_2 = 0.3\text{ A}$

Current through 20 Ω resistor, $I_3 = \frac{12}{20} = 0.6\text{ A}$

∴ Current throught the supply,

$$I = I_1 + I_2 + I_3 = 0.3\text{ A} + 0.3\text{ A} + 0.6\text{ A} = 1.2\text{ A}$$

Applications of Parallel Combination in Daily Life

Parallel combination of resistances is very useful in circuits used in daily life. This is because, these circuits have components of different resistances which requires different amounts of current.

Parallel circuit divides the current among the components (electrical gadgets), so that they can have necessary amount of current to operate properly. This is the reason of connecting electrical appliances in parallel combination in household circuit.

Mixed Combination of Resistors

In this type of combination, circuit has some resistances connected in series combination and some in parallel combination. This type of combination is also called complex circuit.

While solving problems of mixed combination of resistances, there are many points to be considered which are given as below

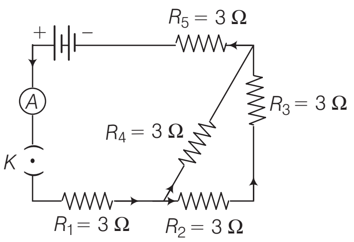
(i) Mixed combination circuit can always be reduced to a simple circuit containing only one resistor. For this examine, the given circuit and replace the resistors that are connected in parallel or in series with their equivalent resistances.

(ii) Draw the new circuit after making the changes and repeat the same procedure again as discussed above, till a simple circuit is obtained.

(iii) If the current through or potential difference across a resistor in the complex circuit is to be found, then start with the simple circuit reduced from the complex circuit and gradually work your way back through the circuits, using $V = IR$.

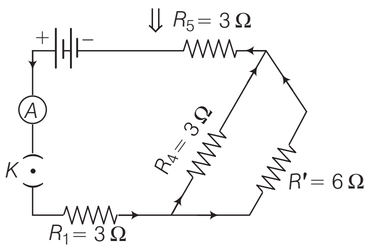
(iv) While calculating the equivalent resistance, do not consider the battery, if its resistance is not given but, if its resistance is given, then consider it and treat it as an individual resistor.

Example 11. Consider the circuit diagram as given below:



If $R_1 = R_2 = R_3 = R_4 = R_5 = 3\,\Omega$, then find the equivalent resistance of the circuit.

Sol. From the given combination, it can be observed that R_2 and R_3 are in series order. As current through R_2 and R_3 is same. So, their equivalent resistance is $R' = R_2 + R_3 = 3\Omega + 3\Omega = 6\Omega$. Now, the given circuit can be redrawn as shown below



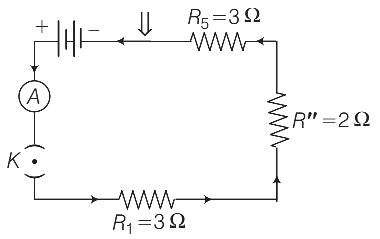
Now, it can be seen that R_4 and R' are in parallel combination. As, currents through R_4 and R' are different. So, their equivalent resistance can be calculated as below

$$\frac{1}{R''} = \frac{1}{R'} + \frac{1}{R_4}$$

$$= \frac{1}{6} + \frac{1}{3} = \frac{1+2}{6} = \frac{3}{6} = \frac{1}{2}$$

$\therefore \quad R'' = 2\Omega$

Now, the given circuit can be redrawn as shown below



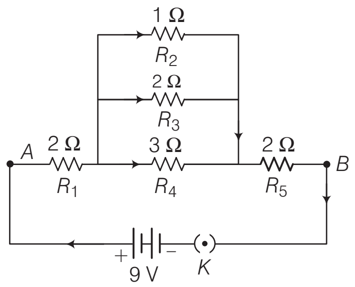
Now, it is clear from the diagram that all the resistances R_5, R'' and R_1 are in series combination.

As, current through R_1, R'' and R_5 is same.

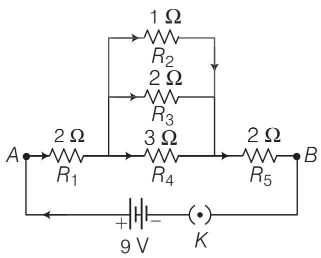
$\therefore$ Equivalent resistance of the circuit is

$$R = R_5 + R'' + R_1$$
$$= 3\Omega + 2\Omega + 3\Omega = 8\Omega$$

Example 12. Find the equivalent resistance of the following circuit. Also, find the current and potential at each resistor.



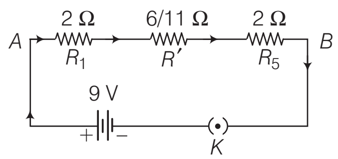
Sol. In the given circuit, R_2, R_3 and R_4 are in parallel combination. As, currents through R_2, R_3 and R_4 are different. Let equivalent resistance of R_2, R_3 and R_4 be R'.



$$\frac{1}{R'} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

$$= \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{6+3+2}{6} = \frac{11}{6} \quad \Rightarrow \quad R' = \frac{6}{11}\,\Omega$$

Now, the given circuit can be redrawn as shown below



Now, R_1, R' and R_5 are in series combination.

As, current through R_1, R' and R_5 is same.

So, equivalent resistance of the whole circuit is

$$R = R_1 + R' + R_5 = 2 + \frac{6}{11} + 2$$

$$= \frac{22 + 6 + 22}{11} = \frac{50}{11} \text{ W}$$

Now, total current flowing through the circuit,

$$I = \frac{V}{R} = \frac{9}{\frac{50}{11}} = \frac{99}{50} \approx 2 \text{ A}$$

Current through R_1 and R_5 will be same as these are in series combination and will be equal to the total current flowing through the circuit.

$\therefore \quad I = I_1 = I_5 = 2\text{ A}$

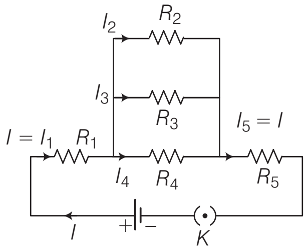
Potential drop at $R_1, V_1 = I_1 R_1 = 2 \times 2 = 4\text{ V}$

Potential drop at $R_5, V_5 = I_5 R_5 = 2 \times 2 = 4\text{ V}$

Now, potential drop at R', V' can be calculated as

$$V = V_1 + V_5 + V' \Rightarrow \quad 9 = 4 + 4 + V'$$

$\Rightarrow \quad V' = 1\text{ V}$



As R_2, R_3 and R_4 are in parallel combination, so potential drop at all resistances will be same as 1 V.

$$V_2 = V_3 = V_4 = V' = 1\text{ V}$$

Current through R_2, $I_2 = \frac{V_2}{R_2} = \frac{V'}{R_2} = \frac{1}{1} = 1\text{ A}$

Similarly, $I_3 = \frac{V_3}{R_3} = \frac{V'}{R_3} = \frac{1}{2} = 0.5\text{ A}$

and $\quad I_4 = \frac{V_4}{R_4} = \frac{V'}{R_4} = \frac{1}{3} = 0.33\text{ A}$

CHECK POINT 03

1 In which type of combination of different resistors it will have an equal value of electric current through each resistor?

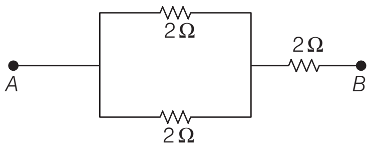
2 Which type of combination of resistors will have equivalent resistance less than the least resistance?

3 If different resistors have same value of electric potential across them, then in which way they are connected to each other?

4 Four resistors of equal resistance R are connected in parellel, find the equivalent resistance. **Ans.** $R/4$

5 What do you understand by mixed combination of resistance?

6 Five resistances are connected as shown in the figure. Determine the total resistance between A and B.



Ans. 3 Ω

Electrical Energy

Now-a-days electricity is used in doing many works through different instruments. Thus, electric energy can be defined as the ability of electric current to do some work through different instrument.

Some examples of electric energy are given below

(i) When an electric current is passed through a heating element of a heater, oven, etc, it gets heated up due to its resistance. Thus, electrical energy is converted into heat energy.

(ii) When an electric current is passed through an electrical motor its coil begin to rotate and simultaneously the coil gets heated up slightly. The electrical energy is converted into mechanical energy and sometimes into heat energy.

(iii) When an electric current is passed through an electric lamp, the filament of the bulb gets heated and it glows. Thus, electrical energy is converted into heat and light energy.

(iv) When the output of a microphone which is in the form of electric pulses is passed to a loud speaker, the electrical energy is converted into sound energy.

Measurement of Electrical Energy

Assuming a conductor as a resistance wire which resists the flow of current through it.

So, work must be done by the current source for continuous flow of the current. Now, we calculate the work done by the source when the current I flows through a wire of resistance R. This work done will be equal to the electric energy.

When an electric charge q moves against a potential difference V. Then,

amount of work, $W = q \times V$ ...(i)

From definition of current, we know that

$$I = \frac{q}{t} \quad \text{or} \quad q = I \times t \qquad \text{...(ii)}$$

From Ohm's law,

$$\frac{V}{I} = R \quad \text{or} \quad V = IR \qquad \text{...(iii)}$$

Substituting the values of q and V in Eq. (i), we get

$$W = (I \times t) \times IR = I^2 Rt = VIt = \frac{V^2 t}{R}$$

$$\therefore \quad \boxed{\text{Electric energy, } E = I^2 Rt = VIt = \frac{V^2 t}{R}}$$

SI unit of electrical energy is joule (J),

where, 1 Joule = 1 volt × 1 ampere × 1 sec

Commercial Unit of Electrical Energy

To measure the electrical energy consumed commercially, joule is not sufficient. So, to express electrical energy consumed commercially a special unit **kilo-watt-hour** is used in place of joule. It is also called 1 unit of electrical energy.

1 kilowatt hour or 1 unit of electrical energy is the amount of energy dissipated in 1 hour in a circuit, when the electric power in the circuit is 1 kilowatt.

1 kilowatt hour (kWh)

$$= 3.6 \times 10^6 \text{ joule (J)} = 3.6 \times 10^{13} \text{ erg}$$

Heating Effect of Electric Current

When an electric current is passed through a high resistance wire like nichrome wire, then the wire becomes very hot and produces heat. This is called the heating effect of current.

This effect is obtained by the transformation of electrical energy into heat energy.

e.g., An electric fan becomes warm, if it is used continuously for longer time, etc.

Assuming that all electrical work done or electrical energy consumed is converted into heat energy, i.e., heat produced. So, heat produced is given by

$$H = I^2 \times R \times t$$

Thus, it is known as **Joule's law of heating.**

This law implies that heat produced in a resistor is

(i) directly proportional to the square of current for a given resistance.

(ii) directly proportional to the resistance for a given current.

(iii) directly proportional to the time for which the current flows through the resistor.

Electric Power

It is defined as the amount of electric energy consumed in a circuit per unit time.

If W be the amount of electric energy consumed in a circuit in t seconds, then the electric power is given by

$$P = \frac{W}{t}$$

But W = electric energy $= Vq = VIt$ $\quad (\because q = It)$

$$\therefore \quad P = \frac{VIt}{t}$$

$$\Rightarrow \quad P = VI$$

According to Ohm's law, $V = IR$

$$\therefore \quad P = IR \times I = I^2R$$

$$\Rightarrow \quad = \frac{V^2}{R} \qquad \left(\because I = \frac{V}{R}\right)$$

The SI unit of electric power is watt (W).

Electric power is said to be 1 watt, if 1 ampere current flows through a circuit having 1 volt potential difference.

i.e., 1 watt = 1 volt × 1 ampere = 1 VA

Note

- Bigger units of power are as given below:
  1 kilowatt (kW) = 10^3 W
  1 megawatt (MW) = 10^6 W
  1 gigawatt (GW) = 10^9 W
- Practical unit of power is horse power.
  1 HP = 746 W
- Number of units consumed by electric appliances is $= \frac{\text{watt} \times \text{hours}}{1000}$

Power Rating of Common Appliances

The electrical appliances such as electric bulb, geyser bulb, heater, etc., are rated with power and voltage. e.g., An electric bulb is rated as 100W – 220V, etc.

With the help of the rating of the appliances, we calculate the following two quantities such as

(i) The resistance of the filament of the bulb (coil).

$$R = \frac{V^2}{P} = \frac{(\text{Voltage rating of appliance})^2}{\text{Power rating of appliance}}$$

This is the resistance of the element (filament) of an appliance (bulb) while in use.

(ii) Safe limit of current through the filament of the bulb (coil).

$$I = \frac{P}{V} = \frac{\text{Power rating of appliance}}{\text{Voltage rating of appliance}}$$

If the current exceeds this value, the power supplied at the rated voltage V exceeds the rated power and the appliance gets damaged.

House Hold Consumption of Electrical Energy

An electric meter measures the electrical energy consumed by the different appliances at home. It always calculate the energy in kWh.

∴ The electrical energy consumed by a household appliance in a certain time (t) is given as, Energy (in kWh) = power (in kW) × time (in hour)

$$= \frac{\text{power (in watt)} \times \text{time (in hour)}}{1000}$$

$$= \frac{V(\text{volt}) \times I(\text{ampere}) \times t(\text{hour})}{1000}$$

Now, cost of the electricity will be given as,
cost of electricity = energy consumed (in kWh) × rate in rupees per unit.

Example 13. An electric fan runs from the 220 V mains. The current flowing through it is 0.5 A. At what rate is the electrical energy transformed by the fan? How much energy is transformed in 2 min?

Sol. Given, potential difference, $V = 220$ V,
current, $I = 0.5$ A, time, $t = 2\,\text{min} = 120\,\text{s}$, power, $P = ?$
We know that,
power, $P = VI = 220 \times 0.5 = 110$ W
and $E = Pt = 110 \times 120 = 13200$ J
So, the power of fan is 110 W and it transforms 13200 J of energy.

Example 14. An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat developed in 0.5 min.

Sol. Given, resistance, $R = 20\,\Omega$, Current, $I = 5$ A
Time, $t = 0.5\,\text{min} = 0.5 \times 60 = 30$ s
Heat, $H = ?$
We know that, heat, $H = I^2Rt$

$$H = (5)^2 \times 20 \times 30 = 25 \times 20 \times 30 = 15000\,\text{J} = 1.5 \times 10^4\ \text{J}$$

So, the heat developed is 1.5×10^4 J.

Example 15. 200 J of heat is produced 10 s in a 5 Ω resistance. Find the potential difference across the resistor.

Sol. Given, heat, $H = 200$ J, resistance, $R = 5\,\Omega$,
time, $t = 10$ s, potential difference, $V = ?$
We know that,

$$\text{heat, } H = I^2Rt \Rightarrow I = \sqrt{\frac{H}{Rt}} = \sqrt{\frac{200}{5 \times 10}} = 2\text{A}$$

So, the potential difference across the resistor is

$$V = IR \qquad \text{(by Ohm's law)}$$
$$= 2 \times 5 = 10\,\text{V}$$

Example 16. An electric refrigerator rated 500W operates 6 hours/day. What is the cost of the energy to operate it for 30 days at ₹4.5 per kWh?

Sol. Energy consumed by refrigerator in 30 days

$$= 500\text{W} \times 6\frac{\text{hour}}{\text{day}} \times 30\,\text{days}$$
$$= 90000\,\text{Wh} = 90\,\text{kWh}$$

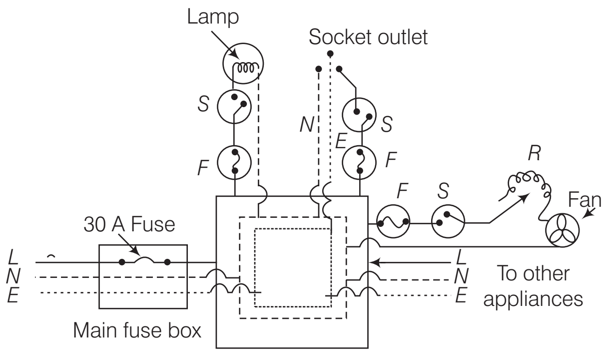
∴ Cost of energy to operate the refrigerator for 30 days
= 90 kWh × ` 4.5 per kWh = ` 405

CHECK POINT 04

1. Explain, why the current that makes the heater element very hot, only slightly warms the connecting wires leading to the heater?
2. An electric heater of resistance 500 Ω is connected to a mains supply for 30 min. If 15 A current flows through the filament of the heater, then calculate the heat energy produced in the heater. ***Ans.*** 20.25×10^7 J
3. What is the maximum power in kilowatts of the appliance that can be connected safely to a 13A, 230V mains socket? ***Ans.*** 2.99 kW
4. Power of a lamp is 60W. Find the energy in joules consumed by it in 1 s. ***Ans.*** 60 J
5. What is the heating effect of electric current?
6. What is the safe limit of current through the filament of the bulb?

House Wiring (Ring System)

In a house, the wiring is commonly done by the ring system. A ring system of wiring connecting a lamp, a socket with switch and a fan with regulator is shown in the figure given below.



A schematic diagram of main circuit

In this system, the wires starting from the main fuse box run around all the rooms of the house and then come back to the fuse box again forming the ring. The fuse box contains a fuse of rating about 30 A for each ring circuit.

Advantages of the Ring System

The advantages of the ring system are given as

(i) Each appliance can operate independently, without affecting the other appliances connected in the system.

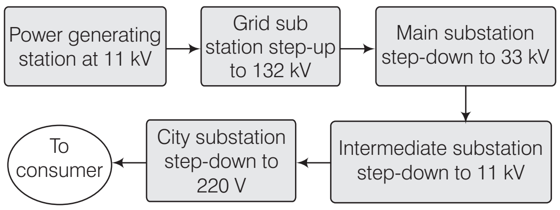
(ii) If a new appliance has been installed in a room, a new line up to the distribution box is not required but it can directly connect to the ring circuit of the room.

Power Distribution

The electric power is generated at the power generating stations. The power from these station is transmitted over long distances at a high voltage to minimise the loss of energy in form of heat in the line wires used for transmission.

This is because at high voltages the value of current is very less. Therefore, from the relation of the heating effect produced i.e., $H = I^2RT$, will also be less at low current.

Hence, the energy loss will be least.



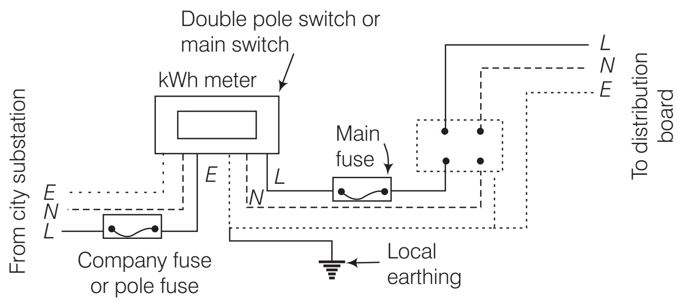
Block diagram representing the power distribution

Components of Household Electric Circuit

1. Main Circuit

Electricity generated at power stations is brought to our homes by two thick copper or aluminium wires. One of these is called **live wire** (in red insulation cover), which is at a potential of 220 V with a frequency of 50 Hz and the other is called **neutral wire** (in black insulation cover), which is at zero potential. There is also a third wire i.e., earth wire.

The neutral and the earth wires are connected together at the local substation, so that both the wire are at the same potential.



A schematic diagram of main circuit

The live wire carries current from the source to the distribution board while the neutral wire is for the return path of current. The connections are made to the distribution board through a main fuse and a main switch.

The main fuse is connected in the live wire while the main switch is connected in the live and neutral wires. The main switch is a double pole switch. It has an iron covering.

The covering is earthed. This switch is used to cut the connections of the live as well as the neutral wires. Usually, there are two separate circuits in a house, the lighting circuit with a 5 A fuse (bulbs, fans, etc) and the power circuit with a 15 A fuse (geysers, air coolers, etc.).

2. Switch

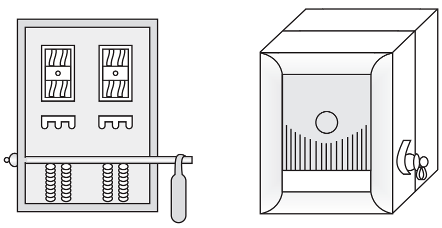
In an electrical circuit switch is used to start or stop the flow of current.

Depending upon work, construction and current rating, switches are classified as given below

(i) **Main Switch** It is a two pole or three pole single way switch. Normally, it is DPIC or TPIC type switch. They are used to switch ON/OFF the main line current.

It is basically of two types

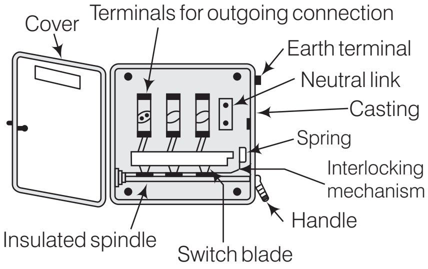
(a) **Double Pole Iron Clad or DPIC Switch** It works as a main switch for single phase AC or DC. A fuse is connected in series with each line. It is used for controlling single phase 2-wire circuits. The switch switches ON/OFF the phase line and neutral line simultaneously. These switches are constructed for 15 A to 200 A and 250 V to 660 V. The metal covering of switch should be compulsorily grounded.



Double pole iron clad switch

(b) **Three Pole Iron Clad or TPIC Switch** It works as a main switch for 3-phase AC line. It is used for controlling a 3-phase power with 4-wire system. A fuse and a neutral link is connected in series with each line. The switch switches ON/OFF all the three phase lines simultaneously. These switches are constructed for 30 A to 400 A and 400 V to 1100 V.

The metal covering of switch should be compulsorily grounded.

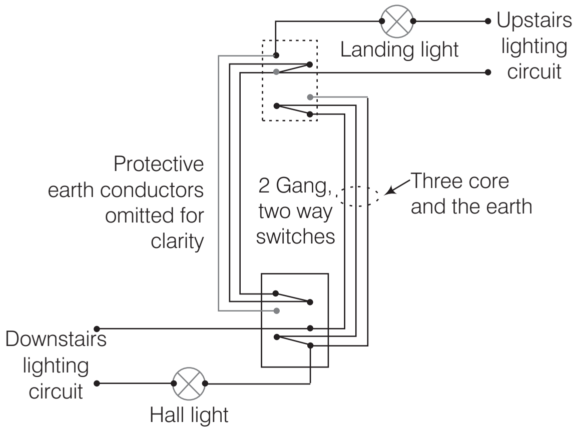


Three pole iron clad or TPIC switch

Note **DPIC and TPIC are Different from Other Switches** DPIC and TPIC switches are switched ON in upward direction and OFF in downward direction but rest other switches are ON in downward direction and OFF in upward direction. This property makes them different from others.

(c) **Two-way Switch** It means two or more switches in different locations to control one lamp. They all are wired in such a way, so that operation of either switch will control the lights.

This figure illustrates how lights is controlled from two different locations

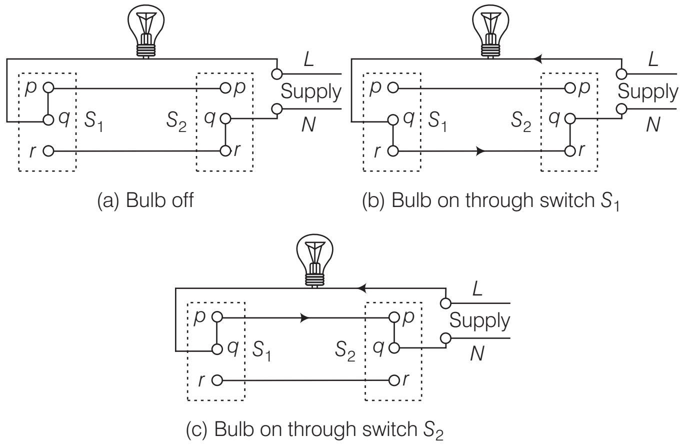


A schematic diagram of two-way switch circuit

3. Staircase Wiring

It is a dual control switch system in which the double pole type switches are used at the top and bottom of a staircase. Let a switch S_1 be fitted at the bottom and a switch S_2 at the top of the staircase.

While going up a person puts on the light by operating the switch S_1 so that the connection '*pq*' changes to '*qr*' and makes the current to flow in the circuit. On reaching at the top, he operates the switch S_2 to put off the light so that the connection '*rq*' changes to '*qp*' and the flow of current stops.

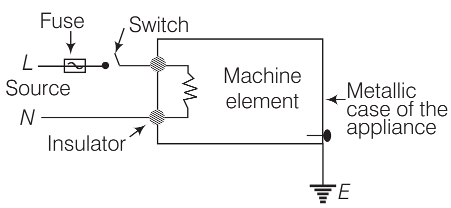


(a) Bulb off
(b) Bulb on through switch S_1
(c) Bulb on through switch S_2

4. Earthing

Earthing means to connect the metal case of the appliance to the earth (i.e., zero potential) by means of a metal wire called the earth wire (in green insulation cover). One end of the metal wire is buried in the earth. The appliances are connected to the earth by using the top pin of a 3-pin plug.

Earthing saves us from electrical shocks. The symbol ⏚ used for earthing appliances.



Earthing of an appliance

5. Electric Fuse

Fuse is used as a safety device in household circuits and is based on heating effect of current. It is connected in series with the mains supply.

A fuse consists of an alloy of **lead** and **tin** which has appropriate melting point.

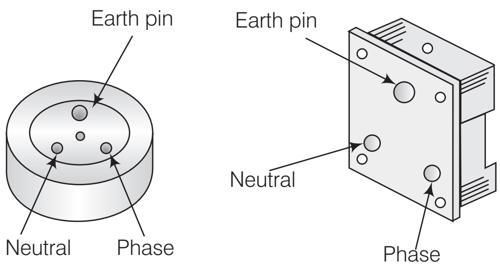
It is required to rate the fuses for different current values such as 1 A, 2 A, 5 A, 10 A, 15 A, etc.

When the current flowing through the circuit exceeds the safe limit, the temperature of the fuse wire increases and due to heating effect it gets melts and breaks the circuit. This helps to protect the other circuit elements from hazards caused by heavy current.

6. 3-Pin Plug and Socket with Conventional Location of Wires

According to electricity rules, 3-pin socket should be used where third pin is used as the earth pin, it is thick pin and is at the top between the other two pins of the other two pins, right pin is used as phase and the left pin as neutral.

There is no pin for the earth available in 2-pin socket and it is used in low voltage applications. The pins are splitted at the ends to provide a spring action so that it gets fit in the socket holes tightly. The earth pin is thicker and longer than the other two. Whereas socket is used to supply the current to the electrical equipment from the switch board. They are of 2-pin with rating 5 A, 250 V and 3-pin of rating 5 A/ 15 A, 250 V. Similar to switches, sockets are of two types i.e., one type is fixed above the surface of switch board and second type below the surface of switch board.



3-Pin socket

Safety Precautions

The safety precautions are as

(i) a switch should not be touched with wet hands.
(ii) the switch should always be connected in the live wire.
(iii) electrical appliances should be properly earthed.
(iv) always use appropriate fuse rating in the live wire of the circuit.

Conventional Colour Coding of Wires

The colour coding of wires in a cable are as

Wires	Colour	
	Old Convention	New Convention
Live	Red	Brown
Neutral	Black	Light blue
Earth	Green	Green or Yellow

CHECK POINT 05

1 Write on advantage of using ring system in house wiring.
2 What is a two-way switch?
3 Why electrical appliances are earthed?
4 What is a fuse?
5 Define a socket.
6 Write colour codes of live and neutral wire.

SUMMARY

- An electric charge is a physical entity which is defined by excess or deficiency of electrons on a body. The SI unit of electric charge is coulomb (C).
- The total charge acquired by a body is an integral multiple of magnitude of charge on a single electron. This principle is called quantisation of charge.
- Electric current is defined as the rate of flow of electric charge through any cross-section of a conductor in unit time. Electric current $(I) = \frac{\text{Charge } (q)}{\text{Time } (t)}$. The SI unit of electric current is ampere (A).
- Electric potential is defined as the amount of work done when a unit positive charge is moved from infinity to a point. Electric potential $(V) = \frac{\text{Work done } (W)}{\text{Charge moved } (q)}$. The SI unit of electric potential is volt (V).
- Electric potential difference is defined as the work done per unit charge in moving a unit positive charge from one point to other point.
- A closed and continuous path through which electric current flows is known as electric circuit.
- According to Ohm's law, the electric current flowing through a conductor is directly proportional to the potential difference applied across its ends, providing the physical conditions (such as temperature) remains unchanged.

  $$V \propto I \quad \text{or} \quad V = IR$$

  where, R is the constant of proportionality called resistance of the conductor at a given temperature.
- Resistance is the property of a conductor due to which it opposes the flow of electric current through it. Mathematically,

  $$\text{Resistance } (R) = \frac{\text{Potential difference } (V)}{\text{Electric current } (I)}$$

The SI unit of resistance is ohm (Ω).

- At a given temperature resistance of a conductor depends on its (i) length l, (ii) cross-section area A and (iii) nature of the material of the conductor.

  It is found that $R \propto l$ and $R \propto \frac{1}{A}$, Mathematically, $R = \rho\frac{l}{A}$

  where, ρ is the constant of proportionality called resistivity or specific resistance of the conductor.
- Resistivity of a conductor is defined as the resistance of a conductor of unit length and unit area of cross-section. The SI unit of resistivity is ohm-metre (Ω-m).
- If R_1, R_2 and R_3 be the individual resistors joined in series, then the equivalent resistor R_S is given by

  $$R_S = R_1 + R_2 + R_3$$
- If R_1, R_2 and R_3 be the individual resistors joined in parallel, then the equivalent resistor R_P is given by

  $$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$
- When an electric current is passed through a high resistance wire like nichrome wire, then the wire becomes very hot and produces heat. This is called the heating effect of current.
- As per Joule's law of heating the electric energy consumed is given by

  $$W = qV = VIt = I^2Rt = \frac{V^2t}{R}$$
- Electric power (P) is defined as the amount of electric energy consumed in a circuit per unit time $(P) = \frac{W}{t}$.
- The SI unit of electric power is watt (W).
- In the ring system, the wires starting from the main fuse box run around all the rooms of the house and then come back to the fuse box again forming the ring.
- The electric power is generated at the power generating stations. The power from the generating station is transmitted over long distances at a still high voltage to minimise the loss of energy in form of heat in the live wires used for transmission.
- In an electrical circuit switch is used to start or stop the flow of current.
- Main Switch It is a two pole or three pole single way switch.
- Two-way switch means two or more switches in different locations to control one lamp.
- Staircase wiring is a dual control switch system in which the double pole type switches are used at the top and bottom of a staircase.
- To avoid from the risk of electrical shock, the metal body of appliances is earthed. Earthing means to connect the metal case of the appliance to the earth (i.e., zero potential) by means of a metal wire called the earth wire.
- Fuse is a safety device which protects the electrical circuit from short circuiting and overload.
- In a 3-pin plug, the top pin is for earthing, the left pin is for live and the right pin is for neutral. The pins are splitted at the ends to provide a spring action so that the fit in the socket holes tightly. The earth pin is thicker and longer than the other two.
- Conventional colour codes of wires are live-brown, neutral-light blue and earth-green or yellow.

EXAM PRACTICE

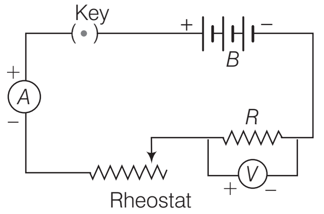
a 2 Marks Questions

1. (i) State Ohm's law.

(ii) Diagrammatically illustrate how you would connect a key, a battery, a voltmeter, an ammeter, an unknown resistance R and a rheostat so that it can be used to verify the above law.

Sol. (i) According to Ohm's law, the electric current flowing through a conductor is directly proportional to the potential difference applied across its ends, providing the physical conditions (such as temperature) remain unchanged. ***[1]***

(ii) *To illustrate the Ohm's law, we draw the following circuit as*

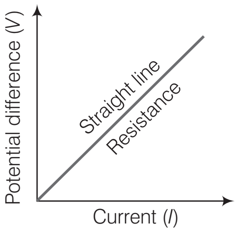


where, B is battery, V is voltmeter and A is ammeter. ***[1]***

2. (i) Sketch a graph to show the change in potential difference across the ends of an ohmic resistor and the current flowing in it. Label the axes of your graph.

(ii) What does the slope of the graph represent? ***[2008]***

Sol. (i)



[1]

(ii) The slope of the graph represents resistance of the resistor. ***[1]***

3. Define specific resistance and state its SI unit. ***[2017]***

Sol. **Specific Resistance** or **Resistivity** (ρ), of a conductor is defined as the resistance of a conductor of unit length and unit area of cross-section.

Specific resistance or resistivity is the characteristic property of the material of the conductor and depends only on the nature of the material and temperature. ***[1]***

As we known, the resistance is given by

$$R = \rho\frac{l}{A} \Rightarrow \rho = \frac{RA}{l} = \frac{\Omega \text{m}^2}{\text{m}} = \Omega\text{-m}$$

Its SI unit is ohm-m (Ω-m). ***[1]***

4. (i) What is an ohmic resistor?

(ii) Two copper wires are of the same length, but one is thicker than the other.

(a) Which wire will have more resistance?

(b) Which wire will have more specific resistance? ***[2014]***

Sol. (i) **Ohmic Resistor** The conductor which obeys Ohm's law is called ohmic resistor or linear resistance., e.g., Silver, aluminium, copper, nichrome, etc. ***[1]***

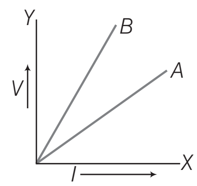
(ii) (a) Thin wires will have more resistance, because the resistance of the wire varies inversely to the area of the wire, i.e., $R \propto \frac{1}{A}$. ***[1/2]***

(b) Thick wire will have more specific resistance. Because $\rho = \frac{RA}{l}$. ***[1/2]***

5. Should the resistance of an ammeter be low or high? Give reason.

Sol. The resistance of an ammeter should be low. An ammeter has to be connected in series with the circuit to measure current. In case, its resistance is not very low, its inclusion in the circuit will reduce the current to be measured. In fact, an ideal ammeter is one which has zero resistance. ***[2]***

6. The V-I graph for a series combination and for a parallel combination of two resistors is shown in the figure below. Which of the two A or B, represents the parallel combination? Give a reason for your answer. ***[2016]***



Sol. In parallel combination, resultant resistance becomes less than the resultant resistance in series combination. From the given graph, the scope represents the resistance. According to graph, slope of line A is less than the slope of line B. So, line A represents the parallel combination. ***[2]***

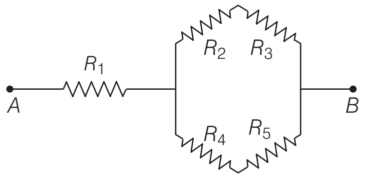
7. n resistors, each of resistance R are first connected in series and then in parallel. What is the ratio of the total effective resistance of the circuit in series to parallel combination?

Sol. In series combination, $R_S = nR$ **[1/2]**

In parallel combination, $R_P = \frac{R}{n}$ **[1/2]**

$$\because \quad \frac{R_S}{R_P} = \frac{nR}{R/n} = n^2$$ **[1]**

8. Derive an expression for equivalent resistance in the following case



Decide which resistances are in series and parallel. Solve for series and then for parallel. Combine both the results to get the equivalent resistance.

Sol. R_2 and R_3 are in series.

Thus, for this combination, $R' = R_2 + R_3$

Similarly, R_4 and R_5 are in series,

So, $R'' = R_4 + R_5$ **[1]**

R' and R'' are in parallel.

$$\therefore \quad R''' = \frac{R'R''}{R'+R''} = \frac{(R_2+R_3)(R_4+R_5)}{R_2+R_3+R_4+R_5}$$

R_1 and R''' are in series.

$$\therefore \quad R_{eq} = R_1 + \frac{(R_2+R_3)(R_4+R_5)}{R_2+R_3+R_4+R_5}$$ **[1]**

9. In an electrical circuit, three incandescent bulbs A, B and C of ratings 40 W, 60 W and 100 W respectively, are connected in parallel to an electric source. Write the order of brightness.

Sol. Bulbs are rated presuming that they all are to be connected with the same voltage supply (say 220 V in India). In parallel combination, voltage remains same, so greater the power (watt), greater the brightness. Therefore, brightness B of three bulbs are as

$$B_{100} > B_{60} > B_{40}$$ **[1 + 1]**

10. (i) What is the colour code for the insulation on the earth wire?

(ii) Write an expression for calculating electrical power in terms of current and resistance.

Sol. (i) The colour code for the insulation on the earth wire is green or yellow. **[1]**

(ii) The expression for calculating electrical power (P) in terms of current (I) and resistance (R) is given by $P = I^2R$. **[1]**

11. (i) Which part of an electrical appliance is earthed?

(ii) State a relation between electrical power, resistance and potential difference in an electrical circuit.

Sol. (i) Metallic body of an electrical appliance is earthed. **[1]**

(ii) The relation between electrical power, resistance and potential difference in a circuit is given by

$$P = \frac{V^2}{R}$$ **[1]**

12. Of the three connecting wires in a household circuit

(i) Which two of the three wires are at the same potential?

(ii) In which of the three wires should the switch be connected?

Sol. (i) Neutral and the earth wire are at the same potential, because the earth wire and neutral wire are connected together. **[1]**

(ii) Switch should be connected in live wire. **[1]**

13. Identify the following wires used in a household circuit.

(i) The wire is also called as the phase wire.

(ii) The wire is connected to the top terminal of a three pin socket. **[2018]**

Sol. (i) Live wire is also called as the phase wire. **[1]**

(ii) Earth wire is connected to the top terminal of three pin socket. **[1]**

14. (i) Name the device used to protect the electric circuits from overloading and short circuit.

(ii) On what effect of electricity does the above device work? **[2013]**

Sol. (i) Electric fuse is used to protect the electric circuit from overloading and short circuits. **[1]**

(ii) Heating effect of electric current. **[1]**

15. (i) Give two characteristic properties of copper wire which make it suitable for use as fuse wire.

(ii) Name the material which is used as a fuse wire.

Sol. (i) *The two characteristic properties of copper wire are as*

(a) it should be of low melting point and high resistivity. **[1]**

(b) it should be a good conductor of electricity.

(ii) The alloy of tin and lead is used as fuse wire. **[1]**

16. State the characteristics required in a material to be used as an effective fuse wire. ***[2016]***

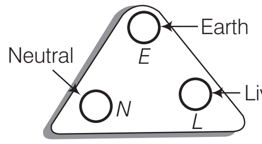
Sol. *Characteristics required in a material to be used as an effective fuse wire are given below*

(i) High resistance and ***[1]***

(ii) Low melting point. ***[1]***

17. Draw a labelled diagram of a 3-pin socket.

Sol. *The 3-pin socket diagram is shown below*



[2]

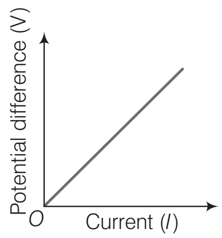
C 3 Marks Questions

18. (i) Draw a graph of potential difference (V) *versus* current (I) for an ohmic resistor.

(ii) How can you find the resistance of the resistor from this graph?

(iii) What is a non-ohmic resistor?

Sol. (i) *The graph of potential difference (V) and current (I) for ohmic resistance is shown below* ***[1]***



(ii) The resistance of the resistor is given by the slope of the straight line in the V-I graph. ***[1]***

(iii) **Non-ohmic Resistor** The conductor which does not obey Ohm's law is known as non-ohmic resistor. ***[1]***

19. (i) A substance has nearly zero resistance at a temperature of 1K. What is such a substance called?

(ii) State any two factors which affect the resistance of a metallic wire. ***[2010]***

Sol. (i) The substance which has nearly zero resistance at a temperature of 1K is called as superconductor. ***[1]***

(ii) *The two factors which affect the resistance of a metallic wire are*

(a) length of the wire (l), i.e., $R \propto l$

(b) area of cross-section (A), i.e., $R \propto \frac{l}{A}$ ***[2]***

20. Read the following informations :

(i) Resistivity of copper is lower than that of aluminium which in turn is lower than that of constantan.

(ii) Six wires labelled as A, B, C, D, E and F have been designed as per the following parameters :

Wire	Length	Diameter	Material	Resistance
A	l	$2d$	Aluminium	R_1
B	$2l$	$d/2$	Constantan	R_2
C	$3l$	$d/2$	Constantan	R_3
D	$l/2$	$3d$	Copper	R_4
E	$2l$	$2d$	Aluminium	R_5
F	$l/2$	$4d$	Copper	R_6

Answer the following questions using the above data:

(a) Which of the wires has maximum resistance and why?

(b) Which of the wires has minimum resistance and why?

(c) Arrange R_1, R_3 and R_5 in ascending order of their values. Justify your answer.

Sol. (a) Wire C has maximum resistance because it has maximum length, least thickness and highest resistivity. ***[1]***

(b) Wire F has the minimum resistance, since it has least length, maximum thickness and least resistivity. ***[1]***

(using, $R = \rho \frac{l}{A}$)

(c) $R_3 > R_5 > R_1$

(using relation, $R = \rho \frac{l}{A}$ and comparison) ***[1]***

21. What is meant by "electrical resistance" of a conductor? State how resistance of a conductor is affected when (i) a low current passes through it for a short duration and (ii) a heavy current passes through it for about 30 s.

Sol. Electrical resistance of a conductor may be defined as the basis property of any substance due to which it opposes the flow of current through it. Current is inversely proportional to resistance. ***[1]***

(i) The resistance of the conductor will increase when a low current pass through it for a short duration. ***[1]***

(ii) The resistance of the conductor will decrease when a heavy current pass through it. ***[1]***

22. (i) Write an expression for the electrical energy spent in the flow of current through an electrical appliance in terms of I, R and t.

(ii) At what voltage is the alternating current supplied to our houses?

(iii) How should the electric lamps in a building be connected? ***[2012]***

Sol. (i) The expression for the electrical energy, $E = I^2 Rt$. **[1]**

(ii) Alternating current supplied to our houses is at voltage 220 V. **[1]**

(iii) The electric lamp in a building should be connected in parallel. **[1]**

23. (i) An electric bulb is marked 100 W, 250 V. What information does this convey?

(ii) How much current will the bulb draw, if connected to a 250 V supply? **[2011]**

Sol. (i) It conveys that when the bulb is lighted on 250 V supply, it consumes 100 W electrical power i.e., 100 J of electrical energy is consumed in 1s. **[2]**

(ii) Current draw, $I = \dfrac{P}{V} = \dfrac{100}{250} = 0.4 \text{ A}$ **[1]**

24. (i) A fuse is rated 8 A. Can it be used with an electrical appliance rated 5 kW, 200 V? Give a reason.

(ii) Name the safety devices which are connected to the live wire of a household electric circuit. **[2018]**

Sol. (i) Given, power $(P) = 5 \text{ kW} = 5 \times 10^3 \text{ W}$

$V = 200 \text{ V}$

We know that, $I = \dfrac{P}{V}$

$$I = \frac{5 \times 10^3}{200} \Rightarrow I = 2.5 \times 10$$

$\therefore \quad I = 25\text{A} > 8\text{A}$

Thus, it cannot be used as the appliance will get fused. **[1½]**

(ii) Fuse, MCB **[1½]**

25. (i) Two sets *A* and *B* of three bulbs each, are glowing in two separate rooms. When one of the bulbs in set *A* is fused, the other two bulbs also cease to glow. But in set *B*, when one bulb fuses, the other two bulbs continue to glow. Explain why this phenomenon occurs?

(ii) Why do we prefer arrangements of set *B* for house circuiting? **[2014]**

Sol. (i) The bulbs of set *A* are connected in series. Therefore, when one bulb fuse the current stop flowing. Whereas, the bulbs of set *B* are connected in parallel. When one bulb fuse, then current flows through the other bulbs. **[2]**

(ii) We prefer arrangement of set *B* for house circuiting, because the potential difference in it is same. **[1]**

26. (i) Which particles are responsible for current in conductors?

(ii) Two which wire of a cable in a power circuit, should the metal case of a geyser be connected?

(iii) To which wire, should the fuse be connected? **[2017]**

Sol. (i) Electrons are responsible for the conduction of current in conductors. **[1]**

(ii) Earth wire of a cable in a power circuit should be connected to the metal case of geyser. **[1]**

(iii) Fuse should be connected to live wire. **[1]**

27. (i) A cell is sending current in an external circuit. How does the terminal voltage compare with the emf of the cell?

(ii) What is the purpose of using a fuse in an electrical circuit?

(iii) What are the characteristic properties of fuse wire? **[2012]**

Sol. (i) Terminal voltage is less than that of emf of the cell.

(ii) The purpose of using a fuse in an electrical circuit is to limit the electric current in an electric circuit when there is overheating or overloading in the circuit. A fuse is used as safety device. **[2]**

(iii) The characteristic properties of fuse wire are low melting point and high resistance. **[1]**

28. (i) Which particles are responsible for current in conductors?

(ii) To which wire of a cable in a power circuit should the metal case of a geyser be connected?

(iii) To which wire should the fuse be connected? **[2016]**

Sol. (i) Electrons are responsible for the conduction of current in conductors. **[1]**

(ii) Earth wire of a cable in a power circuit should be connected to the metal case of geyser. **[1]**

(iii) Fuse should be connected to live wire. **[1]**

29. (i) An electrical gadget can give an electric shock to its user under certain circumstance. Mention any two of these circumstances.

(ii) What preventive measure provided in a gadget can protect a person from an electric shock? **[2013]**

Sol. (i) *The two circumstances, which give electric shock are as*

(a) an electric shock may be caused due to poor insulation of wires.

(b) when wires of electric appliances are touched with wet hands. **[2]**

(ii) To prevent from electric shocks, the insulation of wires must be of good quality and it should be checked from time to time particularly when they become old. **[1]**

30. (i) Name the colour code of the wire which is connected to the metallic body of an appliance.

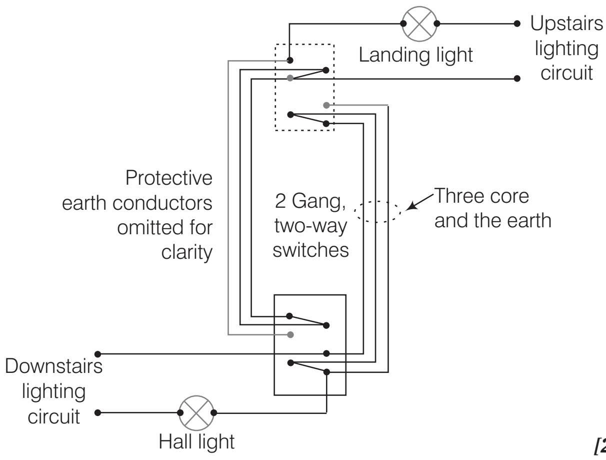
(ii) Draw the diagram of a dual control switch when the appliance is switched 'ON' *[2017]*

Sol. (i) *The colour coding of wires in a cable are as follow*

Wires	Colour	
	Old Convention	New Convention
Live	Red	Brown
Neutral	Black	Light blue
Earth	Green	Green or Yellow

[1]

(ii) **Two-Way or Dual Way Switch** It means two or more switches in different locations to control one lamp. This figure illustrates that lights to be controlled from both locations.

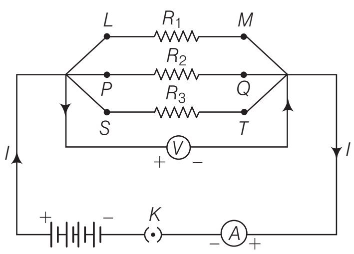


[2]

d 4 Marks Questions

31. How will you conclude that the same potential difference (voltage) exists across three resistors connected in a parallel arrangement to a battery?

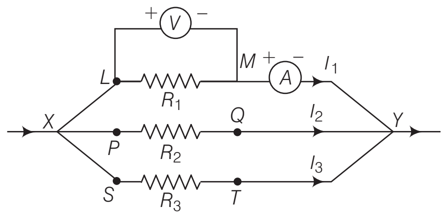
Sol. The experimental set up comprises of three resistors R_1, R_2 and R_3 which are joined in parallel combination and connecting them with a battery, an ammeter (A), a voltmeter (V) and a plug key K, as shown in Fig. (a). The key K is closed and the voltmeter and ammeter readings are recorded.



(a)

[1½]

The key K is open and removing the ammeter and voltmeter from the circuit and insert the voltmeter V in parallel with R_1 and ammeter in series with the resistor R_1, as shown in Fig. (b). Again, the voltmeter and ammeter readings are recorded.



(b)

[1½]

Similarly, measuring the potential differences across resistances, R_2 and R_3. It is found that voltmeter gives identical reading which leads to conclude that the voltage or potential difference across each resistors is same and equal to the potential difference across the combination. *[1]*

32. (i) The potential difference between two points in an electric circuit is 1 V. What does it mean? Name a device that helps to measure the potential difference across a conductor.

(ii) Why does the connecting cord of an electric heater not glow while the heating element does?

(iii) *Electrical resistivities of some substances at 20 °C are given as below*

Silver	: 1.60×10^{-8} Ω-m
Copper	: 1.62×10^{-8} Ω-m
Tungsten	: 5.2×10^{-8} Ω-m
Iron	: 10.0×10^{-8} Ω-m
Mercury	: 94.0×10^{-8} Ω-m
Nichrome	: 100×10^{-8} Ω-m

Answer the following questions using above data:

(a) Among silver and copper, which one is a better conductor and why?

(b) Which material would you advise to be used in electrical heating devices and why?

Sol. (i) The potential difference between two points is 1 V, means that, if a charge of 1 C is moved from one point to the other, then 1 J of work is required. The potential difference across a conductor is measured by means of an instrument called the voltmeter. *[1]*

(ii) The electric power P is given by

$$P = I^2 R$$

The resistance of the heating element is very high. Large amount of heat generates in the heating element and it glows hot.

The resistance of connecting cord is very low. Thus, negligible heat generates in the connecting cord and it does not glow. *[1]*

(iii) (a) Silver is a better conductor due to its lower resistivity.

(b) Nichrome should be used in electrical heating devices due to very high resistivity. *[2]*

33. Obtain an expression for the heat produced in a conductor when a voltage V is applied across it. Heating effect of electric current is desirable as well as undesirable. Explain this statement.

Sol. When an electric charge Q moves against a potential difference V, then the amount of work done is given by

$$W = Q \times V \quad \ldots(i)$$

We also know that, $I = Q / t$

So, $Q = I \times t$ ...(ii)

and from Ohm's law, $V = IR$ ...(iii)

Putting the values of Eqs. (ii) and (iii) in Eq. (i), we get

$$W = I \times t \times I \times R$$

$\therefore$ Work done, $W = I^2 Rt$ *[1½]*

Assuming that all the electrical work done or all the electrical energy consumed is converted into heat energy.

$\therefore$ $W = H = I^2 Rt$ *[1]*

Heating effect of electric current is desirable because it as useful for the functioning of electrical bulbs, etc, and undesirable because it bads to unnecessary loss of energy in the form of heat. *[1½]*

34. (i) Which is the better way to connect lights and other appliances in domestic circuit, series connection or parallel connection? Justify your answer.

(ii) An electrician has made electric circuit of a house in such a way that, if a lamp gets fused in a room of the house, then all the lamps in other rooms of the house stop working.

What is the defect in this type of circuit wiring? Give reason.

Sol. (i) Parallel connection is a better way to connect lights and other appliances in domestic circuit. *[1]*

It is because

(a) when we connect a number of devices in parallel combination, each device gets the same potential as provided by the battery and it keeps on working even, if other devices stop working.

(b) parallel connection is helpful when each device has different resistances and requires different current for its operation as in this case the current divides itself through different devices unlike series connection. *[1]*

(ii) Electrician has made series connection of all the lamps in electric circuit of house because of which, if one lamp gets fused, all the other lamps stop working. *[1]*

This is due to the fact that when devices are connected in series, then if one device fails, the circuit gets broken and all the devices in that circuit stop working. *[1]*

35. (i) Explain the meaning of the statement 'current rating of a fuse is 5A.

(ii) In the transmission of power, the voltage of power generated at the generating stations is stepped up from 11 kV to 132 kV before it is transmitted. Why? *[2017]*

Sol. (i) Current rating of fuse is 5A means, it is a safety device having short length of thin wire having low melting point of a particular amount of current 5A. Whenever current through this fuse exceeds the 5A limit, it will melt and break the circuit and save main circuit components from damage. *[2]*

(ii) Step-up transformer increases the amplitude of alternating voltage from 11 kV to 132 kV before it is transmitted to get better efficiency with less loss of energy. *[2]*

Numerical Based Questions

36. Calculate the amount of charge that flows through a conductor when a current of 5A flows through it for 2 min.

Sol. Given, $I = 5\text{A}$, $t = 2 \text{ min} = 2 \times 60 \text{ s} = 120 \text{ s}$, $q = ?$

We know that, charge, $q = I \times t$

$\Rightarrow$ $q = 5 \times 120 = 600 \text{ C}$

Thus, the amount of charge flowing through conductor is 600 C. *[2]*

37. A current of 1 A is drawn by a filament of an electric bulb. What would be the number of electrons passing through a cross-section of the filament in 16 s?

Sol. Given, $I = 1 \text{ A}$, $t = 16 \text{ s}$

We know that, current, $I = \frac{q}{t} = \frac{ne}{t}$

$(\because q = ne)$

$\Rightarrow$ $n = \frac{I \times t}{e} = \frac{1 \times 16}{1.6 \times 10^{-19}}$

$(\because e = 1.6 \times 10^{-19} \text{ C})$

$= 10^{20}$ electrons *[2]*

38. Calculate the work done in moving a charge of 4 C from a point at 220 V to a point at 230 V.

Sol. Given, charge, $q = 4$ C

Potential at point A, $V_A = 220$ V

Potential at point B, $V_B = 230$ V

Work done, $W = ?$

$\therefore$ Potential difference, $\Delta V = V_B - V_A$

$= 230 - 220 = 10$ V

We know that, work done,

$$W = \Delta V \times q = 10 \times 4 = 40 \text{ J}$$ **[2]**

39. A metal wire of resistance 6 Ω is stretched so that its length is increased to twice its original length. Calculate its new resistance. **[2013]**

Sol. Given, $R_1 = 6\,\Omega$, $l_1 = l$

$l_2 = 2l_1 = 2l$, $R_2 = ?$

$$R_1 = \rho\frac{l_1}{A_1} \text{ and } R_2 = \rho\frac{l_2}{A_2}$$ **[1]**

The volume of metal wire remains same.

$$\therefore \quad A_1 l_1 = A_2 l_2 \quad \Rightarrow \quad \frac{l_2}{l_1} = \frac{A_1}{A_2}$$

Now, $$\frac{R_2}{R_1} = \frac{l_2}{A_2} \times \frac{A_1}{l_1} = \frac{l_2}{l_1} \times \frac{l_2}{l_1}$$

$$\Rightarrow \quad R_2 = R_1\left(\frac{l_2}{l_1}\right)^2 = 6\left(\frac{2l}{l}\right)^2 = 24\,\Omega$$ **[1]**

40. A copper wire of resistivity 1.63×10^{-8} Ω-m has cross-section area of 10.3×10^{-4} cm^2. Calculate the length of the wire required to make a 20 Ω coil.

Sol. Given, $\rho = 1.63 \times 10^{-8}$ Ω-m

$A = 10.3 \times 10^{-4} \text{ cm}^2 = 10.3 \times 10^{-4} \times 10^{-4} \text{ m}^2$

$R = 20\,\Omega$, $l = ?$

We know that, $R = \frac{\rho l}{A}$

$$\Rightarrow \quad l = \frac{RA}{\rho} = \frac{20 \times 10.3 \times 10^{-4} \times 10^{-4} \text{ m}^2}{1.63 \times 10^{-8}\,\Omega\text{-m}}$$

$$= \frac{20 \times 10.3 \times 10^{-8}}{1.63 \times 10^{-8}}$$

$= 126.38$ m **[3]**

41. How is the resistance of a wire affected, if (i) its length is doubled and (ii) its radius is doubled?

Sol. (i) $\therefore$ $R = \frac{\rho l}{A}$ (where, l = length of wire and A = area of cross-section of wire.)

$$R' = \frac{\rho l \times 2}{A}$$

$\because \quad R' = 2R$ **[1½]**

i.e., resistance will be doubled, if length of the wire is doubled.

(ii) $\therefore$ $R = \frac{\rho l}{A} \Rightarrow R = \frac{\rho l}{\pi r^2}$ $(\because A = \pi r^2)$

$$R' = \frac{\rho l}{\pi (2r)^2} = \frac{\rho l}{\pi r^2} \times \frac{1}{4} = \frac{R}{4}$$

Thus, resistance will decrease by four times, if radius of wire is doubled. **[1½]**

42. A metal wire has diameter of 0.25 mm and electrical resistivity of 0.8×10^{-8} Ω-m.

(i) What will be the length of this wire to make a resistance 5 Ω?

(ii) How much will the resistance change, if the diameter of the wire is doubled?

Sol. Given, diameter = 0.25 mm

Resistivity, $\rho = 0.8 \times 10^{-8}$ Ω-m

Resistance, $R = 5\Omega$

(i) We know that, $R = \frac{\rho l}{A}$

$$\Rightarrow \quad l = \frac{RA}{\rho} = \frac{5\Omega \times \pi \times \left(\frac{0.25}{2} \times 10^{-3}\right)^2}{0.8 \times 10^{-8}}$$

$$\left(\because A = \pi r^2 \text{ and } r = \frac{D}{2}\right)$$

$$= \frac{5 \times \pi \times 1.56 \times 10^{-8}}{0.8 \times 10^{-8}}$$ **[1]**

(ii) Resistance,

$$R = \frac{\rho l}{A} = \frac{\rho l}{\pi\left(\frac{D}{2}\right)^2} \quad \left(\because A = \pi r^2 \text{ and } r = \frac{D}{2}\right)$$

$$= \frac{\rho l}{\pi} \times \frac{4}{D^2}$$

New resistance,

$$R' = \frac{\rho l}{A} = \frac{\rho l}{\pi\left(\frac{2D}{2}\right)^2} \quad (\because D \text{ has become } 2D)$$

$$= \frac{\rho\, l}{\pi\, D^2}$$ **[1]**

Now, $$\frac{R'}{R} = \frac{\rho l}{\pi D^2} \div \frac{\rho l \times 4}{\pi D^2} = \frac{\rho l}{\pi D^2} \times \frac{\pi D^2}{\rho l \times 4} = \frac{1}{4}$$

$$\therefore \quad R' = \frac{R}{4}$$

Thus, resistance will decrease by 4 times. **[1]**

43. You have three resistors of values 2 Ω, 3 Ω and 5 Ω. How will you join them so that the total resistance is more than 7 Ω?

(i) Draw a diagram for the arrangement.

(ii) Calculate the equivalent resistance. ***[2018]***

Sol. To get total resistance more than 7Ω. We can connect 2Ω, 3Ω and 5Ω in series.

(i)

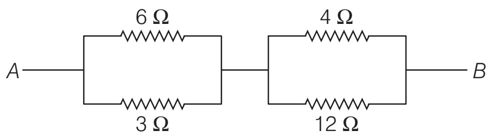
[1]

(ii) $R_{eq} = R_1 + R_2 + R_3$ (for series combination)

$R_{eq} = 2 + 3 + 5$

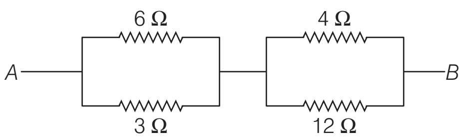
$R_{eq} = 10\Omega$ **[1]**

44. (i) Find the equivalent resistance between A and B.



(ii) State whether the resistivity of a wire changes with the change in the thickness of the wire. ***[2018]***

Sol. (i)



In the circuit 6Ω and 3Ω are in parallel combination.

$$\therefore \quad \frac{1}{R_{P_1}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$R_{P_1} = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{6 \times 3}{6+3} = \frac{18}{9} = 2\Omega$$

4Ω and 12Ω resistance are in parallel combination.

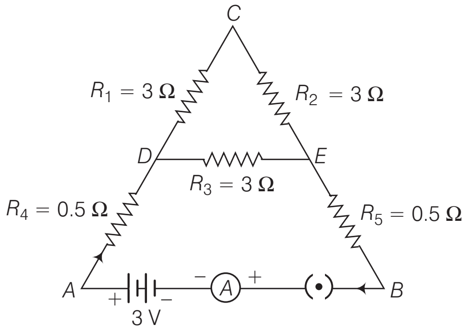
$$R_{P_2} = \frac{R_3 \times R_4}{R_3 + R_4} = \frac{4 \times 12}{4 + 12} = \frac{48}{16} = 3\Omega$$

Total resistance of circuit,

$$R_T = R_{P_1} + R_{P_2} = 2 + 3 = 5\Omega$$ ***[1½]***

(ii) Resistivity is a material property it does not changes with change in thickness of wire. ***[1½]***

45. Five resistors are connected in a circuit as shown in figure. Find the ammeter reading when the circuit is closed.



Sol. R_1 and R_2 are in series.

$$R_{S1} = R_1 + R_2 = 3 + 3 = 6\,\Omega$$

R_{S1} and R_3 are in parallel.

$$\therefore \quad \frac{1}{R_P} = \frac{1}{R_{S1}} + \frac{1}{R_3} = \frac{1}{6} + \frac{1}{3} = \frac{1}{2}$$

$$\Rightarrow \quad R_P = 2\,\Omega$$ **[1]**

R_4, R_P and R_5 are in series.

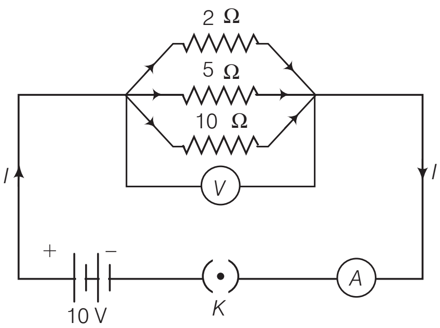
$$\therefore \quad R_S = R_4 + R_P + R_5$$ **[1]**

$$= 0.5 + 2 + 0.5 = 3\,\Omega$$

Then, current, $$I = \frac{V}{R_S}$$

$$= \frac{3}{3} = 1\text{ A}$$ **[1]**

46. A circuit diagram is given as shown below:



Calculate

(i) the total effective resistance of the circuit.

(ii) the total current in the circuit.

(iii) the current through each resistor.

Sol. Given, $R_1 = 2\ \Omega$, $R_2 = 5\ \Omega$, $R_3 = 10\ \Omega$, $V = 10\ \text{V}$

(i) Total effective resistance as the combination is in parallel,

$$\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{2} + \frac{1}{5} + \frac{1}{10} = \frac{5+2+1}{10} = \frac{8}{10}$$

$$\Rightarrow \quad R_{\text{eff}} = \frac{10}{8} = 1.25\ \Omega$$ **[1]**

(ii) Total current, $I = I_1 + I_2 + I_3 = 5 + 2 + 1 = 8\ \text{A}$ **[1]**

(iii) Current through each resistor,

$$I_1 = \frac{V}{R_1} = \frac{10}{2} = 5\ \text{A},$$

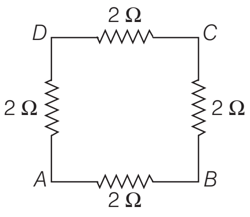
$$I_2 = \frac{V}{R_2} = \frac{10}{5} = 2\ \text{A} \text{ and } I_3 = \frac{V}{R_3} = \frac{10}{10} = 1\ \text{A}$$ **[1]**

47. Four resistances of 2.0 Ω each are joined end to end, to form a square *ABCD*. Calculate the equivalent resistance of the combination between any two adjacent corners. ***[2015]***

Sol. Resistance between two adjacent corners *A* and *B* is

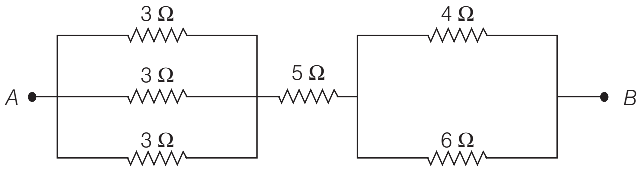
$$\frac{1}{R} = \frac{1}{R_{AB}} + \frac{1}{R_{BC} + R_{CD} + R_{AD}}$$

$$= \frac{1}{2} + \frac{1}{2+2+2} = \frac{1}{2} + \frac{1}{6} = \frac{3+1}{6} = \frac{4}{6} = \frac{2}{3} \Rightarrow R = \frac{3}{2} = 1.5\ \Omega$$



[2]

48. Find the equivalent resistance between points *A* and *B*.



[2014]

Sol. The three resistance 3 Ω are in parallel.

$$\frac{1}{R_1} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = \frac{3}{3} = 1\ \Omega \Rightarrow R_1 = 1\ \Omega$$

and the resistance 4 Ω and 6 Ω are in parallel. **[1]**

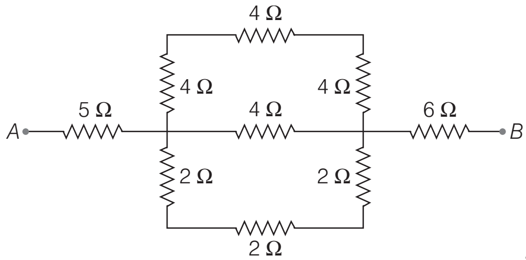
$$\frac{1}{R_3} = \frac{1}{4} + \frac{1}{6} = \frac{3+2}{12} = \frac{5}{12}\ \Omega$$

$$\Rightarrow \quad R_3 = \frac{12}{5} = 2.4\ \Omega$$ **[1]**

The resistances R_1, 5 Ω and R_3 are in series. So, total resistance

$$R = R_1 + 5 + R_3 = 1 + 5 + 2.4 = 8.4\ \Omega$$ **[1]**

49. Calculate the equivalent resistance between the points *A* and *B* for the following combination of resistors.



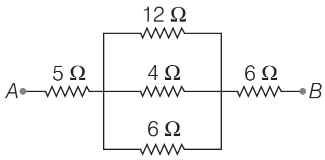
[2013]

Sol. The three resistance each of 4 Ω are in series.

$$\therefore \quad R_1 = 4 + 4 + 4 = 12\ \Omega$$

The three resistance 2 Ω are in series.

$$\therefore \quad R_2 = 2 + 2 + 2 = 6\ \Omega$$



[1]

The resistance 4 Ω, 12 Ω and 6 Ω are in parallel.

$$\therefore \quad \frac{1}{R_2} = \frac{1}{4} + \frac{1}{12} + \frac{1}{6} = \frac{3+1+2}{12} = \frac{6}{12} = \frac{1}{2}\ \Omega$$

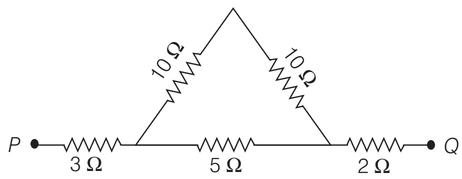
$$\Rightarrow \quad R_3 = 2\ \Omega$$ **[1]**

The resistors R_1, R_2 and R_3 are in series.

$$\therefore \quad R_{\text{eq}} = R_1 + R_2 + R_3$$

$$\Rightarrow \quad R_{\text{eq}} = 5 + 2 + 6 = 13\ \Omega$$ **[1]**

50. Calculate the equivalent resistance between *P* and *Q* from the following diagram.



[2012]

Sol. The two resistance 10 Ω are in series.

$$R = 10 + 10 = 20\ \Omega$$

The resistance 5 Ω and *R* are in parallel. **[1]**

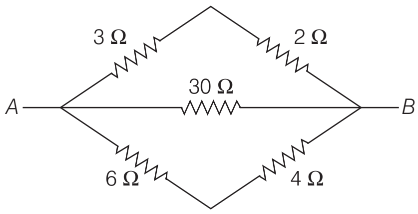
$$\therefore \quad \frac{1}{R_1} = \frac{1}{5} + \frac{1}{20} = \frac{4+1}{20} = \frac{5}{20} = \frac{1}{4}$$

The resistors R_1, 3 Ω and 2 Ω are in series. **[1]**

$\therefore$ Equivalent resistance,

$$R_{\text{eq}} = 3 + 4 + 2 = 9\ \Omega$$ **[1]**

51. Calculate the equivalent resistance between A and B from the following diagram.



[2011]

Sol. Resistance 3 Ω and 2 Ω are in series.

$\therefore \quad R_1 = 3 + 2 = 5\,\Omega$

Also resistance 6 Ω and 4 Ω are in series.

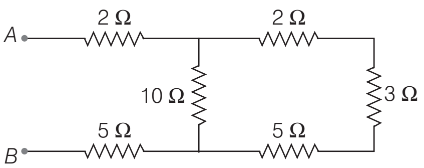
$\therefore \quad R_2 = 6 + 4 = 10\,\Omega$

Equivalent resistance between A and B is

$$\frac{1}{R_{\text{eq}}} = \frac{1}{5} + \frac{1}{30} + \frac{1}{10} = \frac{6+1+3}{30} = \frac{10}{30} = \frac{1}{3}$$

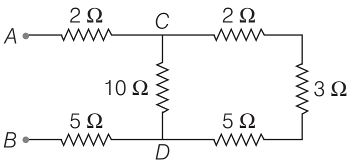
$$R_{\text{eq}} = 3\,\Omega$$ **[2]**

52. Six resistances are connected together as shown in the figure. Calculate the equivalent resistance between the points A and B.



[2010]

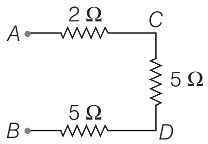
Sol. Resistance between the point C and D,



[1]

$$\frac{1}{R_{CD}} = \frac{1}{10} + \frac{1}{2+3+5} = \frac{1}{10} + \frac{1}{10} = \frac{2}{10} = \frac{1}{5}$$ **[1]**

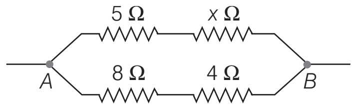
$\therefore \quad R_{CD} = 5\,\Omega$



Now, equivalent resistance between the points A and B.

$$R_{AB} = R_{AC} + R_{CD} + R_{BD}$$
$$= 2 + 5 + 5 = 12\,\Omega$$ **[1]**

53. The equivalent resistance of the following circuit diagram is 4 Ω. Calculate the value of x. **[2009]**



Sol. $\dfrac{1}{R_{AB}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} \Rightarrow \dfrac{1}{4} = \dfrac{1}{5+x} + \dfrac{1}{8+4}$

$\Rightarrow \quad \dfrac{1}{4} = \dfrac{1}{5+x} + \dfrac{1}{12}$

$\Rightarrow \quad \dfrac{1}{5+x} = \dfrac{1}{4} - \dfrac{1}{12} = \dfrac{3-1}{12} = \dfrac{2}{12} = \dfrac{1}{6}$

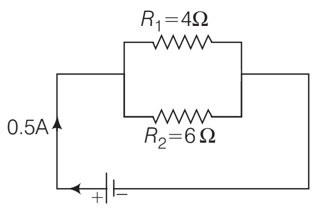
$\Rightarrow \quad 5 + x = 6 \Rightarrow x = 6 - 5 \Rightarrow x = 1\,\Omega$ **[2]**

54. Two resistor of 4 Ω and 6 Ω are connected in parallel to a cell to draw 0.5 A current from the cell.

(i) Draw a labelled circuit diagram showing the above arrangement.

(ii) Calculate the current in each resistor.

Sol. (i) *The circuit is shown below*



[2]

(ii) Let the current flowing through resistance R_1 is I and current flowing through R_2 resistance is $0.5 - I$.

$\therefore \quad I \times 4 = (0.5 - I) \times 6$

$\Rightarrow \quad 4I = 3 - 6I$

$\Rightarrow \quad 10I = 3$

$\Rightarrow \quad I = 0.3$ A

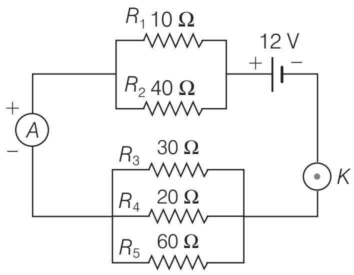
$\therefore$ Current flowing through $R_1 = 4\,\Omega$ is 0.3 A and current flowing through $R_2 = 6\,\Omega$ is

$0.5 - 0.3 = 0.2$ A **[2]**

55. Five resistors of different resistance are connected together as shown in the figure. A 12 V battery is connected to the arrangement. Calculate **[2010]**

(i) the total resistance in the circuit.

(ii) the total current flowing in the circuit.



Sol. (i) $\frac{1}{R_{12}} = \frac{1}{10} + \frac{1}{40} = \frac{4+1}{40} = \frac{5}{40} = \frac{1}{8}$

$\Rightarrow \quad R_{12} = 8\ \Omega$ **[2]**

$$\frac{1}{R_{345}} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60} = \frac{2+3+1}{60}$$

$$\frac{1}{R_{345}} = \frac{6}{60} = \frac{1}{10} \Rightarrow R_{345} = 10\ \Omega$$

Total resistance, $R = R_{12} + R_{345}$

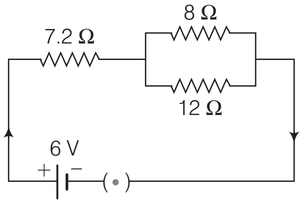
$= 8 + 10 = 18\ \Omega$

(ii) Total current, $I = \frac{V}{R} = \frac{12}{18} = \frac{2}{3} = 0.67$ A **[2]**

56. Three resistors are connected to a 6 V battery as shown in the figure.

Calculate

(i) the equivalent resistance of the circuit.
(ii) total current in the circuit.
(iii) potential difference across the 7.2 Ω resistor. **[2012]**



Sol. (i) Resistances 8 Ω and 12 Ω are in parallel.

$\therefore \frac{1}{R_1} = \frac{1}{8} + \frac{1}{12} = \frac{3+2}{24} = \frac{5}{24} \Rightarrow R_1 = \frac{24}{5} = 4.8\ \Omega$ **[1]**

Now, resistances R_1 and 7.2 are in series.

$\therefore \quad R_{eq} = 4.8 + 7.2 = 12\ \Omega$

(ii) $I = ?$

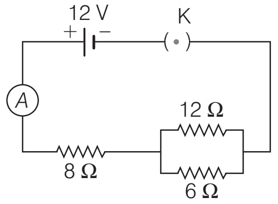
$$I = \frac{V}{V_{eq}} = \frac{6}{12} = \frac{1}{2} = 0.5\text{ A}$$ **[1]**

(iii) Potential difference across 7.2 Ω resistor

$= 0.5 \times 7.2 = 3.6$ V **[1]**

57. Three resistors are connected to a 12 V battery as shown in the figure given below.

(i) What is the current through the 8 Ω resistors?
(ii) What is the potential difference across the parallel combination of 6 Ω and 12 Ω resistors?
(iii) What is the current through the 6 Ω resistor? **[2011]**



Sol. (i) Resistances 12 Ω and 6 Ω are parallel.

So, $\frac{1}{R_1} = \frac{1}{12} + \frac{1}{6} = \frac{3}{12} = \frac{1}{4} \Rightarrow R_1 = 4\ \Omega$

Equivalent resistance,

$$R_{eq} = 4 + 8 = 12\ \Omega \Rightarrow I = \frac{V}{R_{eq}} = \frac{12}{12} = 1\text{A}$$ **[1]**

(ii) Potential Difference (PD) across parallel combination of resistances 6 Ω and 12 Ω is **[1]**

$$V = I \times R_1 = 1 \times 4 = 4\text{ V} \quad \left(\because R_{eq} = \frac{6 \times 12}{6+12} = 4\ \Omega\right)$$

(iii) Current through 6 Ω resistor is $= \frac{4\text{V}}{6\Omega} = 0.67$ A **[1]**

58. A music system draws a current of 400 mA, when connected to a 12 V battery.

(i) What is the resistance of the music system?
(ii) The music system is left playing for several hours and finally the battery voltage drops and the music system stops playing when the current drops to 320 mA. At what battery voltage does the music system stop playing? **[2016]**

Sol. Given, current, $I = 400\text{ mA} = 400 \times 10^{-3}\text{ A} = 0.4$ A

voltage, $V = 12$ V

(i) Resistance of music system,

$$R = \frac{V}{I} = \frac{12}{0.4} = \frac{120}{4} = 30\ \Omega$$ **[1]**

(ii) Resistance of music system, $R = 30\ \Omega$

Current, $I = 320\text{ mA} = 0.32$ A

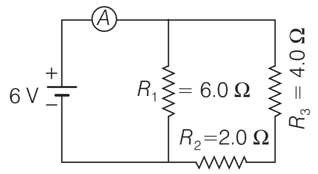
$\because$ By Ohm's law, $R = \frac{V}{I} \Rightarrow V = IR$

$\Rightarrow \quad V = 0.32 \times 30$

$\Rightarrow \quad V = \frac{32}{100} \times 30 = \frac{960}{100}$

$\Rightarrow \quad V = 9.60$ V **[2]**

59. Three resistors of 6.0 Ω, 2.0 Ω and 4.0 Ω respectively are joined together as shown in the figure. The resistors are connected to an ammeter and to a cell of emf 6.0 V. *[2008]*



Calculate
(i) the effective resistance of the circuit.
(ii) the current drawn from the cell.

Sol. (i) $R_S = R_2 + R_3 = 2 + 4 = 6\,\Omega$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{6} + \frac{1}{6} = \frac{1}{3} \Rightarrow R_{eq} = 3\,\Omega$$ *[1]*

(ii) $I = \frac{E}{R} = \frac{6}{3} = 2\text{ A}$ *[1]*

60. Two resistors with resistances 5 Ω and 10 Ω respectively, are to be connected to a battery of emf 6 V, so as to obtain
(i) (a) minimum current.
(b) maximum current.
(ii) How will you connect the resistances in each case?
(iii) Calculate the strength of the total current in the circuit in the two cases.

Sol. (i) (a) For obtaining minimum current, the two resistors should be connected in parallel.
(b) For obtaining maximum current, the two resistors should be connected in series. *[1]*

(ii) Given, $R_1 = 5\,\Omega$, $R_2 = 10\,\Omega$, $V = 6\text{ V}$

For parallel combination, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$

$$= \frac{1}{5} + \frac{1}{10} = \frac{2+1}{10} = \frac{3}{10} \Rightarrow R = \frac{10}{3}\,\Omega$$

∴ Total current in the circuit,

$$I = \frac{V}{R} = \frac{6 \times 3}{10} = 1.8\text{ A}$$ *[1]*

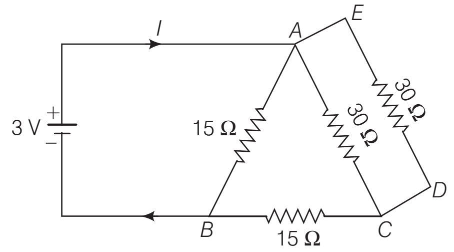
(iii) For series combination,

$$R = 5 + 10 = 15\,\Omega$$

∴ Total current in the circuit,

$$I = \frac{V}{R} = \frac{6}{15} = 0.4\text{ A}$$ *[1]*

61. (i) Find the value of current I in the circuit given as below



(ii) You have four resistors of 8 Ω each. Show how would you connect these resistors to have effective resistance of 8 Ω?

Sol. (i) R_{AC} and R_{ED} are in parallel, so

$$\frac{1}{R'_P} = \frac{1}{R_{AC}} + \frac{1}{R_{ED}} = \frac{1}{30} + \frac{1}{30} = \frac{1}{15}$$

$$\Rightarrow \quad R'_P = 15\,\Omega$$

Now, R'_P and R_{BC} are in series, so

$$R'_S = R'_P + R_{BC}$$
$$= 15 + 15 = 30\,\Omega$$

Again, R_{AB} and R'_S are in parallel, so

$$\frac{1}{R''_P} = \frac{1}{R_{AB}} + \frac{1}{R'_S} = \frac{1}{15} + \frac{1}{30} = \frac{1}{10}$$

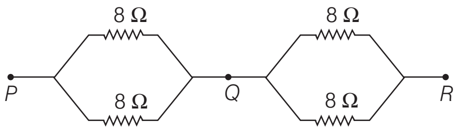
$$\therefore \quad R''_P = 10\,\Omega$$

So, current flowing through the circuit is

$$I = \frac{V}{R''_P} = \frac{3}{10} = 0.3\text{ A}$$ *[2]*

(ii) Two 8 Ω resistors are connected in parallel. Two such parallel combination must be connected in series to get effective resistance of 8 Ω.

Such combination is shown as below



[2]

62. Two resistances when connected in parallel give resultant value of 2 Ω, when connected in series the value becomes 9 Ω. Calculate the value of each resistance.

Sol. We know that two resistances are in parallel and hence

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R_P = \frac{R_1 R_2}{R_1 + R_2}$$

Given, $R_P = 2\,\Omega$

$\Rightarrow \quad 2 = \dfrac{R_1 R_2}{R_1 + R_2}$ **[1]**

$\therefore \quad 2(R_1 + R_2) = R_1 R_2$ ...(i)

Now, same resistances are in series, $R_S = R_1 + R_2$

Given, $R_S = 9\,\Omega$ and $9 = R_1 + R_2$ ...(ii)

From Eqs. (i) and (ii), we get

$$R_1 R_2 = 18$$

Again, using Eq. (ii), we get

$$R_2 = 9 - R_1$$

$\therefore \quad R_1 (9 - R_1) = 18$

$\Rightarrow \quad R_1^2 - 9R_1 + 18 = 0$

$\Rightarrow \quad R_1^2 - 6R_1 - 3R_1 + 18 = 0$ **[1]**

(by splitting the middle term)

$\Rightarrow \quad (R_1 - 6)(R_1 - 3) = 0$

Either, $R_1 = 6$ or $R_1 = 3$ and $R_2 = 3\,\Omega$ or $R_2 = 6\,\Omega$

Thus, two resistances are $3\,\Omega$ and $6\,\Omega$. **[1]**

63. An electric bulb of resistance $500\,\Omega$, draws a current of 0.4 A. Calculate the power of the bulb and the potential difference at its end. ***[2017]***

Sol. Given, resistance of bulb, $R = 500\,\Omega$, current, $I = 0.4$ A, power, $P = ?$, potential difference, $V = ?$

As we known power, $P = I^2 R$

$$= (0.4)^2 \times 500$$

$\therefore$ Power, $P = 80$ W

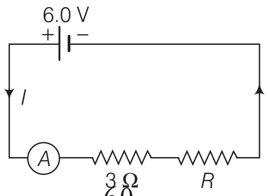
Potential difference, $V = IR = 0.4 \times 500 = 200$ V **[2]**

64. The figure shows a circuit, when the circuit is switched on, the ammeter reads 0.5 A.

(i) Calculate the value of the unknown resistor R.

(ii) Calculate the charge passing through the $3\,\Omega$ resistor in 120 s.

(iii) Calculate the power dissipated in the $3\,\Omega$ resistor. ***[2013]***



Sol. (i) $I = \dfrac{V}{R} \Rightarrow 0.5 = \dfrac{6.0}{3 + R}$ **[1]**

$\Rightarrow 3 + R = \dfrac{6}{0.5} \Rightarrow R = \dfrac{60}{5} - 3 = 9\,\Omega$

(ii) $Q = I \times t = 0.5 \times 120 = 60$ C **[1]**

(iii) $P = VI = I^2 R = (0.5)^2 \times 3$

$= 0.25 \times 3 = 0.75$ W **[1]**

65. Calculate the quantity of heat produced in a $20\,\Omega$ resistor carrying 2.5 A current in 5 min. ***[2016]***

Sol. Given, resistance, $R = 20\,\Omega$

Current, $I = 2.5$ A

Time, $t = 5$ min $= 5 \times 60 = 300$ s **[1]**

According to Joule's law of heating,

$$H = I^2 Rt = (2.5)^2 \times 20 \times 300$$

$$= \frac{625}{100} \times 20 \times 300 = 625 \times 20 \times 3$$

$H = 37500$ J **[1]**

66. An electrical heater is rated 4 kW, 220 V. Find the cost of using this heater for 12 h, if one kWh of electrical energy costs 3.25.

Sol. Given, $P = 4$ kW, $V = 220$ V, $t = 12$ h

$$E = P \times t = 4 \times 12 = 48 \text{ kWh}$$

Cost of energy consumed = 48 × 3.25 = ₹156 **[2]**

67. An electric iron is rated 220 V, 2 kW.

(i) If the iron is used for 2 h daily, find the cost of running it for one week if it costs ₹4.25 per kWh.

(ii) Why is the fuse absolutely necessary in a power circuit? ***[2018]***

Sol. (i) Given, power $(P) = 2 \times 10^3$ W $= 2$ kW

Voltage $(V) = 220$ V

Time (t) = 2h daily for 1 week $= 2 \times 7 = 14$h

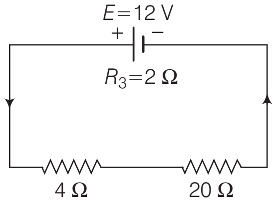
Electrical energy (in kWh)

$= P \times t = 2 \times 14 = 28$ kWh

Running cost = 28×4.25=₹119. **[2]**

(ii) The purpose of using a fuse in an electrical circuit is to limit the electric current in a electric circuit. It prevents overheating or overloading in the circuit when a short circuit occurs. **[2]**

68. A battery of emf 12 V and internal resistance $2\,\Omega$ is connected with two resistors A and B of resistance $4\,\Omega$ and $6\,\Omega$ respectively joined in series. ***[2016]***



Find

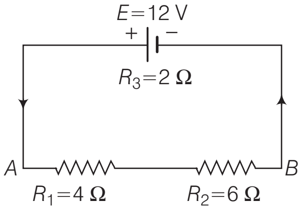
(i) current in the circuit.

(ii) the terminal voltage of the cell.

(iii) the potential difference across 6 Ω resistor.

(iv) electrical energy spent per minute in 4 Ω resistor.

Sol. According to question,



(i) Current in the circuit is given by

$$V = IR_{eq}$$
$$I = \frac{V}{R_{eq}} = \frac{12}{4+6+2} = 1\text{A}$$ **[1]**

($R_{eq} = R_1 + R_2 + R_3$, for series combination)

(ii) Terminal voltage of cell is given by

$$TPD = E - Ir = 12 - 1\times 2 = 10 \text{ V}$$ **[1]**

(iii) Potential difference across 6 Ω resistance is given by

$$V = IR_2 = 1\times 6 = 6 \text{ V}$$ **[1]**

(iv) Electric energy spent per minute is given by

$$I^2Rt = 1^2 \times 4 \times 60 \quad (\because 1 \text{ min} = 60 \text{ s})$$
$$= 240 \text{ J}$$ **[1]**

69. An electrical appliance is rated at 1000 kVA, 220 V. If the appliance is operated for 2h, calculate the energy consumed by the appliance in

(i) kWh (ii) joule

Sol. Given, $P = 1000$ kVA $= 1000$ kW, $t = 2h$

(i) Energy consumed in kWh is

$$E = P \times t = 1000 \times 2 = 2000 \text{ kWh}$$ **[1]**

(ii) Energy consumed in joule is

$$E = 2000 \times 3.6 \times 10^6 \text{ J} = 7.2 \times 10^9 \text{ J}$$ **[1]**

70. Two bulbs are marked 100 W, 220 V and 60 W, 110 V. Calculate the ratio of their resistance. **[2011]**

Sol. $P_1 = 100$ W, $P_2 = 60$ W, $V_1 = 220$ V,

$$V_2 = 110 \text{ V}, \frac{R_1}{R_2} = ?$$

We know that power is given by **[1]**

$$P = \frac{V^2}{R}$$

$$\therefore \quad R_1 = \frac{V^2}{P_1} \text{ and } R_2 = \frac{V_2^2}{P_2}$$

$$\Rightarrow \quad R_1 = \frac{(220)^2}{100} \text{ and } R_2 = \frac{(110)^2}{60}$$

$$\frac{R_1}{R_2} = \frac{\frac{(220)^2}{100}}{\frac{(110)^2}{60}} = \frac{(220)^2 \times 60}{(110)^2 \times 100} = \frac{12}{5}$$ **[2]**

71. An electric heater is rated 1000 W – 200 V. Calculate

(i) the resistance of the heating element.

(ii) the current flowing through it. **[2009]**

Sol. Given, $P = 1000$ W, $V = 200$ V **[1]**

(i) $R = \frac{V^2}{P} = \frac{200 \times 200}{1000} = 40\ \Omega$

(ii) $I = \frac{P}{V} = \frac{1000}{200} = 5\text{A}$ **[1]**

72. If the current I through a resistor is increased by 100% (assume that temperature remains unchanged), then find the increase in power dissipated.

Sol. Since, $P = I^2R$

Current after increased by

$$100\% = I + \frac{100I}{100} = 2I$$
$$P' = (2I)^2R = 4I^2R$$ **[1]**

$\therefore$ Percentage increase in power dissipation

$$= \frac{P'-P}{P} \times 100$$
$$= \frac{4I^2R - I^2R}{I^2R} \times 100$$
$$= \frac{I^2R(4-1)}{I^2R} \times 100$$
$$= 3 \times 100 = 300\%$$ **[1]**

73. An electrician puts a fuse of rating 5 A in that part of domestic electrical circuit in which an electric heater of rating 1.5 kW, 220 V is operating. What is likely to happen in this case and why?

Sol. Given, $P = 1.5$ kW $= 1.5 \times 10^3$ W, $V = 220$V

$\therefore$ The current drawn by heater, $I = \frac{P}{V}$ **[1/2]**

$$= \frac{1.5 \times 10^3 \text{ W}}{220 \text{ V}} = 6.8 \text{ A}$$ **[1/2]**

The above amount of current is greater than the rated value of fuse current. Hence, the fuse will melt and break the circuit. **[1]**

74. The potential difference between two terminals of an electric iron is 220V and the current flowing through its element is 5A. Calculate the resistance and wattage of the electric iron.

Sol. The potential difference between two terminals of an electric iron $(V) = 220$V, current flowing through its element $(I) = 5$ A.

Therefore, resistance, $R = \frac{V}{I} = \frac{220}{5}\,\Omega$

$R = 44\,\Omega$ **[1]**

We know that, power, $P = V \times I$

$= 220 \times 5 = 1100$ W **[1]**

75. An electric geyser rated at 1500 W, 250 V is connected to a 250 V line mains. Solve

(i) the electric current drawn by it.
(ii) energy consumed by it in 50 h.
(iii) cost of energy consumed, if each unit costs ₹ 6.

Sol. Given, power, $P = 1500$W, voltage, $V = 250$ V

(i) $\therefore$ Electric current drawn,

$$I = \frac{P}{V} = \frac{1500}{250} = 6\text{ A}$$ **[1]**

(ii) $\therefore$ Energy consumed, E = Power $\times$ Time

$= 1500 \times 50$ $(\because t = 50\text{ h})$

$= 75000$ Wh $(\because 1\text{ kW} = 1000\text{ W})$

$= 75$ unit $(\because 1\text{ unit} = 1\text{ kWh})$

(iii) $\because$ Cost of energy consumed

$= 75 \times 6 =$ ₹ 450 **[1]**

76. An electric iron consumes energy at a rate of 840 W when heating is at the maximum rate and 360 W when the heating is at the minimum rate. The applied voltage is 220 V. What is the value of current and the resistance in each case?

Sol. We know that the power input is $P = VI$

Thus, the current, $I = \frac{P}{V}$ **[1]**

When heating is at the maximum rate,

$$I = \frac{840\text{ W}}{220\text{ V}} = 3.82\text{ A}$$

and the resistance of the electric iron is

$$R = \frac{V}{I} = \frac{220\text{ V}}{3.82\text{ A}} = 57.59\,\Omega$$ **[1]**

When heating is at the minimum rate,

$$I = \frac{360\text{ W}}{220\text{ V}} = 1.64\text{ A}$$

and the resistance of the electric iron is

$$R = \frac{V}{I} = \frac{220\text{ V}}{1.64\text{ A}} = 134.15\,\Omega$$ **[1]**

77. An electrical bulb is rated 40 W, 220 V. How many bulbs can be connected in parallel with each other across the two wires of 220 V line, if the maximum allowable current is 6 A?

Sol. Given, $P = 40$ W, $V = 220$ V, $I = 6$ A

We know that, $R = V^2 / P = (220)^2 / 40$

$= 48400 / 40 = 1210\Omega$ **[1]**

Now, $V = IR_{eq} \Rightarrow R_{eq} = V / I = 220 / 6 = 36.66\,\Omega$

Suppose, there are x number of bulb in parallel

$1 / 36.66 = x / 1210$

$\therefore \quad x = 1210 / 36.66 = 33.006 \approx 33$ **[1]**

78. A heater coil connected to 200 V has a resistance of 80 Ω. If the heater is plugged in for the time t such that 1 kg of water at 20°C attains a temperature of 60°C. Find

(i) the power of heater.
(ii) the heat absorbed by water.
(iii) the value of t in seconds.

Sol. (i) $\therefore$ Power of heater,

$$P = \frac{V^2}{R} = \frac{200 \times 200}{80} = 500\text{ W}$$ **[1]**

(ii) $\therefore$ Heat absorbed by water, $H = mC\theta_R$

$= 1 \times 4200 \times 40$

$(\because \theta_R = 60° - 20° = 40°\text{C}, C = 4200\text{ J/kg °C})$

$= 168000$ J

$= 168$ kJ **[1]**

(iii) $\therefore$ Energy consumed by heater, $H = P \times t$

$$168000 = 500 \times t \Rightarrow t = \frac{168000}{500} = 336\text{ s}$$ **[1]**

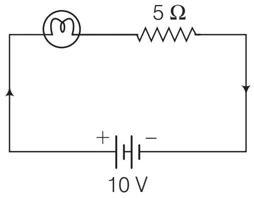
79. (i) A current of 1 A flows in a series circuit having an electric lamp and a conductor of 5 Ω when connected to a 10 V battery. Calculate the resistance of the electric lamp.

(ii) Now, if a resistance of 10 Ω is connected in parallel with this series combination, then what change (if any) in current flowing through 5 Ω conductor and potential difference across the lamp will take place? Give reason.

Sol. (i) Let the resistance of the lamp be R_1 and resistance of conductor be $R_2 = 5\,\Omega$

$\therefore$ Total resistance in series, $R_S = R_1 + R_2 = R_1 + S$

Current, $I = 1\,\text{A}$, voltage, $V = 10\,\text{V}$



Using Ohm's law, $V = IR_S$

$$10 = 1(R_1 + 5) \Rightarrow R_1 = 5\,\Omega$$

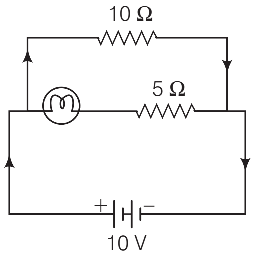
Thus, the resistance of electric lamp is $5\,\Omega$. **[2]**

(ii) Now, a resistance of $10\,\Omega$ is connected in parallel with the series combination. Therefore, the total resistance of the circuit is given by

$$\frac{1}{R_P} = \frac{1}{R_1 + 5} + \frac{1}{10}$$

$$\Rightarrow \quad \frac{1}{R_P} = \frac{1}{5+5} + \frac{1}{10} \Rightarrow \frac{1}{R_P} = \frac{1}{10} + \frac{1}{10}$$

$$\therefore \quad R_P = 5\,\Omega$$



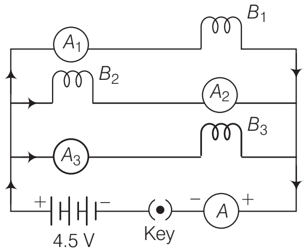
Hence, current flowing in the circuit,

$$I = \frac{V}{R} = \frac{10}{5} = 2\,\text{A}$$

Thus, 1 A current will flow through $10\,\Omega$ resistor and 1 A will flow through the lamp and conductor of $5\,\Omega$ resistance.

Hence, there will be no change in current flowing through 5Ω conductor. Also, there will be no change in potential difference across the lamp. **[2]**

80. B_1, B_2 and B_2 are three identical bulbs connected as shown in figure. Ammeters A_1, A_2 and A_3 are connected as shown in figure. When all the bulbs glow, then the current of 3 A is recorded by ammeter A.



(i) What happens to the glow of the other two bulbs when bulb B_1 gets fused?

(ii) What happens to the reading of A_1, A_2, A_3 and A when the bulb B_2 gets fused?

(iii) How much power is dissipated in the circuit when all the three bulbs glow together?

Sol. Resistance of combination of three bulbs in parallel,

$$R_{eq} = \frac{V}{I} = \frac{4.5}{3} = 1.5\,\Omega$$

If R is the resistance of each wire, then

$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R}$$

or $$\frac{1}{R_{eq}} = \frac{3}{R}$$

or $$R = 3R_{eq} = 3 \times 1.5 = 4.5\,\Omega$$

Current in each bulb,

$$I = \frac{V}{R} = \frac{4.5\,\text{V}}{4.5\,\Omega} = 1\,\text{A}$$

[1]

(i) When bulb B_1 gets fused, then the currents in B_2 and B_3 remain same $I_2 = I_3 = 1\,\text{A}$, so their glow remains unaffected.

(ii) When bulb B_2 gets fused, then the current in B_2 becomes zero and currents in B_1 and B_3 remain 1 A.

$\therefore$ Total current, $I = I_1 + I_2 + I_3$

$$= 1 + 0 + 1 = 2\,\text{A}$$

Current in ammeter $A_1, I_1 = 1$ A

Current in ammeter $A_2, I_2 = 0$

Current in ammeter $A_3, I_3 = 1$ A

Current in ammeter $A, I = 2$ A **[1]**

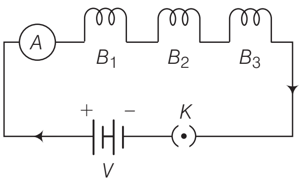
(iii) When all the three bulbs are connected, then power dissipated, $P = \dfrac{V^2}{R_{eq}} = \dfrac{(4.5)^2}{1.5} = 13.5\,\text{W}$ **[1]**

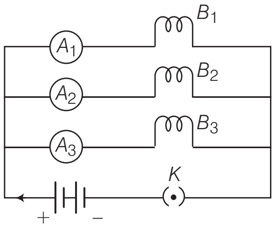
81. Three incandescent bulbs of 100 W each are connected in series in an electric circuit. In another set of three bulbs of the same wattage are connected in parallel to the source.

(i) Will the bulb in the two circuits glow with the same brightness? Justify your answer.

(ii) Now, let one bulb in both the circuits get fused. Will the rest of the bulbs continue to glow in each circuit? Give reason.

Sol. (i) Let us assume that the resistance of each bulb be R. *The circuit diagram in two cases may be drawn as given below*





Equivalent resistance in series combination,

$$R_S = R + R + R = 3R$$

voltage $= V$

Let current through each bulb in series combination be I_1. ***[1]***

By Ohm's law, $V = I_1 \times 3R$

$$\Rightarrow \quad I_1 = \frac{V}{3R}$$

$\therefore$ Power consumption of each bulb in series combination,

$$P_1 = I_1^2(3R) = \left(\frac{V}{3R}\right)^2 \times 3R = \frac{V^2}{9R^2} \times 3R = \frac{V^2}{3R} \quad \text{...(i)}$$

For parallel circuit, ***[1]***

the resistance of each bulb $= R$

Voltage across each bulb $= V$

($\because$ same voltage in parallel combination)

$\therefore$ Power consumption of each bulb in parallel combination is given by

$$P_2 = \frac{V^2}{R} \quad \text{...(ii)}$$

From Eqs. (i) and (ii), we get

$$\frac{P_2}{P_1} = \frac{(V^2/R)}{(V^2/3R)} = \frac{V^2}{R} \times \frac{3R}{V^2} = 3$$

$$\Rightarrow \quad P_2 = 3P_1$$ ***[1]***

Therefore, each bulb in parallel combination glows 3 times brighter to that of each bulb in series combination.

(ii) When one bulb gets fused in both the circuits, then in series combination, circuit gets broken and current stops flowing, whereas in parallel combination, same voltage continues to act on the remaining bulbs and hence other bulbs continues to glow with same brightness. ***[1]***

CHAPTER EXERCISE

2 Marks Questions

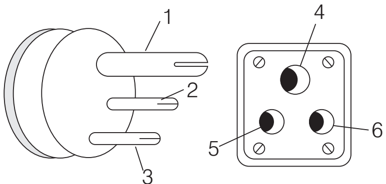
1. Mention two special features of the material used as arms element of an electric iron.
2. It is possible to replace resistors joined in series by an equivalent single resistor of resistance. How?
3. Derive the relation between kilowatt hour and joule.
4. What kind of graph is obtained by plotting values of V and I? Why?
5. You are given three bulbs of 40W, 60W and 100W. Which of them has lower resistance? Also, relate 1kWh and SI unit of energy.
6. Electric fuse is an important component of all domestic circuits. Why? Also, name two common materials used as heating elements.

3 Marks Questions

7. (i) Name two devices based on Joule's heating effect.
   (ii) Name two safety devices used in domestic circuiting.
   (iii) A bulb is rated at 110V, 80W. What does this mean?
8. Make a table with the names of three electrical appliances used in your home in one column, their power, voltage rating and approximate time for which each one is used in one day in the other columns.
9. (i) How does earthing prevent electrical shock?
   (ii) In a 3-pin plug, why is the earth pin made longer and thicker than the other two pons?
10. Draw a labelled diagram of a 3-pin socket. Also, state the purpose of a fuse in an electric or circuit.

4 Marks Questions

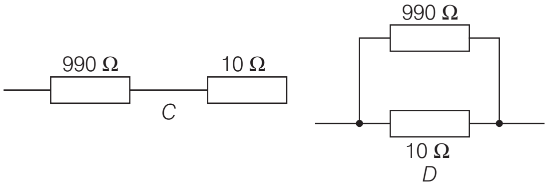
11. A wire is cut into three equal parts and then connected in parallel with the same source.
    How will its
    (i) resistance and resistivity gets affected?
    (ii) How would the total current and the current through the parts change?
12. How will you conclude that the same potential difference (voltage) exists across three resistors connected in a parallel arrangement to a battery?
13. How does the heat produced in a wire or a conductor depend upon the
    (i) current passing through the conductor?
    (ii) resistance of the conductor?
14. (i) Under what circumstances does one get an electric shock from an electric gadget?
    (ii) What is meant by earthing of an electrical appliance? How does earthing offer protection?
15. (i) What is a fuse wire?
    (ii) The diagram (a) and (b) given below are of a plug and a socket with arrow marked as 1, 2, 3 and 4, 5, 6 respectively on them. Identify and wite live (L), neutral (N) and the earth (E) against the correct number.



(a) Plug (b) Socket

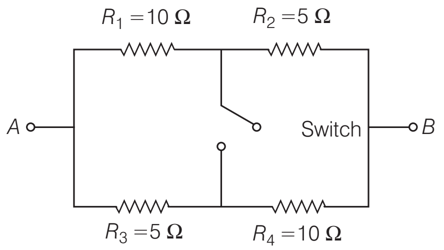
Numerical Based Questions

16. A copper wire of resistivity $1.63\times10^{-8}\,\Omega$-m has cross-section area of $16.3\times10^{-4}\text{cm}^2$. Calculate the length of the wire required to make a 20 Ω coil.
    Ans. 200 m
17. Which resistor arrangement, C or D has the lower resistance?



18. You have two metallic wires of resistances 3 Ω. How will you connect these wires to get the effective resistance of 2 Ω?

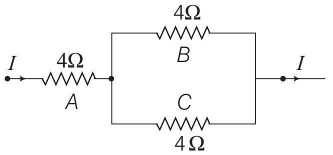
19. Find the equivalent resistance for the following circuit, when



(i) switch is closed (ii) switch is open

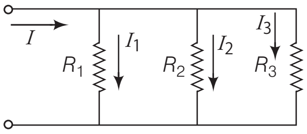
Ans. (i) $\frac{20}{3}\Omega$, (ii) 7.5Ω

20. Three 4 Ω resistors, A, B and C are connected as shown in figure. Each of them dissipates energy and can with stand a maximum power of 36 W without melting. Find the maximum current that can flow through the three resistors.



Ans. 3A, 1.5A, 1.5A

21. What is current resistance in each resistor for a parallel combination of 3.0 Ω, 3.5 Ω and 4.0 Ω resistors. The battery connected is of 8 V. Also, find the effective resistance and effective current.



Ans. $I_1 = 2.7\,A$, $I_2 = 2.3\,A$, $I_3 = 2.0\,A$

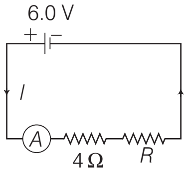
22. A geyser has a label 2kW, 240V. What is the cost of using it for 30 min, if the cost of electricity is 3 per commercial unit? **Ans.** 3

23. A family uses a light bulb of 100W, a fan of 100W, and heater of 1000W, each for 8h a day. If the cost of electricity is ` 2 per unit, what is the expenditure for the family per day on electricity? **Ans.** 19.20

24. In a house, an electric bulb of 100W is used for 10 h and an electric heater of 1000W is used for 2 h. Calculate the cost of using bulb and the heater for 30 days. Take the cost of one unit of electrical energy as 2. **Ans.** 180

25. In an electrical circuit, two resistors of 4 Ω and 8 Ω are connected in series to a 12V battery. Find the heat dissipated by the 4 Ω resistor in 5s. **Ans.** 5J

26. The figure shows a circuit, when the circuit is switched on the ammeter reads 0.5A.



(i) Calculate the value of the unknown resistor R.
(ii) Calculate the charge passing through the 4 Ω resistor in 60s.
(iii) Calculate the power dissipated in the 4 Ω resistor.

Ans. (i) 8 Ω, (ii) 30 C, (iii) 1W

ARCHIVES* *(Last 6 Years)*

Collection of Questions Asked in Last 6 Years' (2018-2013) ICSE Class 10th Examinations

2018

1. Identify the following wires used in a household circuit.

(i) The wire is also called as the phase wire.

(ii) The wire is connected to the top terminal of a three pin socket. ***[2]***

2. (i) A fuse is rated 8 A. Can it be used with an electrical appliance rated 5 kW, 200 V? Give a reason.

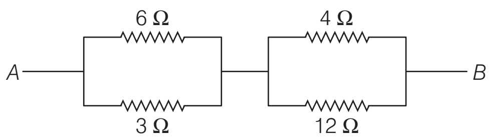
(ii) Name the safety devices which are connected to the live wire of a household electric circuit. ***[3]***

3. You have three resistors of values $2\ \Omega$, $3\ \Omega$ and $5\ \Omega$. How will you join them so that the total resistance is more than $7\ \Omega$?

(i) Draw a diagram for the arrangement.

(ii) Calculate the equivalent resistance. ***[2]***

4. (i) Find the equivalent resistance between A and B.



(ii) State whether the resistivity of a wire changes with the change in the thickness of the wire. ***[3]***

5. An electric iron is rated 220 V, 2 kW.

(i) If the iron is used for 2 h daily, find the cost of running it for one week if it costs ₹ 4.25 per kWh.

(ii) Why is the fuse absolutely necessary in a power circuit? ***[4]***

2017

6. Define specific resistance and state its SI unit. ***[2]***

7. An electric bulb of resistance $500\ \Omega$, draws a current of 0.4 A. Calculate the power of the bulb and the potential difference at its end. ***[2]***

8. (i) Name the colour code of the wire which is connected to the metallic body of an appliance.

(ii) Draw the diagram of a dual control switch when the appliance is switched 'ON'. ***[3]***

9. (i) Which particles are responsible for current in conductors?

(ii) To which wire of a cable in a power circuit, should the metal case of geyser be connected?

(iii) To which wire, should the fuse be connected? ***[3]***

10. (i) Explain the meaning of the statement 'current rating of a fuse is 5A'.

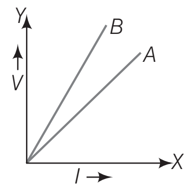
(ii) In the transmission of power, the voltage of power generated at the generating stations is stepped up from 11 kV to 132 kV before it is transmitted. Why? ***[4]***

2016

11. State the characteristics required in a material to be used as an effective fuse wire. ***[2]***

12. Calculate the quantity of heat produced in a $20\ \Omega$ resistor carrying 2.5 A current in 5 min. ***[2]***

13. The V-I graph for a series combination and for a parallel combination of two resistors is shown in the figure below. Which of the two A or B, represents the parallel combination? Give a reason for your answer. ***[2]***



14. (i) Which particles are responsible for current in conductors?

(ii) To which wire of a cable in a power circuit should the metal case of a geyser be connected?

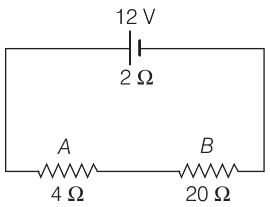
(iii) To which wire should the fuse be connected? ***[3]***

15. A music system draws a current of 400 mA, when connected to a 12 V battery.

(i) What is the resistance of the music system?

(ii) The music system is left playing for several hours and finally the battery voltage drops and the music system stops playing when the current drops to 320 mA. At what battery voltage does the music system stop playing? ***[3]***

16. A battery of emf 12 V and internal resistance $2\ \Omega$ is connected with two resistors A and B of resistance $4\ \Omega$ and $6\ \Omega$ respectively joined in series.



Find

(i) current in the circuit.

(ii) the terminal voltage of the cell.

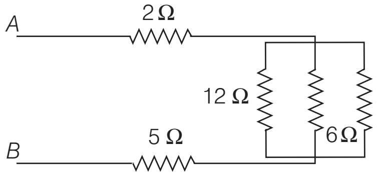
(iii) the potential difference across 6 Ω resistor.

(iv) electrical energy spent per minute in 4 Ω resistor. ***[4]***

2015

17. What happens to the resistivity of semiconductors with increase of temperature? ***[2]***

18. Find the equivalent resistance between the point *A* and *B*.



[2]

19. The relationship between the potential difference and the current in a conductor is stated in the form of law.

(i) Name the law.

(ii) What does the slope of *V*-*I* graph for conductor represent?

(iii) Name the material used for making the connecting wire. ***[3]***

2014

20. (i) What is an ohmic resistor?

(ii) Two copper wires are of the same length, but one is thicker than the other.

(a) Which wire will have more resistance?

(b) Which wire will have more specific resistance? ***[3]***

21. Two resistors of 4 Ω and 6 Ω are connected in parallel to a cell to draw 0.5 A current from the cell.

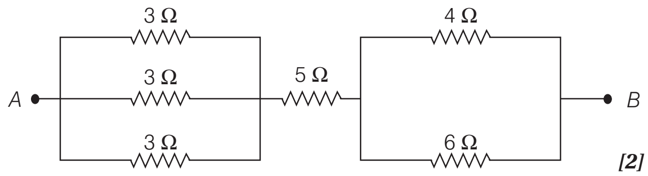
(i) Draw a labelled circuit diagram showing the above arrangement.

(ii) Calculate the current in each resistor. ***[2]***

22. (i) Two sets *A* and *B* of three bulbs each, are glowing in two separate rooms. When one of the bulbs in set *A* is fused, the other two bulbs also cease to glow. But in set *B*, when one bulb fuses, the other two bulbs continue to glow. Explain, why this phenomenon occurs?

(ii) Why do we prefer arrangements of set *B* for house circuiting? ***[3]***

23. Find the equivalent resistance between points *A* and *B*.



[2]

2013

24. (i) Name the device used to protect the electric circuits from overloading and short circuits.

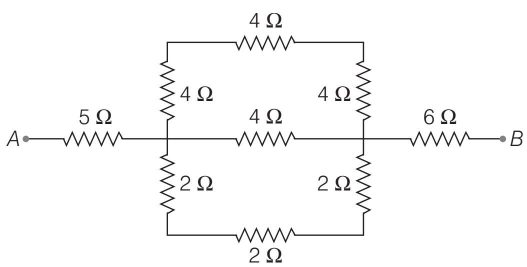
(ii) On what effect of electricity does the above device work? ***[2]***

25. (i) An electrical gadget can give an electric shock to its user under certain circumstance. Mention any two of these circumstances.

(ii) What preventive measure provided in a gadget can protect a person from an electric shock? ***[3]***

26. A metal wire of resistance 6 Ω is stretched so that its length is increased to twice its original length. Calculate its new resistance. ***[2]***

27. Calculate the equivalent resistance between the points *A* and *B* for the following combination of resistors.

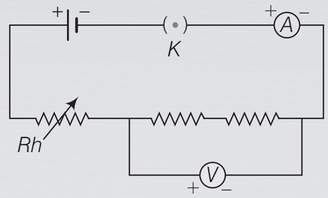


[2]

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

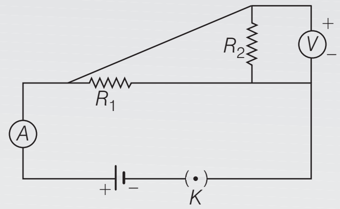
1 To determine the equivalent resistance of two resistors when connected in series, a student arranged the circuit components as shown in the diagram. But he did not succeed to achieve the objective.



Which of the following mistakes has been committed by him in setting up the circuit?

(a) Position of ammeter is incorrect
(b) Position of voltmeter is incorrect
(c) Terminals of ammeter are wrongly connected
(d) Terminals of voltmeter are wrongly connected

2 For the given circuit, name the components which are connected in parallel.

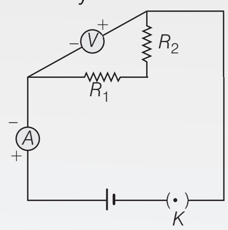


(a) Both R_1 and R_2
(b) R_1, R_2 and V
(c) Both R_2 and V
(d) Both R_1 and V

3 Two unequal resistances are connected in parallel by a student. Which of the following is true?

(a) Current is same in both
(b) Current is larger in higher resistance
(c) Voltage drop is same across both
(d) Voltage drop is lower in lower resistance

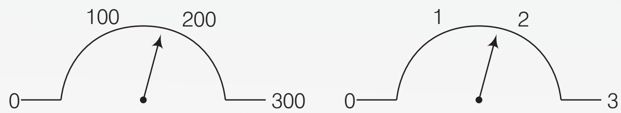
4 I. The resistors R_1 and R_2 have not been correctly connected in parallel.
II. The voltmeter has not been correctly connected in the circuit.
III. The ammeter and the key have not been correctly connected in the circuit.



Out of these three, the actual fault in this circuit is/are

(a) Both I and II
(b) Both II and III
(c) Only I
(d) Only II

5 The current flowing through a resistor connected in an electric circuit and the potential difference applied across its ends are shown in figure below. The value of the resistance of the resistor is



(a) 1 Ω
(b) 5 Ω
(c) 8 Ω
(d) 10 Ω

Answers

1. (c) **2.** (b) **3.** (c) **4.** (c) **5.** (d)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 244.

CHAPTER

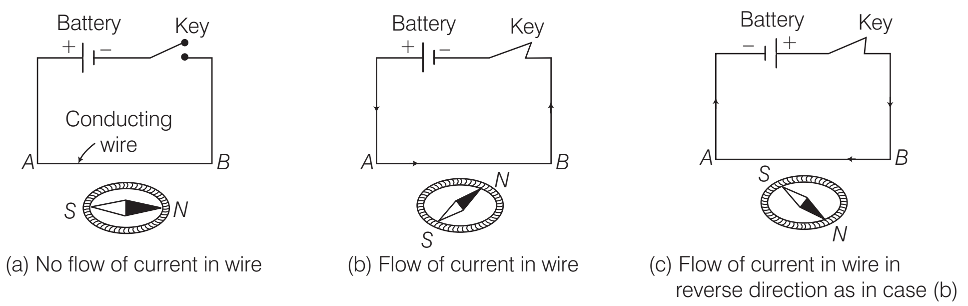
9

Electromagnetism

The branch of Physics which deals with study of electricity and magnetism and the interaction between them is known as electromagnetism. In electrostatics, we have studied that a static charge produces an electric field. Similarly, a moving charge or current flowing through a conductor also produces a magnetic field. This is called the magnetic effect of electric current.

Oersted's Experiment on the Magnetic Effect of Electric Current

In 1820, Hans Oersted observed experimentally that, when an electric current is passed through a conducting wire, a magnetic field is produced around it. **The phenomena of production of magnetic field around a current carrying conductor is called magnetic effect of current.** The presence of magnetic field at a point around a current carrying wire can be detected with the help of a compass needle, a compass needle shows deflection in presence of a magnetic field. This has been depicted in the figure given below.



Phenomena of magnetic effect of electric current in a conducting wire

When current flows through the conductor, then the compass needle shows deflection. The deflection of the needle indicates that a magnetic field is established around a current carrying wire. If the current is reversed, then the needle is deflected in opposite direction. There is no deflection in compass needle, if no current flows through the conductor.

On increasing the current in the wire or bringing the needle closer to the wire, the deflection of the needle increases.

This experiment shows that, the magnetic field is produced due to electric current or flow of charges.

Chapter Objectives

- Magnetic Field
- Electromagnet
- Force on a Current Carrying Conductor in a Magnetic Field
- Electric Motor
- Electromagnetic Induction
- Direct Current and Alternating Current
- Electric Generator
- Transformer

Magnetic Field

The space around a magnet or a current carrying conductor in which its effect can be experienced i.e., its force can be detected, is called magnetic field.

Magnetic field is a **vector** quantity. Its SI unit is **tesla** (T) named after an American engineer Nikola Tesla. Its smaller unit is **gauss**.

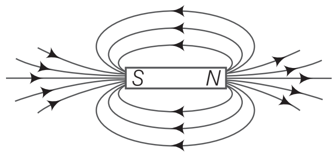
$$1\text{ tesla} = \frac{1\text{ newton}}{1\text{ ampere-metre}}$$

$$1\text{ T} = 1\text{ N/A-m} = \text{kg/A-s}^2$$

$$\boxed{1\text{ tesla} = 10^4\text{ gauss}}$$

Magnetic Field Lines

The imaginary lines representing magnetic field around a magnet are known as magnetic field lines. When iron filings are kept near a magnet, then they get arranged in a pattern which represent the magnetic field lines.



Field lines around a bar magnet

Magnetic field lines can be plotted by using a magnetic compass. The lines are drawn along the direction in which a magnetic North pole of the compass needle would move under the influence of the field produced by the magnet. It is taken by convention that the field lines emerge from North pole and merge at the South pole.

Note A compass needle behave as a small bar magnet whose one end point approximately towards North called North seeking or North pole and other end pointing towards South called South seeking or South pole.

Properties of Magnetic Field Lines

The magnetic field lines have the following properties

(i) The magnetic field lines originate from North pole of a magnet and end at its South pole, by convention.

(ii) The magnetic field lines are closed and continuous curves.

(iii) The magnetic field lines are crowded near the poles, where the magnetic field is strong and separated far from the poles, where the magnetic field is weak.

(iv) The magnetic field lines never intersect each other. If they do, so that would mean there are two directions of the magnetic field at the point of intersection, which is impossible.

(v) When magnetic compass is placed at different points on magnetic field lines, then it comes to rest along the direction of magnetic field at that point.

(vi) The direction of the magnetic field is indicated by the arrow of the lines at any point.

Magnetic Field due to a Current through a Straight Conductor

The magnetic field lines around a current carrying straight conductor are concentric circles whose centres lie on the wire and lying in the plane perpendicular to straight wire.

The strength of magnetic field B produced by a straight current carrying wire at a given point is

(i) Directly proportional to the current I passing through the wire

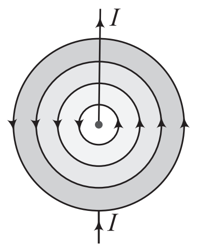
i.e., $B \propto I$ ...(i)

If current is increased, then the magnetic field produced is stronger and magnetic field lines become chosen to each other i.e., become denser. If current is decreased, then weaker magnetic field is produced and magnetic lines of force move away from each other.

(ii) Inversely proportional to the distance r from the wire

i.e., $B \propto \frac{1}{r}$ ...(ii)

The magnetic field is stronger at the point which is nearer to the conductor and goes on decreasing for the far away points.



Concentric field lines around a straight conductor

(iii) When direction of current in the wire is reversed, then direction of magnetic field i.e., direction of magnetic field lines also reverses.

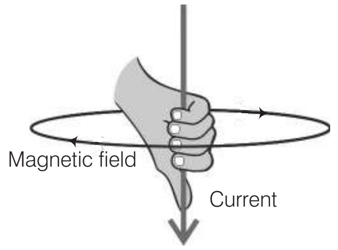
By using Eqs. (i) and (ii), we get

$$B \propto \frac{I}{r}$$

If the direction of current in a straight wire is known, then the direction of magnetic field produced by a straight carrying current conductor is obtained by **Maxwell's right hand thumb rule**.

Maxwell's Right Hand Thumb Rule

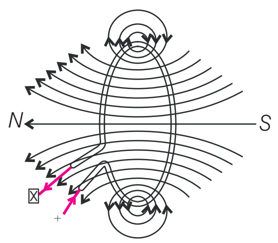
It states that, if you hold the current carrying straight wire in the grip of your right hand in such a way that the stretched thumb points in the direction of current, then the direction of the curl of the fingers will give the direction of the magnetic field. This rule is also called Maxwell's corkscrew rule.



Maxwell's right hand thumb rule

Magnetic Field Due to a Current through a Circular Loop

The magnetic field lines due to a circular coil is shown in given figure. At every point of a current carrying circular loop, the concentric circles represent the magnetic field around it. At the centre of loop, the field appears to be a straight line.



Magnetic field lines due to a current through a circular loop

The magnetic field produced by current carrying circular wire at a given point depends on the following factors

(i) **Amount of Current Flowing through a Wire** The strength of magnetic field (B) due to a current carrying circular wire is directly proportional to the amount of current (I) flowing through it.

i.e., $B \propto I$ ... (i)

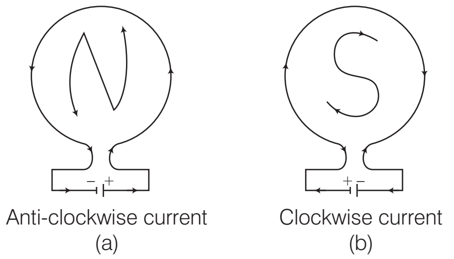
(ii) **Number of Turns of the Circular Wire** The strength of the magnetic field due to a current carrying circular wire is directly proportional to the number of turns (N) of the wire.

i.e., $B \propto N$ ... (ii)

Thus, the strength of magnetic field produced by a current carrying circular coil can be increased by

(a) increasing the number of turns of wire in the coil.
(b) increasing the current flowing through the coil.
(c) decreasing the radius of the coil.

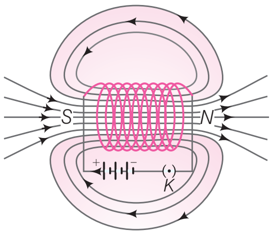
By looking at the direction of current in the face of loop, we can identify its polarity i.e., whether it will behave like North pole or South pole. If current around the face in loop is in anti-clockwise direction, then it will behave like North pole while in case of clockwise direction it will behave like South pole.



Polarities at the faces of a loop carrying current

Magnetic Field Due to a Current in a Solenoid

A **solenoid** is defined as a coil consisting of a large number of circular turns of insulated copper wire. These turns are wound closely to form a cylinder.



Magnetic field lines of force due to a current carrying solenoid

The field lines around a current carrying solenoid are similar to that produced by a bar magnet. This means that a current carrying solenoid behaves as having North pole and South pole.

The strength of magnetic field produced by a current carrying solenoid depends on the following factors

(i) The number of turns of solenoid ($B \propto N$) i.e., on increasing the number of turns in solenoid strength of magnetic field produced can be increased.

(ii) The strength of current ($B \propto I$) i.e., by increasing the amount of current flowing in solenoid strength of magnetic produced can be increased.

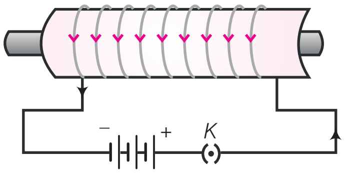
(iii) The nature of core material used to make solenoid.

The field lines inside the solenoid are parallel to each other. Thus, the strength of magnetic field is the same at all points inside a solenoid.

The strong magnetic field produced inside a solenoid can be used to magnetise a piece of magnetic material like soft iron when placed inside the coil.

Electromagnet

An electromagnet is a solenoid that works like a magnet when current flows through it. It consists of a long insulated copper wire wound around a soft iron core. The magnetic effect remains, till the current is flowing through the solenoid.



An electromagnet

The strength of an electromagnet increases with

(i) increase in number of turns in the coil

(ii) increase in the amount of current flowing through the coil.

(iii) decrease in the air gap between poles.

Uses of Electromagnet

Following are the uses of electromagnet

(i) It is used for lifting and transporting large masses of iron scrap, girder, plates, etc.

(ii) It is used for loading the furnace with iron.

(iii) It is used for separating the magnetic substances such as iron from debris and raw materials.

(iv) It is used for removing pieces of iron from wounds.

Comparison between Electromagnet and Permanent Magnet

Electromagnet	Permanent Magnet
It is a temporary magnet.	It is a permanent magnet i.e., cannot be demagnetised easily.
It is made up of soft iron.	It is made up of steel.
It produces the magnetic field as long as current flows in its coils i.e., it produces temporary magnetic field.	It produces permanent magnetic field.
The magnetic field strength can be changed.	The magnetic field strength cannot be changed.
It can produce very strong magnetic field.	It produces comparatively weak magnetic field.
Its polarity can be reversed.	Its polarity cannot be reversed.

CHECK POINT 01

1 How can we predict the strength of a magnetic field in a space?

2 Where is the magnetic field due to a straight current wire (i) stronger (ii) weaker?

3 A circular loop carrying a current is placed on a horizontal surface. If the current is in the clockwise direction, then what is the direction of its magnetic field at the centre? What is the direction of the magnetic field at a point outside the surface of the loop?

4 What is the difference in the pattern of magnetic field due to a circular loop and inside a solenoid?

5 What is electromagnet? State its principle.

Force on a Current Carrying Conductor in a Magnetic Field

When a current carrying conductor is placed in a magnetic field in a direction other than the magnetic field, it experiences a force. The force acting on a current carrying conductor in a magnetic field is due to interaction between magnetic field due to current carrying conductor and external magnetic field in which the conductor is placed.

The direction of force on the conductor depends on

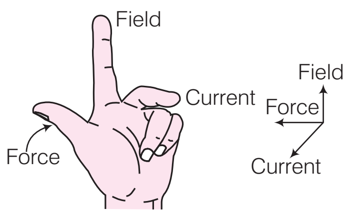
(i) **Direction of Current** The direction of force on the conductor can be reversed by reversing the direction of current.

(ii) **Direction of Magnetic Field** The direction of force on the conductor can be reversed by reversing the direction of magnetic field by interchanging the position of poles.

Force on the current carrying conductor is maximum when the direction of current is at right angles to the direction of magnetic field. If the current carrying conductor is placed parallel to direction of magnetic field, then no face acts on it.

Fleming's Left Hand Rule

The direction of force which acts on a current carrying conductor placed in a magnetic field is given by Fleming's left hand rule.



Fleming's left hand rule

It states that, if the forefinger, thumb and middle finger of left hand are stretched mutually perpendicular to each other and the forefinger points along the direction of external magnetic field, middle finger indicates the direction of current, then thumb points the direction of force acting on the conductor.

Example 1. Current carrying conductor enters a magnetic field at right angles to it as shown in figure. What will be the direction of force acting on the conductor?

Sol. According to Fleming's left hand rule, the direction of force on conductor is perpendicular to the direction of magnetic field and current. Since, the direction of current is taken opposite to the direction of motion of electrons, therefore the force on electron is directed into the page.

Electric Motor

It is a rotating device which used for converting electric energy into mechanical energy.

It is based on the principle that when a current carrying rectangular coil is placed in a magnetic field, then two equal and opposite forces act on the coil, which rotates it continuously.

Construction of Electric Motor

The main parts of electric motor are described below

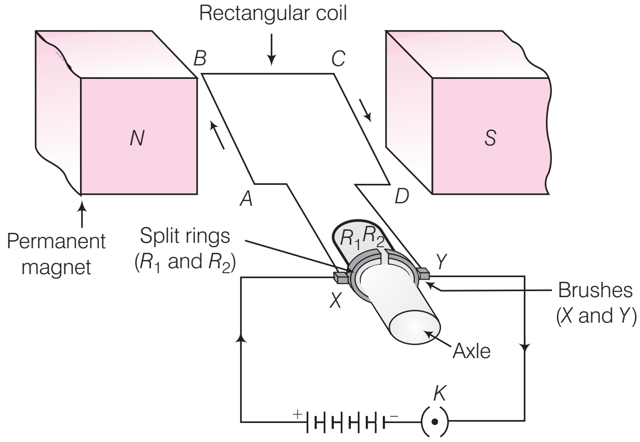
(i) **Armature** It is a rectangular coil wound around a soft iron core which is kept in between the poles of a permanent magnet. When current flow through armature coil, then magnetic force act on it and it rotates along its axis.

(ii) **Split Rings** These are the parts of a ring, fixed to the coil, these are used to reverse the direction of current flowing through armature coil every time, it passes through the vertical position.

(iii) **Brushes** These are made up of carbon/copper, these are pressed tightly against split rings. Their main function is to connect the coil with the current supply.

(iv) **Magnet** It is a strong house-shoe magnet either permanent or electromagnet. Its function is to produce magnetic field, so that magnetic force can act on armature coil.

(v) **DC Source** It is battery connected to the brush to flow the electric current in armature coil, so that magnetic force can act on it.



A simple electric motor

The speed of rotation of the motor can be increased by

(i) increasing the strength of the current in the coil.
(ii) increasing the number of turns in the coil.
(iii) increasing the area of the coil.
(iv) increasing the strength of magnetic field.

Electromagnetic Induction

The phenomenon of production of emf in a conductor on changing the magnetic field around it, is called electromagnetic induction.

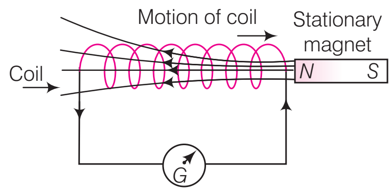
The emf produced here is called **induced emf**, if the circuit is closed, then electric current flows due to this emf, known as **induced current**.

This effect is the reverse effect of magnetic effect of electric current, it was discovered by Michael Faraday.

Ways to Induce the Current in a Circuit

There are different methods by which current can be induced in a circuit as given below

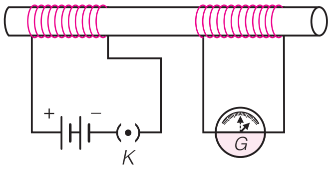
(i) **By Moving a Coil in Magnetic Field** Current can be induced in a coil either by moving it in a magnetic field or by changing the magnetic field around it. In most situations, it is convenient to move coil in a magnetic field.



(a) Moving a coil towards a magnet sets up an electric current in the coil circuit as indicated by deflection in galvanometer needle

The induced current is found to be maximum when the direction of motion of the coil is at right angle to the magnetic field. The direction of induced current can be reversed by reversing the direction of magnetic field. If the coil as well as the magnet are stationary, then no current is induced in the coil.

(ii) **In a Stationary Coil** Consider two coils such as coil 1 primary coil and coil 2 as secondary coil. Primary coil is connected with a battery.



(b) Current is induced in coil 2 when current in coil 1 is changed as indicated by deflection in galvanometer needle

When the current in primary coil is switched on, then it takes a little time to rise from zero to a maximum value i.e., current in the primary coil changes. This causes a momentary change in the magnetic field around this coil and hence induces a momentary current in the secondary coil. The same happens in the reverse direction when the current in primary coil is switched off.

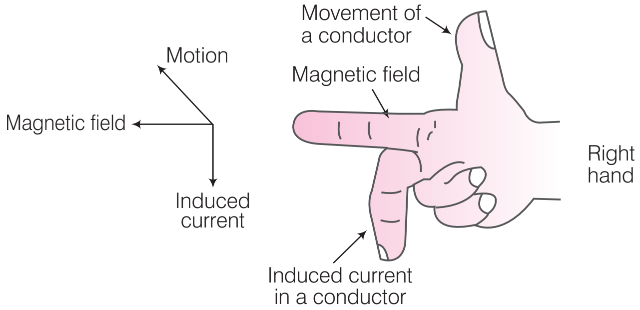
Galvanometer

It is an instrument that can detect the presence of a current in a circuit. The pointer remains at zero (the centre of the scale) for zero current flowing through it. Depending upon the direction of current, it can be deflected either to the left or to the right of the zero mark.

Fleming's Right Hand Rule

The direction of induced current in a straight conductor is given by Fleming's right hand rule.

It states that, if the forefinger, middle finger and thumb of the right hand are stretched at right angles to each other, with the forefinger in the direction of the field and the thumb in the direction of the motion of the wire, then the current in the wire is in the direction of the middle finger.



Fleming's right hand rule

CHECK POINT 02

1. State the function of a split ring in a DC motor.
2. If area of the coil becomes twice, then what is the effect on speed of rotation of the motor?
3. In DC motor, why must the current to the coil be reversed twice during each rotation?
4. Name the phenomenon used for producing current in coil due to relative motion between a magnet and the coil.
5. Explain the meaning of the word 'electromagnetic' and 'induction' in the term electromagnetic induction.

Direct Current and Alternating Current

Direct Current (DC)

An electric current whose magnitude is either constant or variable but the direction of flow in a conductor remains the same is called direct current. It is denoted by DC. Sources of DC are voltaic cell, a dry cell, battery, DC generator, etc.

Alternating Current (AC)

An electric current whose magnitude changes with time and direction reverses periodically is called alternating current. It is denoted by AC. Sources of AC are hydro-electric generators, thermal power generators and nuclear power generators, etc.

The number of cycles completed by the AC in one second is called the **frequency of AC.** The frequency of AC in India is 50 Hz which means that AC changes its polarity after $\frac{1}{100}$ second as it completes one cycle. The major difference between AC and DC is that DC always flows in one direction, while AC reverses its direction periodically.

Advantages of AC over DC

Advantages of AC over DC are as follow

(i) With the help of a transformer, AC at any desired voltage can be obtained.

(ii) AC can be easily converted into DC by using a device called **rectifier**.

(iii) The cost of generation of AC is less than the cost of generation of DC.

(iv) AC can be controlled without much loss of electric power than DC.

(v) AC machines are very durable and do not need much maintenance.

(vi) For long distance transmission, AC is preferred as it causes minimum loss of energy during transmission.

Disadvantages of AC over DC

Disadvantages of AC over DC are as follow

(i) AC is more dangerous than DC as it attracts a person towards it, whereas DC repels.

(ii) AC can give a serious shock to a person as compared to the DC.

(iii) AC cannot be used for electroplating, electrotyping, etc., but DC is used for these processes.

Electric Generator

It is based on the principle of electromagnetic induction. It is used to produce electric current by varying magnetic field through a coil.

Parts of Electric Generator

The different parts of electric generator are explained as below

(i) **Armature** It is a coil having large number of turns of insulated copper wire wound over a soft iron core.

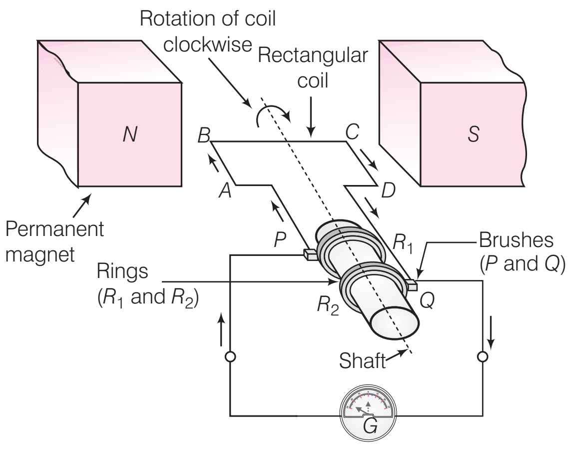
(ii) **Field Magnet** It is a powerful magnet that provides a uniform magnetic field perpendicular to the axis of rotation of coil between the North and South poles.

(iii) **Slip Rings** In an AC generator, we use slip rings–full rings with which the ends of coil are in contact. DC generator uses split ring type commutator-half rings with which the ends of the armature coil are in contact.

(iv) **Brushes** There are two stationary metallic carbon brushes which are in contact with external device and rings.

AC Generator

It generates the current which changes its direction after equal intervals of time i.e., **alternating current**.



AC generator

Differences between a DC motor and an AC generator

DC Motor	AC Generator
It converts electrical energy into mechanical energy.	It converts mechanical energy into electrical energy.
It is based on the principle that when a coil carrying current is held in a magnetic field, it experiences a torque which rotates the coil.	It is based on the phenomenon of electromagnetic induction.

Similarities between AC generator and DC motor

The similarities between AC generator and DC motor are as follow

(i) Both AC generator and DC motor work on magnetic effect of electric current.

(ii) In both cases, a coil rotates in a magnetic field between the pole pieces of strong electromagnet.

Transformer

It is a device which is used to increase or decrease the amplitude of an alternating emf.

The transformers are of following types

(i) Step-up transformer

(ii) Step-down transformer

Principle of Transformer

It is based on the principle of mutual induction i.e., producing a momentary current in second coil by the first coil.

Construction of Transformer

It consists of two coils primary (p) and secondary (s), insulated from each other wounded on soft iron core. Offenly, the primary coil is the input coil and secondary coil is the output coil.

These soft iron cores are laminated to minimise eddy current loss.

Transformer Action

When the primary coil having the primary winding is connected with an AC supply, then due to the flow of alternating current, a magnetic field of alternating nature is developed in it. So that, the change in magnetic field takes place.

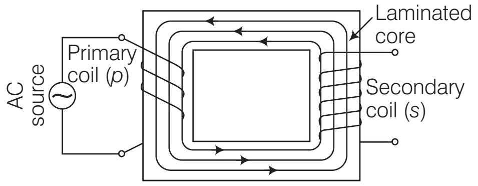
This induces a momentary current or emf in the secondary coil. In this way without any connection or touch, an electrical energy is transferred between the primary and secondary windings, this action is called the **transformer action**.

Step-up and Step-down Transformer

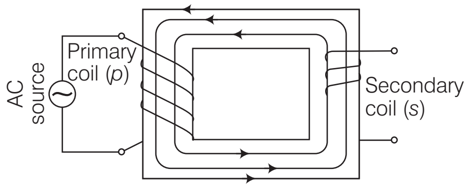
The transformer which converts low voltage current into high voltage current are called **step-up transformer.**

In these transformers, the number of turns in secondary coil is more than the number of turns in primary coil. The transformers which converts high voltage current to low voltage current are called **step-down transformer**. In these transformer, the number of turns in secondary coil is less than the number of turns is primary coil.

The following figures show step-up and step-down transformer



Step-down transformer



Step-down transformer

Uses of Transformers

Transformers are used in almost all AC operations.

Some of them are given below

(i) In the induction furnaces.

(ii) In voltage regulators for TV, computer, refrigerator, etc.

(iii) A step-down transformer is used for the purpose of weldings.

(iv) In the transmission of AC over long distances.

Note
- The alternating magnetic flux induces eddy current in the iron core and causes heating the effect is reduced by having a laminated core.
- The wire used for the winding has some resistance, which causes energy loss due to heating. This can be minimised by using thick wire.
- DC current is not used in transformer, because constant current produces constant magnetic field, which means no change in the magnetic flux. Hence, no emf will be induced.

CHECK POINT 03

1 The frequency of AC in India is …… .

2 The generator is based on which principle?

3 What type of generator is used at power stations?

4 Write one similarity between AC generator and DC motor.

4 In a step-up transformer, what will be the value of $\frac{N_s}{N_p}$?

SUMMARY

- The region surrounding a magnet or a current carrying conductor in which its effect can be experienced i.e., its force can be detected, is called magnetic field.
- Direction of magnetic field is found by right hand thumb rule.
- Electromagnet is a coil that attains magnetism due to flow of current.
- Direction of force on a current carrying conductor in a magnetic field is given by Fleming's left hand rule.
- DC motor is a rotating device used for converting electric energy into mechanical energy.
- The phenomenon of generation of an electric current in a closed circuit by changing the magnetic field is called electromagnetic induction.
- Current can induce in a circuit by two methods i.e., by moving a coil in a magnetic field or by changing the magnetic field.
- AC generator generates atternating current. It is based on the phenomenon of electromagnetic induction.
- Transformer is used to increase or decrease the amplitude of an alternating emf current. There are two types of transformer i.e., step-up and step-down transformer.

EXAM PRACTICE

a 2 Marks Questions

1. How does the strength of magnetic field due to a current carrying conductor depend upon
(i) distance from the conductor
(ii) current flowing through the conductor?

Sol. (i) Strength of magnetic field decreases as the distance from conductor increases. ***[1]***
(ii) Strength of magnetic field increases with an increase in the magnitude of current flowing through the conductor. ***[1]***

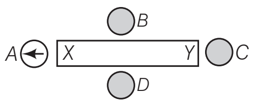
2. What will happen to a compass needle when the compass is placed below a wire and a current is made to flow through the wire? Give a reason to justify your answer. ***[2006]***

Sol. The compass needle will shows deflection when the compass is placed below a wire and a current is made to flow through the wire.
It is so because when a current is passed through a conductor, a magnetic field is produced around the conductor due to which compass needle gets deflected. ***[2]***

3. (i) Why does a current carrying freely suspended solenoid rest along a particular direction?
(ii) State the direction in which it rests. ***[2015]***

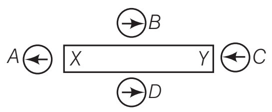
Sol. (i) A current carrying solenoid behaves as a temporary bar magnet having North pole towards the positive terminal of the DC supply. When a current carrying solenoid is suspended freely, then it aligns itself along the geographical North-South directions. ***[1]***
(ii) The North pole of the solenoid aligns itself towards the geographical North direction and the South pole of the solenoid aligns itself towards the geographical South direction. ***[1]***

4. (i) The diagram shows a bar magnet surrounded by four plotting compasses. Copy the diagram and mark the direction of the compass needle for each of the cases *B*, *C* and *D*.



(ii) Which is the North pole, *X* or *Y*?

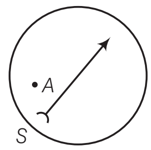
Sol.

(i) 

[1]

(ii) *X* is the North pole. ***[1]***

5. A magnetic compass needle is placed in the plane of paper near point *A* as shown in figure. In which plane should a straight current carrying conductor be placed, so that it passes through *A* and there is no change in the deflection of the compass? Under what condition is the deflection maximum and why?



Sol. The straight current carrying conductor should be placed in the plane of paper, so that it passes through *A*. This produces magnetic field in a plane perpendicular to plane of paper. The compass needle remains undeflected due to vertical magnetic field produced by wire, since compass needle is free to rotate only in horizontal plane.
The deflection in compass needle is maximum when the conductor through *A* is perpendicular to the plane of paper and the magnetic field due to straight current carrying conductor lies in the plane of paper. ***[2]***

6. It is established that an electric current through a metallic conductor produces a magnetic field around it. Is there a similar magnetic field produced around a thin beam of moving (i) α-particles, (ii) neutrons? Justify your answer.

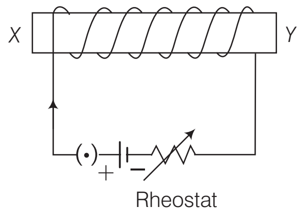
Sol. In case of movement of a charged particle, the magnetic field is created around the path on which the charged particle moves.
(i) Yes, a thin beam of α-particles (which are positively charged) is like straight conductor carrying current in the direction of motion. ***[1)***
(ii) No, as neutrons carry no charge, so no magnetic field would be created around its path. ***[1]***

7. (i) What is the nature of magnetic field inside a long straight solenoid carrying current?
(ii) Consider a circular loop of wire lying in the plane of table. Let the current pass through the loop clockwise. Apply the right hand rule to find out the direction of the magnetic field inside and outside the loop.

Sol. (i) Magnetic field inside a long straight solenoid carrying current is uniform i.e., same at all the points. ***[1]***

(ii) Applying right hand rule, the magnetic field inside the loop is in vertically downward direction and outside the loop, it is in vertically upward direction. ***[1]***

8. The figure given below shows an electromagnet.



(i) What will be the polarity at the end X?

(ii) Suggest a way by which the strength of the electromagnet referred to in the question, may be increased. ***[2009]***

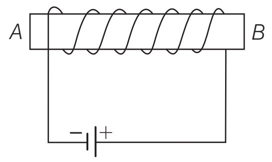
Sol. (i) The polarity at the end X is North polarity. ***[1]***

(ii) The strength of the electromagnet can be increased by increasing the strength of the current or by decreasing the resistance in the rheostat. ***[1]***

9. You have been provided with a solenoid AB.

(i) What is the polarity at the end A?

(ii) Give one advantage of an electromagnet over a permanent magnet. ***[2013]***



Sol. (i) The polarity at end A is South polarity. ***[1]***

(ii) An advantage of an electromagnet over a permanent magnet is that an electromagnet can produce a strong magnetic field. ***[1]***

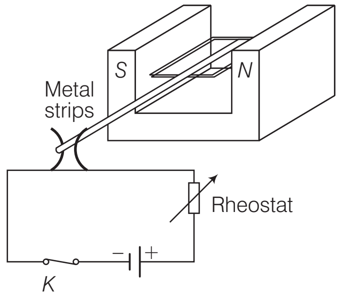
10. State two advantages of an electromagnet over a permanent magnet. ***[2018]***

Sol. *The two advantages of an electromagnet over a permanent magnet are*

(i) The polarity of an electromagnet can be changed by reversing the direction of current in the solenoid while polarity of a permanent magnet can never be changed. ***[1]***

(ii) An electromagnet can produce a stronger magnetic field than permanent magnet. ***[1]***

11. The given figure shows a DC motor model used by a student to study electromagnetism.



The two ends of the coil are fixed to a pair of curve elastic metal strips. The metal strips are connected to the power supply with a rheostat.

(i) State the direction of rotation of the coil when viewed from the front.

(ii) The student is still testing on the feasibility of using the metal strips in the model. What is he trying to achieve?

Sol. (i) The direction of rotation of the coil when viewed from the front is anti-clockwise. ***[1]***

(ii) He is trying to achieve the rotation of coil in one direction. As the current in the coil reverses for every half turn, the coil rotates in one direction. ***[1]***

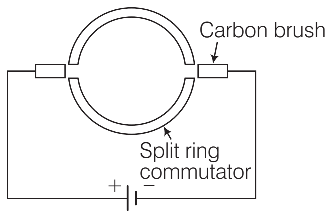
12. Name four appliances wherein an electric motor, a rotating device that converts electrical energy to mechanical energy, is used as an important component. In what respect motors are different from generators?

Sol. The four appliances such as electric fans, washing machines, mixers grinders, electric drills, tape recorders, etc., use an electric motor as a rotating device that converts electrical energy to mechanical energy.

The motor is a machine which converts the electric energy into mechanical energy.

The generator is the device which converts mechanical energy into electrical energy. It is used to convert the mechanical power to electric power which varies in the magnitude with a specific frequency. ***[2]***

13. The figure shows the split ring commutator and the two carbon brushes in their respective positions.



What can you say about carbon brush and split ring commutator?

Sol. When the gaps of the split ring commutator are in alignment with the carbon brushes, then contacts are broken and the current is temporarily cut-off. ***[1]***

However, the coil keeps on rotating in the same direction due to its inertia until the split ring commutator and the carbon brushes are in contact again. ***[1]***

14. State the energy change which takes place, when a magnet is moved inside a coil having a galvanometer at its ends. Name this phenomenon. ***[2005]***

Sol. When a magnet is moved inside a coil having a galvanometer at its ends, the mechanical energy is converted into electrical energy. This phenomenon is known as electromagnetic induction. ***[1+1]***

15. Two circular coils *A* and *B* are placed close to each other. If the current in the coil *A* is changed, will some current be induced in the coil *B*? Give reason.

Sol. Yes, current will be induced in the coil *B*. When the current in coil *A* is changed, the magnetic field around it changes. So, the changing of magnetic field lines around coil *B* induce a current in coil *B*. ***[2]***

16. A wire is dropped freely towards Earth. Will any emf be induced across the ends of wire, if wire is initially in

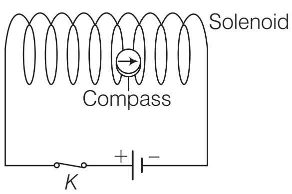
(i) North-South direction?

(ii) East-West direction?

Sol. (i) No, because it will not cause any change in the magnetic field lines due to Earth being cut. ***[1]***

(ii) Yes, because in this position, the wire will cut magnetic field lines due to horizontal component of Earth's magnetic field. ***[1]***

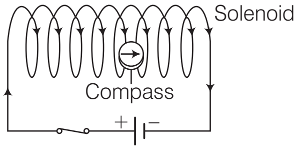
17. A plotting compass is placed inside a solenoid and the compass needle is pointing in the direction as shown.



(i) Complete the diagram by drawing arrow heads to indicate the direction of the current flow.

(ii) Describe the direction of the magnetic field inside the solenoid.

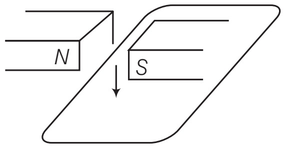
Sol. (i)



[1]

(ii) The direction of the magnetic field inside the solenoid always points from the induced South pole towards the induced North pole. ***[1]***

18. The wire in the figure below is being moved downwards through the magnetic field so as to produce induced current.



What would be the effect of

(i) moving the wire at a higher speed?

(ii) moving the wire upwards rather than downwards?

(iii) using a stronger magnet?

(iv) holding the wire still in the magnetic field?

Sol. (i) The induced current increases at a higher speed.

(ii) The induced current is reversed.

(iii) The induced current increases.

(iv) The induced current is zero. ***[1/2 × 4]***

19. Explain different ways to induce current in a coil.

Sol. *Current is induced in a coil in following ways*

(i) When a magnet is moved towards or away from coil or there is a relative motion between coil and magnet, a current is induced in the coil circuit. ***[1]***

(ii) When a current passing through a coil changes, then a current is induced in a coil placed near to it. ***[1]***

20. Give two similarities between an AC generator and a DC motor.

Sol. *Similarities between an AC generator and a DC motor are*

(i) Both AC generator and DC motor work on magnetic effect of electric current. ***[1]***

(ii) In both cases, a coil rotates in a magnetic field between the pole pieces of a strong electromagnet. ***[1]***

21. (i) Which sources produce Alternating Current (AC)?

(ii) Name some sources of direct current.

Sol. (i) Some sources that produce alternating current are AC generators, thermal power stations, car alternators, etc. ***[1]***

(ii) Some sources of direct current are electrochemical dry cells, solar cells, lead acid accumulator batteries, DC generators, etc. ***[1]***

22. State what would happen to the direction of rotation of a motor, if

(i) the current were reversed?

(ii) both current and magnetic field were reversed simultaneously?

Sol. (i) Direction of rotation would be reversed. ***[1]***

(ii) Direction of rotation would remain unchanged. ***[1]***

23. Give two differences between a DC motor and an AC generator. ***[2010]***

Sol. *The two differences between a DC motor and an AC generator are*

DC Motor	AC Generator
It converts electrical energy into mechanical energy.	It converts mechanical energy into electrical energy.
It is based on the principle that when a coil carrying current is held in a magnetic field, it experiences a torque which rotates the coil.	It is based on the phenomenon of electromagnetic induction.

[1 × 2]

24. (i) What is an AC generator or dynamo used for?

(ii) Name the principle on which it works. ***[2012]***

Sol. (i) An AC generator or dynamo is used to convert mechanical energy into electrical energy. ***[1]***

(ii) It works on the principle of electromagnetic induction. ***[1]***

25. (i) How is the emf across primary and secondary coils of a transformer related with the number of turns of coil in them?

(ii) On which type of current do transformers work? ***[2018]***

Sol. (i) Let the emf across primary and secondary coils are E_S and E_P respectively.

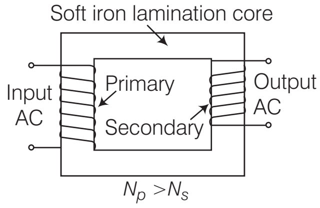
$$\therefore \qquad \frac{E_S}{E_P} = \frac{N_S}{N_P}$$

where, N_S = number of turns in secondary coil and N_P = number of turns in primary coil.
Hence, emf is directly proportional to the number of turns in coil. ***[1]***

(ii) Transformer works with alternating current (AC). ***[1]***

26. Draw a simple sketch of a step-down transformer. Label the different parts in the diagram. ***[2008]***

Sol. *The sketch of step-down transformer is shown as below*



[2]

27. A device is used to transform 12 V AC to 200 V AC.

(i) What is the name of this device?

(ii) Name the principle on which it works. ***[2010]***

Sol. (i) The name of this device is step-up transformer. ***[1]***

(ii) It is based on the principle of mutual induction. ***[1]***

28. State two causes of energy loss in a transformer. ***[2016]***

Sol. *The two causes of energy loss in a transformer are as follow*

(i) **Eddy Currents** The alternating magnetic flux induces eddy currents in the iron core and causes heating. ***[1]***

(ii) **Resistance of the Windings** The wire used for the windings has some resistance and so energy is lost due to heat produced in the wire (I^2R). ***[1]***

b 3 Marks Questions

29. (i) List three methods of producing magnetic fields.

(ii) Imagine that you are sitting in a chamber with your back to one wall. An electron beam moving horizontally from back wall towards the front wall is deflected by a strong magnetic field to your right side. What is the direction of magnetic field?

Sol. (i) *Three methods of producing magnetic field are as given below*

(a) Passing electric current through a straight conductor/circuit.

(b) Passing electric current through a circular loop.

(c) Passing electric current through a solenoid. ***[2]***

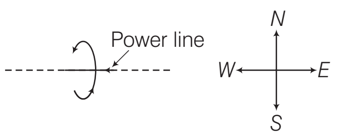
(ii) According to Fleming's left hand rule, the direction of magnetic field is vertically downward. ***[1]***

30. A horizontal power line carries current in East to West direction. What is the direction of the magnetic field due to the current in the power line at a point above and at a point below the power line?

Sol. *According to right hand thumb rule,*

(i) the direction of magnetic field at a point above the power line is from South to North. ***[1]***

(ii) the direction of magnetic field at a point below the power line is from North to South.



[2]

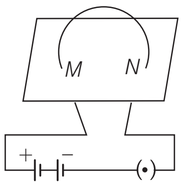
31. The flow of current in a circular wire creates a magnetic field at its centre. How can existence of this field be detected? State the rule which helps to predict the direction of magnetic field.

Sol. The existence of this field can be detected by using a magnetic compass needle.

The direction of magnetic field is predicted by using Maxwell's right hand thumb rule. **[1½]**

It states that, if you hold a current carrying conductor in right hand, such that the thumb points in the direction of electric current, then the direction in which fingers encircle, gives the direction of magnetic field. **[1½]**

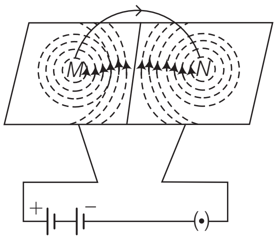
32. The diagram given shows a current carrying loop or a circular coil passing through a sheet of cardboard at the points M and N. The sheet of cardboard is sprinkled uniformly with iron filings.



(i) Copy the diagram and draw an arrow on the circular coil to show the direction of current flowing through it.

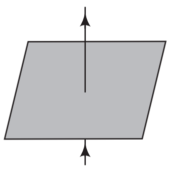
(ii) Draw the pattern of arrangement of the iron filings when current is passed through the loop. **[2012]**

Sol. The direction of current is from M to N. **[1]**



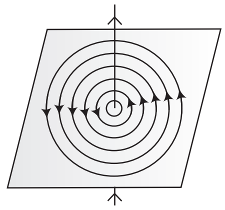
[2]

33. (i) A straight wire conductor passes vertically through a piece of cardboard sprinkled with iron filings as shown in the figure below. Copy the diagram and show the setting of iron filings when a current is passed through the wire in the upward direction and the cardboard is tapped gently. Draw arrows to represent the direction of the magnetic field lines.



(ii) Name the law which helped you to find the direction of the magnetic field lines. **[2010]**

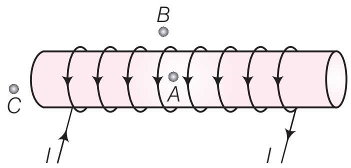
Sol. (i) *The following diagram shows the magnetic field lines.*



[2]

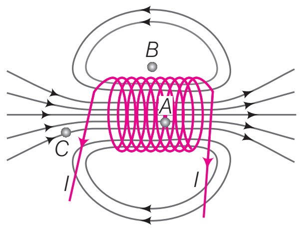
(ii) The right hand thumb rule helps to find the direction of magnetic field lines. **[1]**

34. For the current carrying solenoid as shown below, draw magnetic field lines and giving reason explain that out of the three points A, B and C at which point, the field strength is maximum and at which point it is minimum.



[2015]

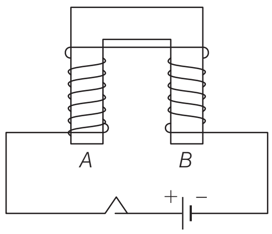
Sol. According to the question, we can draw the following diagram.



[1]

The magnetic field strength is maximum at point A and is minimum at point B, because magnetic field is strong, where magnetic field lines are crowded and is weak, where magnetic field lines are far apart. **[2]**

35. The diagram shows a coil wound around a U-shape soft iron bar AB.



(i) What is the polarity induced at the ends A and B when the switch is pressed?

(ii) Suggest one way to strengthen the magnetic field in the electromagnet.

(iii) What will be the polarities at A and B if the direction of current is reversed in the circuit? **[2018]**

Sol. (i) Current enter at point A (clockwise rotation) and leaving from point B (anti-clockwise rotation). Hence, A will be South pole and B will be North pole. ***[1]***

(ii) Increasing the number of turns of coils, increases current. ***[1]***

(iii) $A =$ North, $B =$ South ***[1]***

36. Explain briefly, how a magnet can be demagnetised using an alternating current?

Sol. To demagnetise a magnet, place it inside a long solenoid with its length in East-West direction.

A 12 V AC supply is connected with a rheostat in series. Switch on the current, when AC is passed, its polarity changes due to which magnetic domains are reversed. ***[1½]***

Thus, it becomes randomly oriented and the bar loses its magnetism to a greater extent.

Gradually, the current is reduced to zero by rheostat which makes the re-alignment of domains most difficult. Thus, the bar of magnet is demagnetised. ***[1½]***

37. (i) State two factors on which the strength of an induced current depends.

(ii) When a solenoid that is carrying current is freely suspended, it uses to rest along a particular direction. Why does this happen? ***[2007]***

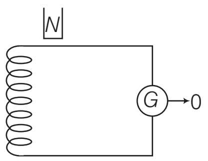
Sol. (i) *The two factors on which the strength of an induced current depends are*

(a) rate of change of magnetic flux within the closed coil.

(b) number of turns in coil. ***[2]***

(ii) Refer to the Sol. 3. (i). ***[1]***

38. From the diagram given below



(i) What will you observe, when

(a) the magnet is dropped into the coil?

(b) the number of turns of the coil is increased?

(ii) What will be the direction of current flowing through the coil, when the magnet is dropped in? (Clockwise or anti-clockwise).

(iii) State the phenomenon on which the observation is made.

Sol. (i) (a) When a magnet is dropped into the coil, sudden deflection is observed in the galvanometer.

(b) If number of turns of the coil is increased, galvanometer shows large deflection i.e., current induced increases.

$\because \qquad B \propto n$ ***[1/2 × 2 = 1]***

(ii) The direction of current flowing through the coil, when the magnet is dropped into, will be anti-clockwise. ***[1]***

(iii) The above observation is made an electromagnetic induction. ***[1]***

39. A coil of insulated copper wire is connected to a galvanometer. What will happen, if a bar magnet is

(i) pushed into the coil

(ii) withdrawn from inside the coil and

(iii) held stationary inside the coil?

Sol. (i) The galvanometer shows a deflection which means current is induced in the coil. Current is induced in the coil due to the relative motion between coil and magnet. ***[1]***

(ii) The galvanometer shows a deflection in opposite direction which means current is induced in opposite direction. In this case, the direction of motion is in the opposite directions w.r.t. coil. ***[1]***

(iii) There is no deflection in galvanometer as no current is induced in the coil. There is no relative motion between coil and current, so no current will be induced in the coil. ***[1]***

40. (i) Two circular coils P and Q are kept close to each other, of which coil P carries a current. If coil P is moved towards Q, will some current be induced in coil Q? Give reason for your answer and name the phenomenon involved.

(ii) What happens, if coil P is moved away from Q?

(iii) State few methods of inducing current in a coil.

Sol. (i) When coil P is moved towards Q, current will be induced in coil Q.

This is because on moving P, the magnetic field associated with Q increases and so a current is induced. The phenomenon is electromagnetic induction. ***[1]***

(ii) If P is moved away from Q, the field associated with Q will decrease and a current will be induced but in the opposite direction. ***[1]***

(iii) *Some of the methods of inducing current in the coil are*

(a) moving a magnet towards or away from the coil.

(b) moving a coil towards or away from a magnet.

(c) rotating a coil within a magnetic field. ***[1]***

41. State the rule to determine the direction of a

(i) magnetic field produced around a straight conductor carrying current.

(ii) force experienced by a current carrying straight conductor placed in a magnetic field.

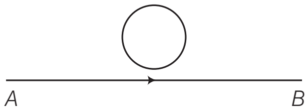
(iii) current induced in a coil due to its rotation in magnetic field.

Sol. (i) **Maxwell's Right Hand Thumb Rule** Refer to theory (Page 184).

(ii) **Fleming's Left Hand Rule** Refer to theory (Pages 185 and 186).

(iii) **Fleming's Right Hand Rule** Refer to theory (Page 187).

42. A circular metallic loop is kept above the wire AB as shown below



What is the direction of induced current produced in the loop, if any, when the current flowing in the straight wire

(i) is steady i.e., does not vary?

(ii) is increasing in magnitude?

Justify your answer in each case.

Sol. (i) No induced current will not be produced in the loop, since the constant current flowing in the straight wire produces a constant magnetic field. Hence, no induced current is produced in the loop. *[1]*

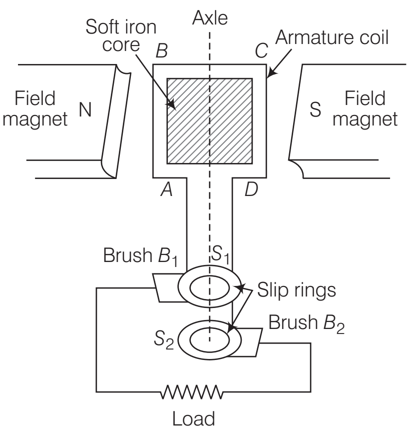
(ii) Since, current in the straight wire is changing, the magnetic flux associated with the loop will change and hence induced current will be produced in it.

Applying Fleming's right hand rule, the current flowing in the loop will be in clockwise direction. *[1+1]*

43. (i) Draw a neat and labelled diagram to show the structure of an AC generator.

(ii) State the energy conversion taking place in the AC generator, when it is working. *[2009]*

Sol. (i) *The labelled diagram of an AC generator is shown as below*



[2]

(ii) In the AC generator, mechanical energy of the rotation of the coil converts into electrical energy. *[1]*

44. State whether the following statements are true or false.

(i) An electric motor converts mechanical energy into electrical energy.

(ii) An electric generator works on the principle of electromagnetic induction.

(iii) The field at the centre of a long circular coil carrying current will be parallel straight lines.

Sol. (i) False, electric motor converts electric energy into mechanical energy.

(ii) True (iii) True *[1 × 3 = 3]*

45. What is a commutator? How does it bring direct current?

Sol. A commutator is used in a DC generator and helps to produce direct current. *[1]*

If a commutator is used, one brush is at all times in contact with the wire moving up in the field, while the other is in contact with the wire moving down, as split rings change their position after every half rotation. Thus, a unidirectional current is produced. *[2]*

46. (i) Name the transformer used in the power transmitting station of a power plant.

(ii) What type of current is transmitted from the power station?

(iii) At what voltage is this current available to our household? *[2017]*

Sol. (i) In the power transmission station, step-up transformer is used to minimise the loss of electrical energy in transmission. *[1]*

(ii) Alternating current (AC) is transmitted from the power station. *[1]*

(iii) At our household 220 V of current is supplied by the step-down transformer. *[1]*

C 4 Marks Questions

47. (i) What is the function of the split rings in a DC motor? *[2013, 2010]*

(ii) State two ways by which the magnetic field of a solenoid can be made stronger.

Sol. (i) In DC motor, when the coil rotates, the split ring rotates with it to make the current flow in the armature coil in such a way that it always keep on rotating in the same manner. *[2]*

(ii) Magnetic field of a solenoid can be made stronger by increasing

(a) the current in the solenoid. **[1]**

(b) the number of turns in the solenoid. **[1]**

48. Draw a representative diagram of a DC motor. Label the following in your diagram.

(i) The field magnet

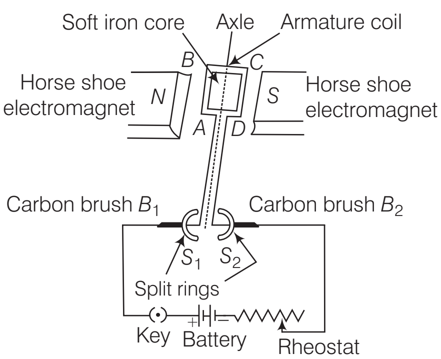
(ii) The armature

(iii) Commutator

(iv) Wire brushes

What is the energy change in this case? **[2011]**

Sol. The labelled diagram of DC motor is as shown below



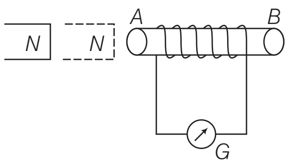
(i) The magnetic field is labelled as *N-S*. It is an electromagnet with concave pole pieces. **[1]**

(ii) The armature coil mounted on an axle is labelled as *ABCD*. **[1]**

(iii) The commutators are labelled as S_1, S_2. **[1]**

(iv) Wire brushes are labelled as B_1, B_2 .
In an electric DC motor, the electrical energy is converted into mechanical energy. **[1]**

49. The diagram shows a coil connected to a centre zero galvanometer *G*. The galvanometer shows a deflection to the right, when the *N*-pole of a powerful magnet is moved to the right as shown in below figure.



(i) Explain, why the deflection occurs in the galvanometer?

(ii) Does the direction of the current on the coil appear clockwise or anti-clockwise, when viewed from the end *A*?

(iii) State the observation in *G*, when the coil is moved away from *N*.

(iv) State the observation in *G*, when both the coil and the magnet are moved to the right at the same speed.

Sol. (i) When *N*-pole of the magnet is moved to the right, the current flows in the coil. Due to this, there is a change in the magnetic flux linked with the coil.

As a result, an emf is induced across the end which causes induced current to flow in the coil. Thus, the galvanometer shows deflection. **[1]**

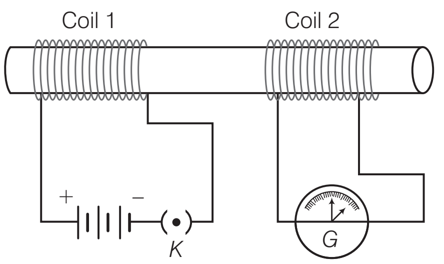
(ii) Anti-clockwise. **[1]**

(iii) When the coil is moved away from *N*, the galvanometer needle deflects to left side. **[1]**

(iv) When both the coil and the magnet are moved at the same speed there is no change in the magnetic flux linked with the coil. So, the galvanometer needle does not deflect. **[1]**

50. Describe an experiment to show that a current is set up in a closed loop when an external magnetic field passing through the loop increases or decreases.

Sol. Let two different coils of copper wire, namely coil 1 and coil 2, having large number of turns are arranged as per the circuit (as shown in figure).



The coil 1, having larger number of turns, is connected in series with a battery and a plug key, whereas the other coil 2 is connected with a galvanometer. **[2]**

Case I When key *K* is closed, the galvanometer shows a deflection, its needle instantly jumps to one side and just as quickly returns to zero, indicating a momentary current in coil 2. This happens due to an external magnetic field passing through the loop increases. **[1]**

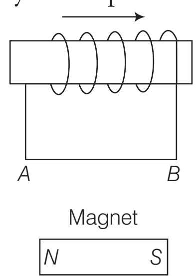
Case II When key *K* is open, the coil 1 is disconnected from the battery. The needle momentarily moves, but to the opposite side. It means that now the current flows in the opposite direction in coil 2. This happens due to an external magnetic field passing through the loop decreases. **[1]**

51. (i) Name two factors on which the magnitude of an induced emf in the secondary coil depends.

(ii) In the given diagram, an arrow shows the motion of the coil towards the bar magnet.

(a) State in which direction the current flows, *A* to *B* or *B* to *A*?

(b) Name the law used to come in the conclusion. **[2014]**



Sol. (i) *The two factors on which the magnitude of an induced emf in the secondary coil depends are*

(a) the change in magnetic flux. **[1]**

(b) the time in which magnetic flux changes. **[1]**

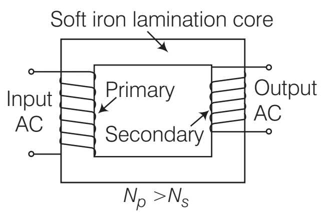
(ii) (a) The current flows from *A* to *B*. **[1]**

(b) The law used to come to the conclusion is Lenz's law. **[1]**

52. (i) Draw a labelled diagram to show the various components of a step-down transformer.

(ii) State the main difference between a step-up and step-down transformer.

Sol. (i) The sketch of step-down transformer is shown below



[2]

(ii) *The difference between step-up and step-down transformer are as below*

Step-up Transformer	Step-down Transformer
It is used to change a low voltage alternating emf to high voltage alternating emf.	It is used to change a high voltage alternating emf to low voltage alternating emf.
The number of turns in primary coil is less than the number of turns in secondary coil.	The number of turns in primary coil is greater than the number of turns in secondary coil.

[1 × 2 = 2]

Numerical Based Questions

53. A power transmission line feeds input power at 2300V to a step-down transformer with its primary windings having 4000 turns. What should be the number of turns in the secondary in order to get output power at 230V?

Sol. Given, primary voltage, $V_p = 2300\text{ V}$

Secondary voltage, $V_s = 230\text{ V}$

Primary turns, $N_p = 4000$ turns

Here, we assume that the transformer is ideal.
No power loss in the form at heat.

Using the formula, $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$ or $\dfrac{230}{2300} = \dfrac{N_s}{4000}$

$\Rightarrow \quad N_s = 400$ **[2]**

54. A 60 W load is connected to the secondary at transformer whose primary draws line voltage. If current of 0.54 A flows in the load, what is the current in the primary coil? Comment on the type a transformer a being used.

Sol. Given, power, $P_L = 60\text{ W}$, current, $I_L = 0.54\text{ A}$

$\therefore$ Voltage, $V_L = \dfrac{P_L}{I_L} = \dfrac{60}{0.54} = 111.11\text{ V} = 111\text{ V}$ **[1]**

On average the input current is half a load current,

$$I_P = \frac{I_L}{2} = \frac{0.54}{2} = 0.27\text{ A}$$

The transformer is step-down. **[1]**

55. A step-up transformer operated on a 2.5 kV line. It supplies a load with 20 A. The ratio of the primary winding to the secondary is 10 : 1. If the transformer is 100% efficient, then calculate

(i) the power output

(ii) the voltage and

(iii) the current is the secondary.

Sol. Given, input voltage, $V_p = 2.5\text{ kV} = 2.5 \times 10^3\text{ V}$

Input current, $I_p = 20\text{ A}$

Also, $\dfrac{N_p}{N_s} = \dfrac{10}{1} \Rightarrow \dfrac{N_s}{N_p} = \dfrac{1}{10}$ ...(i)

(i) $\therefore$ Output power $= (V_p I_p)$
(as transformer is 100% efficient)

$= (2.5 \times 10^3) \times (20)$

$= 5 \times 10^4\text{ W}$ ...(ii) **[1]**

(ii) As, $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p} \Rightarrow V_s = \dfrac{N_s}{N_p} \times V_p$

$\therefore$ Voltage, $V_s = \dfrac{1}{10} \times 2.5 \times 10^3 = 250\text{ V}$ ...(iii) **[1]**

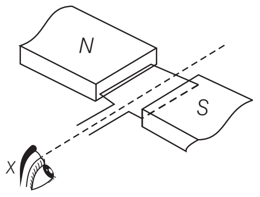
(iii) As, $V_s I_s = 5 \times 10^4$

Current, $I_s = \dfrac{5 \times 10^4}{V_s} = \dfrac{5 \times 10^4}{250} = 200\text{ A}$ **[1]**

CHAPTER EXERCISE

2 Marks Questions

1. In the simple electric motor of figure given below, the coil rotates anti-clockwise as seen by the eye from the position *X*, when current flows in the coil.



Is the current flowing clockwise or anti-clockwise around the coil, when viewed from above?

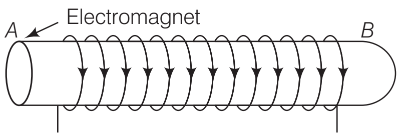
2. (i) What is the function of a step-up transformer?
(ii) Can a transformer work, when it is connected to a DC source?

3 Marks Questions

3. A coil is connected to a galvanometer. When the *N*-pole of a magnet is pushed into the coil, the galvanometer deflected to the right. What deflection, if any is observed, when
(i) the *N*-pole is removed?
(ii) the *S*-pole is inserted?

4. (i) Draw the pattern of magnetic field lines through and around a current-carrying loop of wire.
Mark the direction of
(a) electric current in the loop
(b) magnetic field lines
(ii) How would the strength of magnetic field due to current-carrying loop be affected if
(a) radius of the loop is reduced to half of its original value?
(b) strength of current through the loop is doubled?

5. The diagram shows a coil of wire wound on a soft iron core forming an electromagnet. A current is passed through the coil in the direction indicated by the arrows. Mark the *N* and *S*-poles produced in the iron core.



6. What is the purpose of using transformer? Can it be used with both the current sources alternating and direct? If not, why? What appliance will you use to step-down DC voltage?

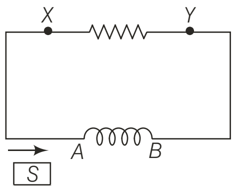
4 Marks Questions

7. (i) State at least two ways to increase the force on a current-carrying conductor in a magnetic field.
(ii) With the help of a labelled circuit diagram, illustrate the pattern of field lines of the magnetic field around a current-carrying straight long conducting wire. How is the right-hand thumb rule useful to find direction of magnetic field associated with a current-carrying conductor?

8. (i) Prachi draws magnetic field lines of field close to the axis of a current-carrying circular loop. As she moves away from the centre of the circular loop, she observes that the lines keep on diverging. How will you explain her observation?
(ii) How will you use a solenoid to magnetise a steel bar?

9. (i) Name two devices which work on the magnetic effect of current.
(ii) Name the essential parts of a DC motor.

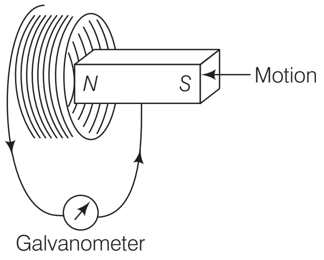
10. A small valued resistance *XY* is connected across the ends of a coil. Predict the direction of induced current in the resistance *XY*, when



(i) South pole of a magnet moves towards end *A* of coil.
(ii) South pole of magnet moves away from end *A* of the coil.

11. A coil made of insulated copper wire is connected to a galvanometer. What will happen to the deflection of the galvanometer if this coil is moved towards a stationary bar magnet and then moved away from it? Give reason for your answer and name the phenomenon involved.

12. When the magnet shown in the diagram below is moving towards the coil, the galvanometer gives a reading to the right.

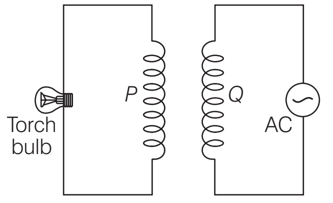


(i) What is the name of the effect being produced by the moving magnet?

(ii) State what happens to the reading shown on the galvanometer, when the magnet is moving away from the coil?

(iii) The original experiment is repeated. This time, the magnet is moved towards the coil at a great speed. State two changes you would notice in the reading on the galvanometer.

13. A coil P is connected to a torch bulb and placed parallel to another coil Q as shown in figure.



Explain the following observations

(i) Bulb lights

(ii) Bulb gets dimmer, if the coil P is moved upwards.

Numerical Based Questions

14. The primary coil of a transformer has 800 turns and the secondary coil has 8 turns. It is connected to a 220V AC supply. What will be the output voltage?

Ans. 2.2 V

15. The input and output voltages of a transformer are 220 V and 44 V respectively. Find (i) the turns ratio, (ii) the current in input circuit if the output current is 2A.

Ans. (i) 1: 5, (ii) 0.4 A

ARCHIVES* *(Last 7 Years)*

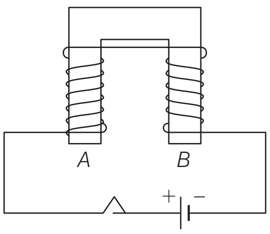
Collection of Questions Asked in Last 7 Years' (2018-2012) ICSE Class 10th Examinations

2018

1. (i) How is the emf across primary and secondary coils of a transformer related with the number of turns of coil in them?

(ii) On which type of current do transformers work? ***[2]***

2. The diagram shows a coil wound around a *U*-shape soft iron bar *AB*.



(i) What is the polarity induced at the ends *A* and *B* when the switch is pressed?

(ii) Suggest one way to strengthen the magnetic field in the electromagnet.

(iii) What will be the polarities at *A* and *B* if the direction of current is reversed in the circuit? ***[3]***

2017

3. (i) Name the transformer used in the power transmitting station of a power plant.

(ii) What type of current is transmitted from the power station?

(iii) At what voltage is this current available to our household? ***[3]***

2016

4. State two causes of energy loss in a transformer. ***[2]***

5. (i) Why does a current-carrying freely suspended solenoid rest along a particular direction?

(ii) State the direction in which it rests. ***[2]***

2015

6. (i) Name the device used to increase the voltage at a generating station. ***[1]***

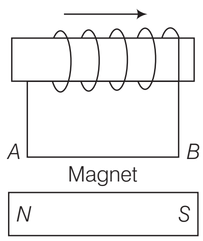
(ii) At what frequency is AC supplied to residential houses? ***[1]***

7. Give two similarities between an AC generator and a DC motor. ***[2]***

2014

8. (i) Name two factors on which the magnitude of an induced emf in the secondary coil depends. ***[2]***

(ii) In the following diagram, an arrow shows the motion of the coil towards the bar magnet.

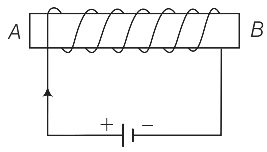


(a) State in which direction the current flows, *A* to *B* or *B* to *A*? ***[1]***

(b) Name the law used to come in the conclusion. ***[1]***

2013

9. You have been provided with a solenoid *AB*.



(i) What is the polarity at end *A*?

(ii) Give one advantage of an electromagnet over a permanent magnet. ***[2]***

10. (i) Draw a simple labelled diagram of a DC electric motor.

(ii) What is the function of split rings in a DC motor?

(iii) State one advantage of AC over DC. ***[4]***

2012

11. (i) What is an AC generator or dynamo used for?

(ii) Name the principle on which it works. ***[2]***

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

CHALLENGERS*

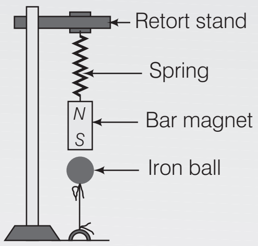
A Set of Brain Teasing Questions for Exercise of Your Mind

1 A straight wire lying in a horizontal plane carries a current from North to South. Magnetic field at a point directly below the wire is
(a) East (b) West
(c) North (d) South

2 On reversing the direction of current in a wire the magnetic field produced by it
(a) get reversed in direction
(b) increases in strength
(c) decreases in strength
(d) remains unchanged in strength and direction

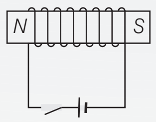
3 In which of the following cases emf is not induced?
(a) A current is started in a wire held near a loop of wire
(b) The current is switched off in a wire held near a loop of wire
(c) A magnet is moved through a loop of wire
(d) A loop of wire is held near a magnet

4 Ravi designed the toy shown below using a bar magnet, a spring and an iron ball.

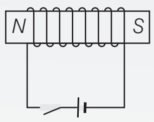


Which of the following correctly shows how the forces are interacting to keep the ball floating?
(a) Magnetic force is equal to gravitational force
(b) Elastic spring force is equal to magnetic force
(c) The sum of elastic spring force and magnetic force is equal to gravitational force
(d) The sum of elastic spring force and gravitational force is equal to frictional force

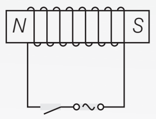
5 A permanent magnet can be demagnetised by using a solenoid and switching the current on then off.
Which diagram shows the most effective method of producing demagnetisation?

(a) 

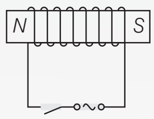
Magnet left in place

(b) 

Magnet withdrawn before switching off

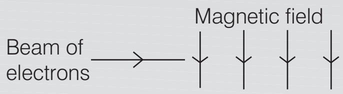
(c) 

Magnet left in place

(d) 

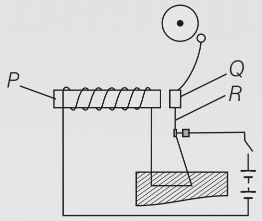
Magnet withdrawn before switching off

6 The diagram shows a beam of electrons entering a magnetic field.



(a) they are deflected into the plane of the diagram
(b) they are deflected out of the plane of the diagram
(c) they are deflected towards the bottom of the diagram
(d) they are deflected towads the top of the diagram

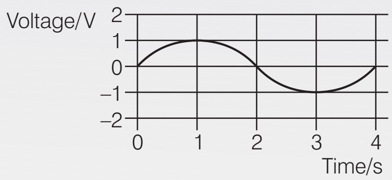
7 The diagram shows an electric bell.



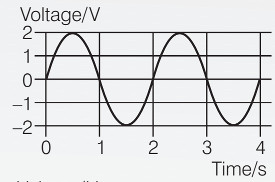
Which materials would be suitable for the parts labelled *P*, *Q* and *R*?

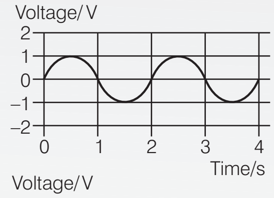
	P	*Q*	*R*
(a)	Soft iron	Brass	Soft iron
(b)	Soft iron	Soft iron	Spring steel
(c)	Soft iron	Brass	Brass
(d)	Spring steel	Soft iron	Spring steel

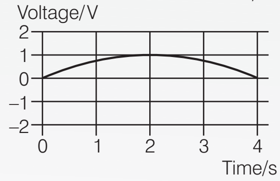
8 A simple AC generator produces a voltage that varies with time as shown below:.

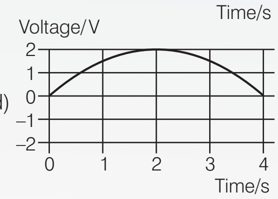


Which graph shows how the voltage varies with time when the generator rotates at twice the original speed?

(a) 

(c) 

(b) 

(d) 

Answers

1. (a) **2.** (a) **3.** (d) **4.** (c) **5.** (d) **6.** (d) **7.** (b) **8.** (a)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 245.

CHAPTER

10

Heat

When heat is introduced to a certain substance, its molecules start moving faster and collide with one another, which produce more heat and the temperature of the substance goes up. This implies that heat introduced to a substance, changes the temperature of the body. Thus, heat and temperature both are interrelated to each other. In this chapter, we will study the concept of heat and its measurement and also the process of transfer of heat during the change of state of a substance, which constitute the concept of latent heat.

Chapter Objectives

- Temperature
- Heat
- Thermal (Heat) Capacity
- Specific Heat Capacity
- Calorimetry
- Change of Phase (State)
- Latent Heat
- Heating Curve for Water

Temperature

It is the measure of degree of hotness or coldness of any body. When two bodies are at different temperatures, i.e., T_1 and T_2, where $T_1 > T_2$, then the body with temperature T_1 is called hotter with respect to another body with temperature T_2.

The SI unit of temperature is Kelvin (K). Other units of temperature are Celsius (°C) and Fahrenheit (F).

Heat

The form of energy which flows from one part to other part of the system due to difference in temperature of two parts is known as heat. It measures the total internal energy possessed by the molecules. It flows from a hot body to a cold body when they are kept in contact. It is represented by Q.

The sum of the potential energy and kinetic energy of a molecule is called its internal energy. The total internal energy of all molecules of a substance is called its heat energy.

Units of Heat

Like other forms of energy, the SI unit of heat is **joule** (J). Apart from this, there are other two commonly used units; **calorie** and **kilocalorie**.

Calorie

The amount of heat energy which is required to raise the temperature of 1 g of water through 1°C is known as a calorie.

But, it was found that this definition is not true due to non-uniform thermal expansion of water.

So, the definition of calorie was restated as the amount of heat energy required to raise the temperature of 1 g of water from 14.5°C to 15.5°C is known as one calorie of heat.

Kilocalorie

The amount of heat energy required to raise the temperature of 1 kg of water from 14.5°C to 15.5°C is known as one kilocalorie of heat.

1 kilocalorie = 1000 calories

Kilocalorie is usually used for measuring the energy value of foods.

Note 1 calorie = 4.186 J = 4.2 J (approx)
1 kilocalorie = 4186 J = 4200 J (approx)

Differences between Heat and Temperature

Heat	Temperature
It measures the total internal energy possessed by the molecules of the body.	It determines the direction of flow of heat between the two bodies in contact with each other.
Its SI unit is Joule (J).	Its SI unit is Kelvin (K).
By using the principle of calorimetry, this quantity can be measured.	By using thermometer, this quantity can be measured.
It is an additive quantity.	It is not an additive quantity.

Note The quantity of heat which is absorbed by a body to raise its temperature depends upon its mass, rise in temperature and its material.

Thermal (Heat) Capacity

It is defined as the amount of heat needed to change the temperature of a body by unity, i.e., 1° C or 1 K. It is denoted by C′.

$$\text{Heat capacity, } C' = \frac{\Delta Q}{\Delta T}$$

where, ΔQ = heat absorbed or rejected by body
and ΔT = change in temperature.

Units of Heat Capacity

SI unit of heat capacity is J/K.

Calorie $°C^{-1}$ (or cal K^{-1}) and kilocalorie $°C^{-1}$ (or kilocalorie K^{-1}) are some other units of heat capacity.

$$1 \text{ kilocalorie } °C^{-1} = 1000 \text{ cal}°C^{-1}$$

$$1 \text{ cal } K^{-1} = 4.2 \text{ JK}^{-1}$$

Water Equivalent

Mass of water having the same thermal capacity as that of a given body is called **water equivalent** of the body. The unit of water equivalent is gram (g).

Example 1. Determine the thermal (heat) capacity of iron ball if it requires 5000 J heat energy to raise its temperature by 10°C.

Sol. Here, Q = 5000 J and ΔT = 10° C

As, the size of a degree is the same on the Celsius and Kelvin scales, so the change in temperature has the same magnitude in °C and K.

Since, heat capacity

$$C' = \frac{\text{Heat energy required } (Q)}{\text{Rise in temperature } (\Delta T)} \Rightarrow C' = \frac{5000}{10} = 500 \text{ JK}^{-1}$$

Daily Life Examples of High and Low Thermal Capacity

(i) The calorimeter which is used to measure the heat, is made of thin sheet of copper. It is because the specific heat capacity of copper is low and by making the calorimeter thin, its thermal capacity also becomes low. So, in order to attain its temperature, it takes a negligible amount of heat from its contents.

(ii) In order to increase the thermal capacity of cooking pan, its base is made thick. Due to which, it imparts sufficient heat energy at a low temperature to the food for its proper cooking. It also keeps the food warm for a long time.

(iii) By making the base of an electric iron thick and heavy, the thermal capacity of base of electric iron increases due to which it remains hot for a longer period of time even after switching OFF the current.

CHECK POINT 01

1 What is the mutual relation between heat and temperature?
2 Which single property decides the direction of the flow of heat?
3 Two bodies at different temperatures are placed in contact. State the direction in which heat will flow.
4 Name the SI unit of heat and how is it related to the unit calorie?
5 Determine the heat capacity of iron ball if it requires 4750 J heat energy to raise its temperature by 10 K. ***Ans.*** 475 JK^{-1}

Specific Heat Capacity

The amount of heat needed to raise the temperature of unit mass of a substance by unity is known as the specific heat capacity or specific heat. It is denoted by c.

$$\text{Specific heat capacity, } c = \frac{1}{m}\frac{\Delta Q}{\Delta T} \Rightarrow \Delta Q = m \times c \times \Delta t$$

where, m = mass of given substance.

The substance with low specifie heat capacity shows a rapid and high rise in temperature. Thus, it is a better conductor of heat than the substance with high specific heat capacity which shows a slow and small rise in temperature.

Units of Specific Heat Capacity

Joule per kilogram per kelvin ($Jkg^{-1}K^{-1}$) or joule per kilogram per degree celsius ($Jkg^{-1}\,^\circ C^{-1}$) is the SI unit of specific heat capacity. $Calg^{-1}\,^\circ C^{-1}$ and kilocalorie $kg^{-1}\,^\circ C^{-1}$ are some other units of specific heat capacity.

$1\ calg^{-1}\,^\circ C^{-1} = 1\ kilocal\ kg^{-1}K^{-1} = 4.2\times 10^3\ Jkg^{-1}K^{-1}$

Specific Heat Capacity of Some Common Substances

	Substance	Specific Heat Capacity	
		In $J\,kg^{-1}\,K^{-1}$	In $cal\,g^{-1}\,^\circ C^{-1}$
(i)	Water	4180	1.0
(ii)	Ice	2100	0.50
(iii)	Iron	483	0.115
(iv)	Copper	399	0.095
(v)	Lead	130	0.031

Relationship between Heat Capacity and Specific Heat Capacity

The relationship between the quantities thermal (heat) capacity (C') and specific heat capacity (c) can be given as

$$C' = \text{mass}(m)\times c$$

or

$$c = \frac{C'}{m}$$

Example 2. Find the specific heat capacity of a body whose mass is 500 g and requires 2000 J of heat energy, so to raise its temperature from 35°C to 45°C.

Sol. Given, $m = 500\ g = 0.5\ kg$

Heat energy required, $\Delta Q = 2000J$

Rise in temperature, $\Delta T = (45^\circ - 35^\circ) = 10^\circ C = 10\ K$

$\therefore$ Specific heat capacity,

$$c = \frac{\Delta Q}{m\times\Delta T} = \frac{2000}{0.5\times 10} = 400\ Jkg^{-1}K^{-1}$$

Example 3. A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8.0 kg. How much is the rise in temperature of the block in 2.5 min, assuming 50% of power is used up in heating the machine itself or lost to the surroundings? (Take, specific heat of aluminium $= 0.91\ Jg^{-1}\,^\circ C^{-1}$)

Sol. Given, power, $P = 10\ kW = 10\times 10^3\ W$

Time, $t = 2.5\ min = 2.5\times 60\ s$

Rise in temperature, $\Delta T = ?$

From $P = \frac{W}{t} \Rightarrow W = Pt$

Total energy used $= Pt$

$= 10\times 10^3 \times 2.5\times 60 = 1.5\times 10^6\ J$

Given, energy absorbed by aluminium block,

$\Delta Q = 50\%$ of the total energy

$$\therefore \quad \Delta Q = \frac{1.5\times 10^6}{2} = 0.75\times 10^6\ J$$

Applying the formula, $\Delta Q = mc\Delta T \Rightarrow \Delta T = \frac{\Delta Q}{mc}$

Substituting the given values, we get

$$= \frac{0.75\times 10^6}{8.0\times 10^3\times 0.91} = 103.02^\circ C$$

Differences between Heat Capacity and Specific Heat Capacity

Heat Capacity	Specific Heat Capacity
It is the amount of heat required to raise the temperature of whole body by 1°C.	It is the amount of heat required to raise the temperature of unit mass of the body by 1°C.
Its SI unit is JK^{-1}.	Its SI unit is $Jkg^{-1}K^{-1}$.
It depends on the material and mass of the body.	It is the characteristic of the material of body, so it does not depend on the mass of the body.
It can be calculated as $C' = \text{Mass}(m)\times$ Specific Heat Capacity $(c) = \frac{\Delta Q}{\Delta T}$	It can be calculated as $c = \frac{\text{Heat capacity }(C')}{\text{Mass }(m)} = \frac{1}{m}\frac{\Delta Q}{\Delta T}$

Natural Phenomena and High Specific Heat Capacity of Water

(i) Water is used in cold countries as heat reservoir for wine and juice bottles to prevent their freezing. This is because of its high specific heat capacity. So, it imparts a large amount of heat before reaching to the freezing temperature. Hence due to this, bottles kept in water remains warm and do not get freeze even when there is a considerable decrease in surrounding temperature.

(ii) Almost, all the plants and animals have a high water content in their bodies (i.e., nearly 80% to 90%). It is because of high specific heat capacity of water, the body temperature nearly same in all the seasons.

(iii) For fomentation, the hot water bottles are used. It is because of the high specific heat capacity of water, it does not get cool quickly. So, due to this, a hot water bottle provides the heat energy for fomentation for a longer period of time.

(iv) In car radiators, water is used as coolant. This is because it can absorb a large amount of heat energy from the engine of a car, but itself does not rise to very high temperature.

(v) During a cold winter night, if the atmospheric temperature falls below 0°C, then the chances of destroying of crops becomes high. So, in order to save the crop on such cold nights, farmers fill their fields with water.

It is because of high specific heat capacity of water, it does not permit the temperature in the surrounding area of plant to fall upto 0°C.

(vi) The wet soil does not get heated up so quickly as compared to sandy soil. It is because wet soil requires about five times more heat energy than sandy soil for the same rise in temperature.

CHECK POINT 02

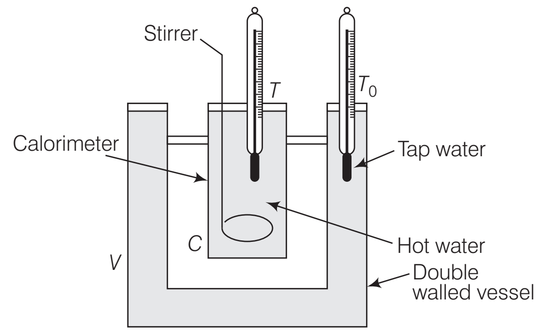
1. Define the term heat capacity and write its SI unit.
2. Why temperature of a human body is nearly same throughout the year ?
3. Mention any two changes which are possible on heating.
4. If the two substances are mixed at the different temperatures, state whether it is necessary that the temperature of substance at lower temperature increases or not.
5. Give the amount of heat energy required to change the temperature of unit mass be unit temperature.
6. Mention the name of a liquid which has the highest specific heat capacity.

Calorimetry

The branch of science which deals with the measurement of heat is known as calorimetry.
Thus, calorimetry is the process of measuring the amount of heat released or absorbed during a process.

Calorimeter

It is a cylindrical vessel which is used to measure the amount of heat gained (or lost) by a body when it is mixed with the other body.



Calorimeter

Principle of Methods of Mixtures (Principle of Calorimetry)

When a body at higher temperature is brought in contact with another body at lower temperature, then the heat flows from the body kept at higher temperature to the body kept at lower temperature.

Thus, the principle of calorimetry states that "total heat given by a hotter body equals to the total heat received by colder body," i.e.,

$$\boxed{\text{Heat lost by hotter body} = \text{Heat gained by colder body}}$$

If two bodies are kept in contact with each other, then if there is no exchange of heat between them, the bodies are then said to be **thermal equilibrium**.

Mathematical Expression

Let a body X of mass m_a, specific heat capacity c_a and at a higher temperature t_a gets mixed with another body Y of mass m_b, specific heat capacity c_b and at a lower temperature t_b. If the final temperature of mixture becomes T, then

Fall in temperature of body, $X = t_a - T$

Rise in temperature of body, $Y = T - t_b$

Heat energy lost by $X = m_a \times c_a \times$ fall in temperature

$$= m_a c_a (t_a - T)$$

Heat energy gained by

$$Y = m_b \times c_b \times \text{rise in temperature} = m_b c_b (T - t_b)$$

If no heat energy is lost to the surroundings, then according to principle of calorimetry,

Heat energy lost by X = Heat energy gained by Y

$$\Rightarrow \boxed{m_a c_a (t_a - T) = m_b c_b (T - t_b)}$$

Example 4. **Consider a solid of mass 80 g at 100°C is placed in 200 g of water at 20°C. The final steady temperature recorded is 22°C. What is the specific heat capacity of the solid?**

Sol. Given, mass of solid, $m_s = 80$ g

Mass of water, $m_w = 200$ g

Temperature of solid, $T_1 = 100°$C

Temperature of water, $T_2 = 20°$C

Final temperature, $T = 22°$C

Specific heat of water, $c_w = 4.2$ J/g/K

Let, c_s be the specific heat capacity of the solid. As, the heat is being transferred from solid to water, from the principle of calorimetry,

Heat lost by the solid = Heat gained by water

$$\Rightarrow \quad m_s \times c_s \times (T_1 - T) = m_w \times c_w \times (T - T_2)$$

$$\Rightarrow \quad 80 \times c_s \times (100 - 20) = 200 \times 4.2 \times (22 - 20)$$

$$\Rightarrow \quad 80 \times c_s \times 80 = 200 \times 4.2 \times 2$$

$$\Rightarrow \quad c_s = \frac{400 \times 4.2}{6400} = 0.2625 \text{ J/g°C}^{-1}$$

Example 5. **A piece of iron of mass 100 g kept inside a furnace for a long time and then put in a calorimeter of water equivalent 10 g containing 240 g of water at 20°C. The mixture attains an equilibrium temperature of 60°C. Find the temperature of the furnace specific heat of iron = 470 J/kg-K.**

Sol. Let temperature of furnace be θ.

Given, $m_i = 100\,\text{g}$, $m_w = 240\,\text{g}$

Water equivalent, $m_w = 10\,\text{g}$

Equilibrium temperature = $60°\,\text{C}$

Then, from principle of calorimetry.

Heat given = Heat taken

$$m_i c_i(\theta - 60) = (m_w' + m_w)c_w(60 - 20)$$

$$\Rightarrow \quad 100 \times 470(\theta - 60) = (10 + 240) \times 4200 \times 40$$

$$\Rightarrow \quad \theta - 60 = \frac{250 \times 4200 \times 40}{100 \times 470} = 893.6$$

$$\Rightarrow \quad \theta = 953.6°\,\text{C}$$

Change of Phase (State)

The process of converting one state of a substance into another state is known as change of state of a substance or matter.

Matter generally exists in three states; solid, liquid and gas. These states can be changed into one another by absorbing or rejecting heat.

The common changes of states are

(i) solid to liquid (and *vice-versa*)

(ii) liquid to gas (and *vice-versa*)

The changes can be occurred when the exchange of heat takes place between substance and its surroundings.

Interconversion of States of Matter

The states of matter are interconvertible. They can be interchanged by changing temperature or pressure. The phenomenon of change of matter from one state to another and back to the original state by altering the conditions of temperature and pressure is called **interconversion of states of matter**.

Following two factors (or any one of these) make it possible to convert one state of matter into another

(i) Change in temperature

(ii) Change in pressure

Terms Involved in Change of State

Following terms are involved in change of state

(i) **Fusion or Melting and Melting Point** The process of conversion of a matter from its solid state to its liquid state at specific conditions of temperature and pressure, is called **fusion/melting**.

And the definite temperature at which a solid starts melting is called the **melting point** of that solid, e.g., Melting point of ice is 0°C or 273.16 K. The melting point is infact, an indication of the strength of the force of attraction between the particles of solid. Higher the melting point of a substance, greater will be the force of attraction between its particles.

(ii) **Boiling and Boiling Point** The process of conversion of a matter from its liquid state to vapours (gaseous state) at specific conditions of temperature and pressure is called **boiling**. It is a bulk phenomenon. And the temperature at which a liquid starts boiling at the atmospheric pressure is known as its **boiling point**.

Particles from the bulk of the liquid gain enough energy to change into the vapour state.

In boiling, all the liquids expands.With the increase in the pressure, boiling point also increases.Due to addition of the impurities, the boiling point increases.

(iii) **Sublimation** The process of change of solid state directly into gaseous state without passing through the liquid state upon heating and *vice-versa* on cooling is known as **sublimation**.

e.g., Naphthalene, camphor, iodine, ammonium chloride, etc., are the solids that undergo sublimation.

(iv) **Vapourisation** The process of conversion of a matter from its liquid state to gaseous state at specific conditions of temperature and pressure is called **vapourisation**.

(v) **Freezing and Freezing Point** The process of conversion of matter from its liquid state to solid state at specific conditions of temperature and pressure, is called **freezing**. It is a reverse process of fusion/melting. And the definite temperature at which a liquid changes into solid state by giving out heat energy at 1 atm is called the **freezing point**.

(vi) **Condensation** The process of conversion of matter from its gaseous state to liquid state at specific conditions of temperature and pressure, is called **condensation**. It is a reverse process of vapourisation.

CHECK POINT 03

1 Why does the water used as an effective coolant?

2 State the principle of calorimetry.

3 Mention the name of the material from which the calorimeter is made of?

4 What is solidification point?

5 Briefly explain how does the increase in pressure affect the melting point of ice?

6 When does the solid and liquid states of a substance co-exists?

7 When 0.2 kg of a body at 100°C is dropped into 0.5 kg of water at 10°C, resulting temperature becomes 16°C. Find specific heat of a body. ***Ans.*** $0.75 \times 10^3\ \text{J/kg/°C}$

Latent Heat

When a heat is given to a substance, its temperature increases. However, when heat is supplied to change the physical state of a substance, there is no increase in temperature of a substance.

Thus, the heat energy which has to be supplied to change the state of substance is called its **latent heat**. In actual, the word 'latent' means 'hidden'. Latent heat does not raise (or increase) the temperature. But latent heat is always supplied to change the state of a substance.

Latent heat is of two types

Latent Heat of Fusion (Solid to Liquid Change)

The amount of heat energy that is required to change 1 kg of a solid into liquid at atmospheric pressure at its melting point is known as the **latent heat of fusion**. Particles in water at 0°C (273.16 K) have more energy as compared to particles in ice at the same temperature. It is observed that latent heat of fusion of ice is 3.34×10^5J.

Latent Heat of Vapourisation (Liquid to Gas Change)

The amount of heat energy that is required to convert 1 kg of a liquid into gas (at its boiling point) without any rise in temperature is known as the **latent heat of vapourisation**. Particles in steam, i.e., water vapour at 373 K (100°C) have more energy than water at the same temperature.

Note It has been found that burns caused by the steam are much more severe than those caused by boiling water though both of them are at the same temperature of 100°C.
As particles in steam have absorbed extra energy in the form of latent heat of vapourisation. Thus, when steam falls on our skin and condense to produce water, it gives out 22.5×10^5J/kg more heat than boiling water at the same temperature.

Units of Specific Latent Heat

(i) Jkg^{-1} is the SI unit of specific latent heat.

(ii) The other common units of specific latent heat are cal g^{-1} and kcal g^{-1}.

Some of the conversions of units are given below

$$1 \text{ kcal g}^{-1} = 1000 \text{ cal g}^{-1}$$
$$1 \text{ cal g}^{-1} = 4.2 \text{ Jg}^{-1}$$
$$1 \text{ cal g}^{-1} = 4.2 \times 10^3 \text{ J kg}^{-1}$$

Example 6. A copper block of mass 2.5 kg is heated in a furnace to a temperature of $500°$C and then placed on a large ice block. What is the maximum amount of ice that can melt? (Take, specific heat of copper = 0.39 $\text{Jg}^{-1}\,°\text{C}^{-1}$ and heat of fusion of water = 335 Jg^{-1}).

Sol. Given, mass of copper block, $m = 2.5 \text{ kg} = 2.5 \times 10^3$ g

Specific heat of copper, $c = 0.39 \text{ Jg}^{-1}\,°\text{C}^{-1}$

Fall in temperature, $\Delta T = 500 - 0 = 500°$ C

Heat lost by copper block $= mc\Delta T$

$= 2.5 \times 10^3 \times 0.39 \times 500$ J

Let mass of ice melted $= m$g

Heat gained during fusion of ice $= m \times 335$ J

$(\because L = 335 \text{ Jg}^{-1})$

$\therefore$ Heat gained = Heat lost

$\therefore$ $m \times 335 = 2.5 \times 10^3 \times 0.39 \times 500$

or $m = \dfrac{2.5 \times 10^3 \times 0.39 \times 500}{335}$

$= 1455.2$ g

$= 1.455$ kg

Example 7. A lead bullet penetrates into a solid object and melts. If half of its kinetic energy is used to heat it, calculate the initial velocity of the bullet. The initial temperature of the bullet is 27° C and the melting point of the material of bullet is 327°C. Given that latent heat of fusion of lead is 2.5×10^4 Jkg^{-1} and specific heat capacity of lead is 125 $\text{Jkg}^{-1}\text{ K}^{-1}$.

Sol. Specific heat capacity of lead, $c = 125$ $\text{Jkg}^{-1}\text{ K}^{-1}$

Change in temperature, $\Delta T = 327 - 27 = 300°$C

Latent heat of fusion of lead, $L = 2.5 \times 10^4$ J Kg^{-1}

Initial velocity of the bullet, $v = ?$

Heat absorbed by the lead, $\Delta Q_1 = mc\Delta T$

$\Rightarrow$ $\Delta Q_1 = m \times 125 \times 300$

$= m \times 3.75 \times 10^4$ Jkg^{-1}

Heat required to melt the bullet, $\Delta Q_2 = mL$

$\Rightarrow$ $\Delta Q_2 = m \times 2.5 \times 10^4$ J kg^{-1}

The kinetic energy of bullet $= \dfrac{1}{2}mv^2$

(where, v is velocity)

Half of kinetic energy $= \dfrac{1}{2}\left(\dfrac{1}{2}mv^2\right) = \dfrac{1}{4}mv^2$

From principle of calorimetry, loss in kinetic energy

$= \Delta Q_1 + \Delta Q_2$

$\therefore$ $1/4\, mv^2 = m(3.75 + 2.5) \times 10^4$ Jkg^{-1}

$\Rightarrow$ $v = 500 \text{ ms}^{-1}$

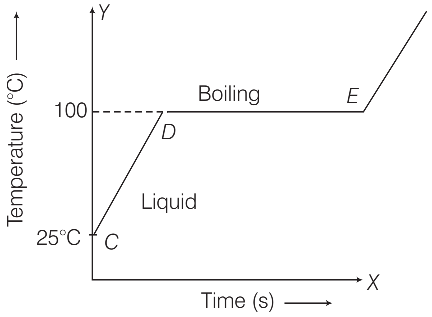
Heating Curve for Water

To evaluate the heating curve for water, the following steps must be followed first.

(i) First of all, take some water in a flask (at room temperature nearly about 25°C) and suspend a thermometer in it.

(ii) By keeping the flask over a bunsen burner, try to heat it and record its temperature after every half minute till the time, it starts boiling and the flask contains vapours.
Now, by taking the temperature along *Y*-axis and the time on *X*-axis, the graph can be plotted. It is called the heating curve for water.

If we see the graph (given below), we will observe that water is at 25°C at C (i.e., room temperature) and the water in a liquid state rises continuously in part *CD* with the absorption of heat energy.



Heating curve of water

At point *D*, the boiling starts and the temperature does not rise further as shown in part *DE*. It can be explained as, at point *D* the water starts to convert into gaseous state from liquid state, so it require latent heat of vapourisation, all the heat being provided here is used in converting the state of water from liquid to gas, so temperature does not rise till all the water converts into vapour.

So, temperature along *DE* remains constant. Again from point *E*, temperature starts to increase because the heat being provided now is not used as latent energy (there is no change of state now), so it increases the temperature.

Natural Consequences of High Specific Latent Heat of Fusion of Ice

Natural consequences of high specific latent heat of fusion of ice are as follows

(i) On the mountains in summer, snow melts very slowly. It is because every kilogram of snow requires 336000 J of heat energy, in order to form water at 0°C.
Therefore, there are no flash floods and the rivers contain the water for whole year.

(ii) During the snow storm, the weather becomes mild, it is because a large amount of heat energy is dissipated in the atmosphere due to the freezing of water vapour.

(iii) When the snow starts melting, the environment becomes bitterly cold, it is because every kilogram of ice on melting absorbs 336000 J of heat energy from the atmosphere.

(iv) The icebergs are carried out by ocean currents over very large distances because of high specific latent heat of fusion of ice.

Uses of High Specific Latent Heat of Fusion of Ice

Use of high specific latent heat of fusion of ice are as follows

(i) Ice is used to cool the soft drinks, because every kg of ice will extract out 336000 J of heat energy more than water at 0°C.

(ii) Ice candy feels colder than water at 0°C, because it can extract out more heat from the mouth as compared to water at 0°C.

CHECK POINT 04

1 How is the volume of water affected when it boils at 100° C?
2 Explain the reason, why is it difficult to cook vegetables on hills and mountains?
3 In what manner does the boiling point of water affect when some salt is added to it?
4 If 1 g of ice at 0°C melts to form 1 g of water at 0° C, then state whether the latent heat is absorbed or given out by ice.
5 Which of the two has more heat 1 g water at 100° C or 1 g of steam at 100° C ? Give reason.
6 Explain the meaning of the given statement, the specific latent heat of fusion of ice is 336 Jg^{-1}.
7 How temperature of the Earth is approximately maintained at 15° C?

SUMMARY

- Temperature is the property of a state of matter by virtue of which we predict its hotness or coldness, relative to some body.
  Its SI unit is Kelvin (K) other units are Celsius (°C) and Fahrenheit (°F).
- Heat is form of energy which determines the change in thermal state of a body. It flows from the body which is at a high temperature to the other at low temperature.
- SI unit of heat is Joule (J). Other units are calorie and kilocalorie.
- Heat Capacity It is the quantity of heat required by the body to raise its temperature by 1°C. It is also known as thermal capacity.
  $$\text{Heat capacity} = \text{mass } (m) \times \text{specific heat capacity (c)}$$
- Water Equivalent It is the quantity of water whose thermal capacity is same as the heat capacity of the body. It is denoted by W.
  $$W = ms = \text{Heat capacity of the body}$$
- Specific Heat The specific heat (c) of a substance is the quantity of heat in calorie required to raise the temperature of 1g of the substance by 1°C. Its unit is cal $g^{-1}\,°C^{-1}$.
- Principle of Methods of Mixtures Heat lost by hotter body = Heat gained by colder body
  $$m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$$
- Change of state is the process of converting one state of a substance into another state.
- Melting is the change from solid to the liquid state at constant temperature. Melting point is the constant temperature at which a solid changes to liquid.
- Vaporisation is the change from liquid to gas (or vapour) phase on heating at a constant temperature.
- Latent Heat The heat required to change the state of a system is proportional to mass of the system. i.e.,
  $$Q \propto m \;\Rightarrow\; Q = mL$$
  where, L = latent heat of the material.
- Specific latent heat of melting is the amount of heat energy required to convert a unit mass of the substance from solid to liquid state without any change in temperature.
- Specific latent heat of fusion is the amount of heat energy released when a unit mass of substance converts from liquid to solid state without any change in temperature.

EXAM PRACTICE

a 2 Marks Questions

1. Define the term 'calorie'. State its relation with joule.

Sol. 1 calorie of heat is defined as the amount of heat energy required to raise the temperature of 1g of water from 14.5°C to 15.5°C. **[1]**

1 calorie = 4.2 joule **[1]**

2. Differentiate between heat and temperature. **[2011]**

Sol. Refer to theory (Page 204). **[2]**

3. Differentiate between heat capacity and specific heat capacity. **[2012]**

Sol. Specific heat capacity is defined as the amount to heat needed to raise temperature of unit mass of a body, whereas heat capacity is defined amount of heat needed raise the temperature for the entire mass of the body. **[2]**

4. State two factors upon which the heat absorbed by a body depends.

Sol. *Heat absorbed by a body depends on*

(i) mass of the body and **[1]**

(ii) specific heat of the body. **[1]**

5. Give two reasons, why copper is preferred over the other metals for using calorimeter? **[2006]**

Sol. *The two factors by which copper is preferred over the other metals for using calorimeter are as follows*

(i) It has low specific heat capacity than other metals. **[1]**

(ii) It takes least amount of heat from its content to attain its temperature. **[1]**

6. Why is the base of a cooking pan generally made thick? **[2017]**

Sol. Thinner base pans definitely transmit heat from the burner to the food, as the base is made up of metal, which is good conductor of heat. But, when it comes to even cooking and maintaining regular heating without hot spots around the pans, it is convenient to use thicker base pans.

Also, it has more thermal mass and it also retain its temperature i.e., the pan will stay at high temperature above and beyond the amount of heat that can immediately supplied by the heat source. **[2]**

7. Define heat capacity and state its SI unit. **[2017]**

Sol. The quantity of heat given to any substance depends on its mass m, the change in temperature ΔT and the nature of substance which is being heated. To change the temperature of substance, a given quantity of heat is absorbed or rejected by it, which is characterised by a quantity known as heat capacity or thermal capacity.

So, thermal capacity is defined as the total amount of heat required to raise the temperature of a body by 1°C. It is represented by C'. **[1]**

$$\text{Heat capacity } (C') = \frac{\text{Heat supplied to the body } (Q)}{\text{Change in temperature } (\Delta T)}$$

Its SI units is joule /°C or Joule /K. Its older unit is cal/° C or cal/K or kcal/°C. **[1]**

8. What do you understand by the following statements? **[2016]**

(i) The heat capacity of the body is 60 JK^{-1}.

(ii) The specific heat capacity of lead is 130 $Jkg^{-1}K^{-1}$.

Sol. (i) The heat capacity of a body is 60 JK^{-1}. It means that 60 J of heat is required to raise the temperature of the body by 1° C. **[1]**

(ii) The specific heat capacity of lead is 130 J / kg-K. It means that 130 J of heat is required to raise the temperature of 1 kg of mass by 1° C.

The temperature change is the difference between the final and initial temperature. **[1]**

9. (i) How can a temperature in degree celsius be converted into SI unit of temperature?

(ii) A liquid X has the maximum specific heat capacity and is used as a coolant in car radiators. Name the liquid X. **[2018]**

Sol. (i) SI unit of temperature is kelvin. To convert temperature in degree celsius to kelvin 273.15 is added to celsius.

$$T\,(\text{in K}) = T\,(°\text{C}) + 273.15 \quad \textbf{[1]}$$

(ii) Liquid 'X' will be water, as water has a high value of specific heat capacity. **[1]**

10. What is a reason of spraying of water on the roads in the evening in the hot summer?

Sol. Since, water has the highest specific heat capacity of 4.2 $Jg^{-1}°C^{-1}$. Therefore, water absorbs large amount of heat from the roads, but its own temperature does not rise much. Due to this the road gets cooled. **[2]**

11. Briefly justify the given statement, "water is considered as the best liquid for quenching thirst".

Sol. As, water has the highest specific heat capacity of 4.2 $Jg^{-1} \circ C^{-1}$, due to which, it absorbs a large amount of heat energy without any rise in temperature. Since, thirst is a natural signal, which means that the body produces more heat energy than required. Therefore, water is ideal for quenching thirst because it absorbs a large amount of heat energy. ***[2]***

12. Briefly explain the terms melting and melting point.

Sol. Melting is defined as the change of phase from solid to the liquid state on heating at a constant temperature, while the fixed temperature at which this change takes place is known as melting point of given solid. ***[2]***

13. What is the effect of pressure on boiling point of a liquid? Give one application of it.

Sol. Boiling point of liquid increases with increase in pressure and decreases with decrease in pressure. ***[1]***

Application In pressure cooker boiling point of water increases upto 25%. ***[1]***

14. Rishi is surprised, when he sees water boiling at 115°C in a container. Give reasons as to why water can boil at the above temperature. ***[2017]***

Sol. The boiling point of water is 100°C at 76 mm of mercury, i.e., atmospheric pressure. But, the boiling point increases with increase in presure. ***[1]***

Since, the water is boiling at 115°C, so the pressure was greater than the atmospheric pressure. ***[1]***

15. Explain, why the weather becomes very cold after a hailstorm? ***[2011]***

Sol. After the hailstorm the ice balls begin to melt and require 336 kJ of heat energy per gram to melt which is taken from the atmosphere thereby decreasing the temperature of atmosphere. ***[2]***

16. Why are burns caused by steam more severe than those caused by boiling water at the same temperature? ***[2007]***

Sol. As the latent heat of vaporisation is more than specific heat of boiling water so, burn caused by steam are more painful than boiling water. ***[2]***

17. State one example which demonstrates that, when liquid evaporates, it takes heat from the surroundings.

Sol. Let us take an example of surahi in which water gets cooled in summer. It is because of the fact that the surahi is made of clay and has pores through which water seeps out and gets evaporated. The latent heat required for evaporation is taken from the water inside the surahi. Therefore, the temperature of water falls and it gets cooled. ***[2]***

18. Explain why does the air passing through a desert cooler become cooler?

Sol. Since, in a desert cooler, hot and dry air pass through wet pads of wood-wool. So, water takes heat from the hot air and evaporates. The evaporation of water cool the pads while the water is circulating. So, as a result, the incoming air gets cooled. ***[2]***

19. Explain why do doctors advise to put strips of wet cloth on the forehead of a person having high temperature?

Sol. When the wet cloth strip is put on the forehead of the person having high temperature, the water being evaporated takes away the necessary heat from the patient's body and lowers his body temperature. ***[2]***

20. In a central heating system, if steam enters a radiator pipe at 100°C and water leaves the radiator pipe at 100°C, state whether this radiator pipe heat the room or not. Give the explanation in support of your answer.

Sol. Yes, this radiator pipe can heat a room. It is because steam at 100°C gives out its latent heat of vaporisation to condense into water at the same temperature of 100°C. ***[2]***

C 3 Marks Questions

21. Specific heat capacity of substance *A* is 3.8 J/gK, whereas the specific heat capacity of substance *B* is 0.4 J/gK.

(i) Which of the two is good conductor of heat?

(ii) How is one led to the above conclusion?

(iii) If substances *A* and *B* are liquid, then which one would be more useful in car radiators? ***[2014]***

Sol. (i) Since, the specific heat capacity of *B* is less than *A*, so *B* is good conductor of heat. ***[1]***

(ii) As, the specific heat capacity of *B* is much less than *A*, so *B* is good conductor of heat. It is because for the same heat energy and same mass rise in temperature of *B* will be more than that of *A*. ***[1]***

(iii) Since, the specific heat capacity of *A* is higher than that of *B*, so it can absorb more heat therefore, it is useful in car radiator. ***[1]***

22. "Farmers fill their fields with water on a cold winter night." Explain in brief along with a reason.

Sol. In order to protect the crops from frost, farmers fill their fields with water. If on a cold winter night during the absence of water, the atmospheric temperature falls below 0°C, then the water in the fine capillaries of plants will freeze. ***[1]***

So, the veins will burst due to increase in volume of water on freezing. As a result, the plants would die and the crop would be destroyed. ***[1]***

But farmers field their land with water as specific heat capacity of water is large and it imparts a large amount of heat energy while it gets cooled in cold winter night. This heat evolved does not permit the temperatures in the surrounding areas to fall upto 0°C. ***[1]***

23. (i) What is the principle of method of mixtures?

(ii) What is the other name given to it?

(iii) Name the law on which the principle is based.

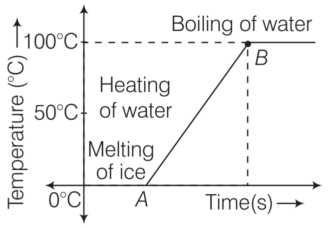
Sol. (i) According to the principle of mixtures, heat lost by the hot body must be equal to heat gained by the cold body, provided there is no heat loss to the surroundings. ***[1]***

(ii) The other name of principle of mixtures is principle of calorimetry. ***[1]***

(iii) Principle of mixture is based on the principle of conservation of energy. ***[1]***

24. Some ice is heated at a constant rate and its temperature is recorded after every few seconds, till steam is formed at 100° C. Draw a temperature time graph to represent the change. Label the two phase change in your graph

Sol. *According to question, the heating curve of ice is given below.*



[3]

25. (i) Heat supplied to a solid changes it into liquid. What is this change in phase called?

(ii) During the phase change does the average kinetic energy of the molecules of the substance increase?

(iii) What is the energy absorbed during the phase change called? ***[2018]***

Sol. (i) Heat supplied to solid changes it into liquid. This change in phase called melting. ***[1]***

(ii) During the phase change, average kinetic energy of the molecules does not change because the temperature remains constant. ***[1]***

(iii) The energy absorbed during the phase change is called latent heat of fusion. ***[1]***

26. (i) Write an expression for the heat energy liberated by a hot body.

(ii) Some heat is provided to a body to raise its temperature by 25°C. What will be the corresponding rise in temperature of the body as shown on the Kelvin scale?

(iii) What happens to the average kinetic energy of the molecules as ice melts at 0°C? ***[2012]***

Sol. (i) The heat energy liberated by a hot body is

$$\Delta Q = mc\Delta T$$

where, m = mass of substance

c = specific heat of substance

and ΔT = change in temperature. ***[1]***

(ii) The temperature rise will be same in both Celsius and Kelvin scale, as it is the change in temperature (ΔT) only. ***[1]***

(iii) The average KE of molecules increases when ice melts as temperature of body increases. ***[1]***

C 4 Marks Questions

27. With reference to climate in coastal areas, briefly describe the role of high specific heat capacity of water.

Sol. Specific heat capacity of water is highest among all the substances. Thus, it can store a large amount of heat energy and retains at an average temperature. ***[1]***

Thus during day time, specially in coastal areas, the temperature of land increases rapidly whereas the temperature of sea water does not vary more. In this way pressure differences occurs, which leads to flow of wind known as sea breeze. ***[1]***

During night, land looses its heat rapidly whereas sea water does not, due to high specific heat capacity. It then leads to land breeze. In this way, the climate of coastal area is not too hot or cold (i.e., moderate). It is due to specific heat capacity of water. ***[1]***

It is important to notice that in solar system only Earth has moderated temperature because it contains 75% of water on it which has very large amount of heat capacity. ***[1]***

28. (i) State two differences between “heat capacity” and “specific heat capacity”.

(ii) Give a mathematical relation between heat capacity and specific heat capacity. ***[2018]***

Sol. (i)

Heat capacity	Specific heat capacity
It is defined as the total amount of heat required to raise the temperature of a body by 1 °C.	It can be defined as the total amount of heat energy required to raise the temperature of unit mass by 1 °C.
Heat capacity $= \dfrac{\text{Heat supplied to the body}}{\text{Change in temperature}}$	Specific heat capacity $= \dfrac{\text{Heat energy supplied}}{\text{Mass of the body} \times \text{Change in temperature}}$

[2]

(ii) The relation between specific heat capacity and heat capacity is

$\Rightarrow$ heat capacity = mass $\times$ specific heat capacity. **[2]**

29. What is the effect of presence of impurity on the melting point of ice? Mention one use of it.

Sol. Due to the presence of impurities, the melting point of ice becomes lowered. The melting point of ice is made lowered to use it in preparing freezing mixture. **[1]**

It is a mixture of ice and salt which produces a temperature much lower than 0°C.

When ice and salt are mixed, the ice begins to melt. For the melting of each gram of ice, 80 calories of heat are required. The same amount of heat is taken from mixture itself due to which the temperature of the mixture falls below 0°C. Moreover, the salt dissolves in water produced by the melting of ice. **[1]**

So, the salt also needs the latent heat of fusion to change from solid into the solution. This heat is also taken from the mixture itself, therefore the temperature of the mixture falls still lower.

When one part by weight of salt and three parts of ice are mixed together, a temperature of –22°C is obtained. In the similar manner, freezing mixture of three parts of ice and four parts of calcium chloride by weight can have a very low temperature of –55°C. **[2]**

30. (i) Define the term "specific latent heat of fusion of a substance."

(ii) What energy change would you expect to take place in the molecules of a substance when it undergoes

(a) a change in its temperature?

(b) a change in its state without any change in its temperature? **[2010]**

Sol. (i) Specific latent heat of fusion is the heat required to change the state of substance from ice to liquid without change in temperature. **[2]**

(ii) (a) Kinetic energy changes which defines specific heat capacity of the substance. **[1]**

(b) Intermolecular or space charges defines latent heat of the substance. **[1]**

31. (i) Water in lakes and ponds does not freeze at once in cold countries. Give a reason in support of your answer.

(ii) What is the principle of calorimetry?

(iii) Name the law on which this principle is based.

(iv) State the effect of an increase of impurities on the melting point of ice. **[2015]**

Sol. (i) The latent heat of fusion of ice is very high because of which a large amount of heat needs to be withdrawn for water in lakes and ponds to freeze. Hence, water in lakes and ponds do not freeze at once in cold countries. **[1]**

(ii) The principle of calorimetry states that when two or more bodies at different temperatures are brought into thermal contact, and if no heat is allowed to escape to the surroundings, then the total heat lost by hot bodies must be equal to the total heat gained by cold bodies. **[1]**

(iii) The principle of calorimetry is based on the law of conservation of energy. **[1]**

(iv) The melting point of ice decreases from 0° C to – 22° C in presence of impurities **[1]**

Numerical Based Questions

32. Determine the specific heat capacity of lead of mass 0.5 kg, if 1300 J of heat is supplied to raise its temperature from 20°C to 40°C.

Sol. Given, mass $m = 0.5$ kg, heat supplied, $Q = 1300$ J,

Rise in temperature, $\Delta T = 40°\text{C} - 20°\text{C} = 20°\text{C}$

$$\text{Since, specific heat} = \frac{\text{heat supplied}}{\text{mass} \times \text{rise in temperature}}$$

$$= \frac{1300}{0.5 \times (40 - 20)}$$

$$= \frac{1300}{0.5 \times 20}$$

$$= \frac{1300}{10} = 130 \text{ Jkg}^{-1}\text{K}^{-1}$$ **[1]**

$\therefore$ Specific heat capacity of lead is 130 $\text{Jkg}^{-1}\text{K}^{-1}$. **[1]**

33. If a liquid A of specific heat capacity 1050 J $\text{kg}^{-1}\text{K}^{-1}$ and at 90°C is mixed with liquid B of specific heat capacity 2362.5 J $\text{kg}^{-1}\text{K}^{-1}$ and at 20°C, when the final temperature recorded is 50°C. Determine in what proportion of the weights of liquids are mixed ?

Sol. By principle of method of mixture,

Heat lost by A = Heat gained by B

$$m_1 \times 1050 \times (90° - 50°) = m_2 \times 2362.5 \times (50° - 20°)$$ **[1]**

$$\Rightarrow \quad \frac{m_1}{m_2} = \frac{2362.5 \times 30}{1050 \times 40} = \frac{27}{16}$$ **[1]**

34. While performing an experiment, it is observed that when 300 g of hot water at 50°C is added to 600 g of cold water, then its temperature rises by 15°C. Find the initial temperature of cold water.

Sol. Consider t°C be the initial temperature of cold water.

$\because$ Heat gained by the cold water = $mc\Delta t$

(Here, $\Delta T = 15°C$)

$$\Delta Q = 600 \times 4.2 \times 15$$

Heat lost by hot water = $300 \times 4.2 \times [50 - (T + 15)]$

$\therefore$ According to principle of calorimetry,

Heat lost = Heat gained

$$600 \times 4.2 \times 15 = 300 \times 4.2 (50 - (T + 15)$$

$$37800 = 1260(35 - T)$$

$$\Rightarrow \quad T = 5°C$$ **[2]**

35. When 8000 J of heat is given to 200 g of copper at 20°C, determine the final temperature, if the specific heat capacity of copper is 0.4 $Jg^{-1}°C^{-1}$.

Sol. Here, heat supplied = 8000 J

Mass of copper = 200 g

Initial temperature = 20°C

Consider the final temperature of copper be T°C. **[1]**

So, the amount of heat required to raise the temperature of 200 g of copper from 20°C to T°C

$$= 200 \times 0.4 \times (T - 20°)$$

$$\Rightarrow \quad 200 \times 0.4 \times (T - 20°) = 8000$$ **[1]**

$$\Rightarrow \quad T = \frac{8000}{200 \times 0.4} + 20° = 120°C$$

$$\Rightarrow \quad T = 120°C$$ **[1]**

36. In a laboratory experiment to measure specific heat capacity of copper, 0.02 kg of water at 70°C was poured into a copper calorimeter with a stirrer of mass 0.16 kg initially at 15°C. After stirring, the final temperature reached to 45°C. Specific heat of water is taken as 4200 J/kg°C.

(i) What is the quantity of heat released per kg of water per 1°C fall in temperature?

(ii) Calculate the heat energy released by water in the experiment in cooling from 70°C to 45°C.

(iii) Assuming that the heat released by water is entirely used to raise the temperature of calorimeter from 15°C to 45°C, calculate the specific heat capacity of copper. **[2007]**

Sol. (i) Quantity of heat released per kg of water per °C falls in temperature is given by 4200 J/kg°C. **[1]**

(ii) Quantity of heat released on cooling is given by

$$Q = mc\,\Delta T$$

$$\Rightarrow \quad Q = 0.02 \times 4200 \times 25\text{ J} = 2100\text{ J}$$ **[1]**

(iii) By assuming that there is no loss of heat therefore, by principle of calorimetry,

Heat gained = Heat taken up by calorimeter

So, $2100 = 0.16 \times c \times 30$

$$\Rightarrow \quad c = \frac{2100}{0.16 \times 30} = 437.5\text{ J/kg°C}$$ **[1]**

37. The temperature of 170 g of water at 50°C is lowered to 5° C by adding certain amount of ice to it. Find the mass of ice added.

(Give, specific heat capacity of water = 4200 J kg^{-1} $°C^{-1}$ and specific latent heat of ice = 33600 J kg^{-1}) **[2018]**

Sol. Given, $M_w = 170$ g, $s_w = 4200$ J kg^{-1} C^{-1}

$\Delta T = 5°C$, $L_f = 80$ cal/g $= 336000$ J/kg

According the principle of calorimetry,

amount of heat given by water = amount of heat absorbed by ice

$$M_w s_w \Delta T = M_{ice} \times L_f$$

$$\Rightarrow \quad 170 \times 1 \times 5 = M_{ice} \times 80$$

$$M_{ice} = \frac{170 \times 1 \times 5}{80} = 10.625\text{ g}$$ **[3]**

38. Calculate the mass of ice required to lower the temperature of 300 g of water at 40° C to water at 0° C. (Take, specific latent heat of ice = 336 J/g, and specific heat capacity of water = 4.2J/g°-C)

Sol. According to question,

mass of water (m_w)= 300g

Temperature of water = 40°C

From principle of calorimetry,

Heat loss by the water at 40°C = Heat gain by the ice at 0° C

$$\Rightarrow \quad m_W \times c \times \Delta t = m_{ice}\text{ (mass of ice)} \times L$$

$$\Rightarrow \quad m_{ice} = \frac{m_w \times s \times \Delta t}{L}$$

$$= \frac{300 \times 4.2 \times 40}{336} = 187.5\text{ g} \quad (\because\ \Delta t = 40°)$$ **[2]**

39. A copper vessel of mass 100 g contains 150 g of water at 50° C. How much ice in needed to cool it to 5°C?
(Take, specific heat capacity of copper $= 0.4\ \text{Jg}^{-1\circ}\text{C}^{-1}$, specific heat capacity of water $= 4.2\ \text{Jg}^{-10}\text{C}^{-1}$ and specific latent heat of fusion of ice $= 336\text{Jg}^{-1}$)

Sol. According to question, mass Cu vessel = 100g
Initial temperature of water = 50°C
Final temperature of water = 5°C
From principle of calorimetery,
Heat gained by ice = Heat lost by Cu vessel and water **[1]**

$$M \times 336 = (100 \times 0.4) + (150 \times 4.2 \times 45)$$
$$= 40 + 28350$$
$$\Rightarrow \quad M = \frac{40 + 28350}{336} \ (\because m = \text{mass of ice})$$
$$= \frac{28390}{336} = 84.49 \text{ g}$$ **[1]**

40. A solid of mass 50 g at 150° C is placed in 100 g water at 11°C when the final temperature recorded is 20°C. Find the specific heat capacity of the solid. (Take, specific heat capacity of water = 4.2 J/g°C) **[2017]**

Sol. According to the question,
mass of solid = 50 g, temperature of solid = 150° C
Mass of water = 100 g
Temperature of water = 11°C, final temperature of mixture = 20° C
Specific heat of water = 1 cal /g°C
Let specific heat capacity of solid = x
Q_1 (heal lost) = Q_c (heat gained)

$$\Rightarrow \ 50 \times x \times (150 - 20) = 100 \times 1 \times (20 - 11)$$
$$\Rightarrow \quad x = \frac{100 \times 9}{50 \times 130}$$
$$\therefore \quad \text{Specific heat} = \frac{9}{65} = 0.13 \text{ cal /g°C}$$
$$\text{Capacity of solid} = \frac{0.13}{4.2\ \text{J/g}\ °\text{C}} = 0.030 \text{ J/g°C}$$ **[2]**

41. A refrigerator converts 100 g of water at 20°C to ice at −10°C in 35 minutes. Calculate the average rate of heat extraction in terms of watts. **[2015]**
(Take, specific heat capacity of ice $= 2.1\ \text{Jg}^{-1\circ}\text{C}^{-1}$, specific heat capacity of water $= 4.2\ \text{Jg}^{-1\circ}\text{C}^{-1}$ and specific latent heat of fusion of ice $= 336\ \text{Jg}^{-1}$)

Sol. Here, $m = 100$ g,
$T_1 = 20\ °\text{C}$,
$T_2 = -10°\text{C}$
Heat released
$$= mc_w (T_1 - 0) + m L_{\text{ice}} + mc_{\text{ice}} (0 - T_2)$$ **[1]**
$$Q = (100 \times 4.2 \times 20) + (100 \times 336) + (100 \times 2.1 \times 10)$$
$$= 8400 + 33600 + 2100 = 44100 \text{ J}$$ **[1]**
$$\text{Power, } P = \frac{Q}{t} = \frac{44100}{35 \times 60}$$
$$\Rightarrow \quad P = 21 \text{ W}$$

42. A solid metal weighing 150 g melts at its melting point of 800 °C by providing heat at the rate of 100 W. The time taken for it to completely melt at the same temperature is 4 min. What is the specific latent heat of fusion of the metal? **[2018]**

Sol. Given, $m = 150\text{g} = 150 \times 10^{-3}\text{ kg} = 0.15\text{ kg}$
Power $(P) = 100$ W
Time $(t) = 4\text{ min} = 4 \times 60 = 240\text{ s}$
The amount of heat supplied in 4 min is given as
heat energy $= P \times t = 100 \times 240 = 24000$ J
This heat energy is used in melting.
Let 'L' be the latent specific heat.

$$\therefore \quad mL = 24000$$
$$L = \frac{24000}{0.15}$$
$$= 16 \times 10^4 \text{ J kg}^{-1}$$ **[2]**

43. While performing an experiment, 17g of ice is used to bring down the temperature of 40 g of water at 34°C to its freezing temperature. The specific heat capacity of water is $4.2\ \text{Jg}^{-1}\text{K}^{-1}$. Determine the specific heat of ice.

Sol. Given, mass of ice, $m = 17$ g
Mass of water, $M = 40$ g
Initial temperature of water = 34° C
Final temperature of water = 0° C
Specific heat capacity of water, $c = 4.2\ \text{Jg}^{-1}\text{K}^{-1}$
$\because$ Heat gained by ice = Heat lost by water **[1]**

$$\Rightarrow \quad m \times L = M \times c\ \Delta T$$
$$\Rightarrow \quad 17L = 40 \times 4.2\ (34 - 0)$$
$$\Rightarrow \quad L = \frac{40 \times 4.2 \times 34}{17}$$ **[1]**
$$\Rightarrow \quad L = 336\ \text{Jg}^{-1}$$ **[1]**

44. Heat energy is supplied at a constant rate to 100 g of ice at 0°C. The ice is converted into water at 0°C in 2 min. How much time will be required to raise the temperature of water from 0°C to 20°C? (Take, specific heat capacity of water $= 4.2\ \text{J g}^{-1}{}^\circ\text{C}^{-1}$ and latent heat of ice $= 336$ J/g)

[2014]

Sol. Given, mass, $m = 100$ g,

time, $t = 2\text{ min} = 2 \times 60 = 120$ s

Heat energy taken by ice at 0°C to convert it into water at 0°C.

$$Q = mL = 100 \times 336 = 33600\text{ J} \qquad \textit{[1]}$$

As we know that,

$$\text{power,} \quad P = \frac{Q\text{ (energy)}}{t\text{ (time)}} = \frac{33600}{2 \times 60} = 280\text{ J/s} \qquad \ldots\text{(i)}$$

[1]

Heat energy required to raise the temperature from 0°C to 20°C.

$$Q = mc\Delta T = 100 \times 4.2 \times 20 = 8400\text{ J} \qquad \ldots\text{(ii)}$$

$$(\because\ c = 4.2\ \text{Jg}^{-1}{}^\circ\text{C}^{-1}) \quad \textit{[1]}$$

Now, from Eqs. (i) and (ii), we get

$$Q = Pt = 8400\text{ J}$$

$$t = \frac{8400}{P} = \frac{8400}{280}$$

$$= 30\text{ s} = \frac{30}{60}\text{ min}$$

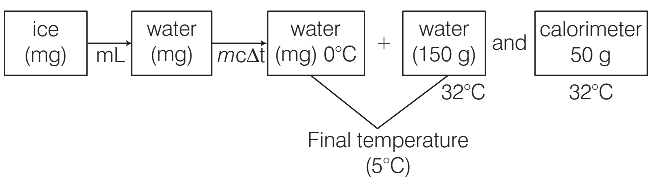
$$= 0.5\text{ min} \qquad \textit{[1]}$$

45. Calculate the mass of ice needed to cool 150 g of water contained in a calorimeter of mass 50 g at 32° C such that the final temperature is 5°C.

(Take, specific heat capacity of calorimeter = 0.4 J/g°C and latent heat capacity of ice = 330 J/g)

[2017]

Sol.



From the principle of calorimetry,

Heat gained by ice = Heat lost by water + Heat lost by calorimeter

$$mL + mc\Delta t = m_w C_w\ \Delta t + m_{\text{cal}}\ C_{\text{cal}}\ \Delta t \qquad \textit{[1]}$$

where, m = mass of ice (suppose),

L = latent heat of ice = 330 J/g,

Δt = change in temperature = 5° C,

C_w = specific heat of water = 4.2 J/g°C,

m_w = mass of water = 150 g,

m_{cal} = mass of calorimeter = 50 g and

c_{cal} = specific heat of calorimeter = 0.4 J/g°C.

Now, heat lost by water and calorimeter will be

$$= 150 \times 4.2 \times (32 - 5) + 150 \times 0.4 \times (32 - 5)$$

$$= 150 \times 4.2 \times 27 + + 150 \times 0.4 \times 27$$

$$= 150 \times 27\ (4.2 + 0.4) = 150 \times 27 \times 4.6 \qquad \textit{[1]}$$

Now, according to relation (i), we have

$$m \times 330 + m \times m \times 4.25 \times 5 = 150 \times 27 \times 4.6$$

$$\Rightarrow \quad m\,(330 + 21) = 150 \times 27 \times 4.6$$

$$\Rightarrow \quad m \times 351 = 150 \times 27 \times 4.6$$

$$\Rightarrow \quad m = \frac{150 \times 27 \times 4.6}{351} = \frac{18630}{351}\text{ g}$$

$$= 53.07 = 53.1\text{ g} \qquad \textit{[1]}$$

46. If a block (made of lead) of mass 250 g at 27°C is heated in a furnace till it completely melts. Determine the quantity of heat required

(i) to bring the block to its melting point.

(ii) total heat energy required to melt the block to its melting point.

(iii) total heat energy required.

(Take, melting point of lead = 327°C, specific heat capacity $= 0.13\ \text{Jg}^{-1}{}^\circ\text{C}^{-1}$ and specific latent heat of fusion $= 26\ \text{Jg}^{-1}$)

Sol. (i) The amount of heat required to raise to its melting point (327°C) $= mc\,\Delta T$

$$= 250 \times 0.13 \times (327 - 27)$$

$$= 250 \times 0.13 \times 300 = 9750\text{ J} \qquad \textit{[2]}$$

(ii) So, the heat required to melt the lead at 327°C

$$= 250 \times 26 = 6500\text{ J} \qquad \textit{[1]}$$

(iii) Therefore, total heat required completely to melt

$$= 6500 + 9750 = 16250\text{ J} \qquad \textit{[1]}$$

CHAPTER EXERCISE

2 Marks Questions

1. (i) Give an example, where high specific heat capacity of water is used as a heat reservoir.
(ii) Give an example, where high specific heat capacity of water is used for cooling purposes.

2. If a body had high heat energy, so does it mean that it has high temperature? Justify.

3. State whether the land cool at a slower or faster rate than water. Give reason in support of you answer.

4. Briefly explain why does a person feel refresh when his forehead is being sponged with Eaude cologne?

5. Why do pieces of ice added to a drink, cool it much faster than ice cold water added to it?

6. We feel relief under a fan when we are perspiring. Explain, why?

7. How is the heat capacity of the body related to its specific heat capacity?

3 Marks Questions

8. Explain the method to determine the specific heat capacity of a liquid like olive oil using the method of mixtures.

9. If same amount of heat is supplied to same masses of two substances X and Y of specific heat capacities C_1 and C_2 respectively. It is given that $C_1 < C_2$. So, which will show a higher rise in temperature?

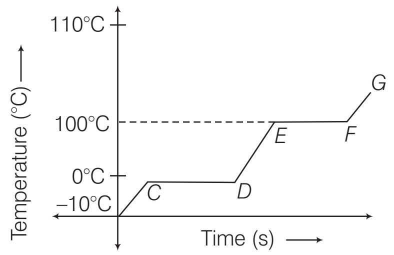
10. It is observed that a beaker containing ether is placed on the top of a little water on a wooden block. Air is, then blown by a tube through the ether. Discuss what happens to the water? Give a reason for your observation.

11. State in brief, the meaning of each of the following:
(i) The heat capacity of a body is 50 $J°C^{-1}$.
(ii) The specific latent heat of fusion of ice is 336000 $J\,kg^{-1}$.
(iii) The specific heat capacity of copper is 0.4 $Jg^{-1}\,°C^{-1}$

4 Marks Questions

12. Briefly describe, how will you determine the specific latent heat of fusion of ice and what observation will you record ?

13. A piece of ice is heated at a constant rate. The variation of temperature with heat input is shown in the graph below:



(i) What do CD and EF represent?
(ii) State the conclusion that can be drawn regarding the nature of ice from the above graph.

14. Draw a neat diagram of temperature *versus* time when a substance is heated from 0°C to 80°C. Along with this, also draw another curve when the molten substance cools to room temperature. How will you find the melting and freezing point from the graphs drawn?

Numerical Based Questions

15. A piece of iron of mass 2.0 kg has a thermal capacity of 996 J/°C.
(i) How much heat is needed to warm it by 15°C?
(ii) What is its specific heat capacity in SI unit?
Ans. (i) 14.94 kJ, (ii) 0.498 kJ/kg/°C ***[2006]***

16. Determine the time taken by a 500 W heater to raise the temperature of 50 kg of material of specific heat capacity 920 $J\,kg^{-1}\,K^{-1}$, from 18°C to 38°C. Assume that all the heat supplied by the heater is given to the material. ***Ans.*** 30 min 40 s

17. Liquids A and B are at 30°C and 20°C. When mixed in equal masses, the temperature of the mixture is found to be 26°C. Find the ratio of their specific heat capacities. ***Ans.*** 3 : 2

18. Some hot water was added to three times its mass of cold water 10°C and the resulting temperature was found to be 20°C. So, earlier, what was the temperature of hot water? ***Ans.*** 50°C

19. 250 g of water at 30°C is present in a copper vessel of mass 50 g. Calculate the mass of ice required to bring down the temperature of the vessel and its contents to 5°C. (Take, specific latent heat of fusion of ice $= 336 \times 10^3\ \text{J kg}^{-1}$, specific heat capacity of copper vessel $= 400\ \text{Jkg}^{-1}\,°\text{C}^{-1}$ and specific heat capacity of water $= 4200\ \text{Jkg}^{-1}\,°\text{C}^{-1}$) ***Ans.*** 8.75 g ***[2011]***

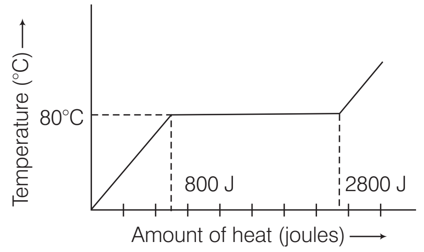
20. 50 g of ice at 0°C is added to 300 g of a liquid at 30°C. What will be the final temperature of the mixture when all the ice gets melted? The specific heat capacity of the liquid is $2.65\ \text{Jg}^{-1}\,°\text{C}^{-1}$, while that of water is $4.2\ \text{Jg}^{-1}\,°\text{C}^{-1}$.

(Take, specific latent heat of fusion of ice $= 336\ \text{Jg}^{-1}$)

Ans. 21.13°C

21. 10125 J of heat energy boils of 4.5 g of water at 100°C to steam at 100°C. Find the specific latent heat of steam. ***Ans.*** 2250 J/g

22. A substance is in the form of a solid at 0°C, the amount of heat added to this substance and the temperature of the substance and the amount of heat energy are plotted on the following graph :



(i) If the specific heat capacity of the solid substance is 500 J/kg°C, then from the above graph, find the mass of the substance. ***Ans.*** 20 g

(ii) Find specific latent heat of fusion of the substance. ***Ans.*** 1000 J/g

ARCHIVES* *(Last 6 Years)*

Collection of Questions Asked in Last 6 Years' (2018-2013) ICSE Class 10th Examinations

2018

1. (i) How can a temperature in degree celsius be converted into SI unit of temperature?

(ii) A liquid X has the maximum specific heat capacity and is used as a coolant in car radiators. Name the liquid X. ***[2]***

2. (i) Heat supplied to a solid changes it into liquid. What is this change in phase called?

(ii) During the phase change does the average kinetic energy of the molecules of the substance increase?

(iii) What is the energy absorbed during the phase change called? ***[3]***

3. (i) State two differences between "heat capacity" and "specific heat capacity".

(ii) Give a mathematical relation between heat capacity and specific heat capacity. ***[4]***

4. The temperature of 170 g of water at 50°C is lowered to 5° C by adding certain amount of ice to it. Find the mass of ice added.

(Give, specific heat capacity of water $= 4200\ \text{J kg}^{-1}\ {}^\circ\text{C}^{-1}$ and specific latent heat of ice $= 33600\ \text{J kg}^{-1}$) ***[3]***

5. A solid metal weighing 150 g melts at its melting point of 800 °C by providing heat at the rate of 100 W. The time taken for it to completely melt at the same temperature is 4 min. What is the specific latent heat of fusion of the metal? ***[2]***

2017

6. Define heat capacity and state its SI unit. ***[2]***

7. Why is the base of a cooking pan generally made thick? ***[2]***

8. A solid of mass 50 g at 150° C is placed in 100 g of water at 11°C, when the final temperature recorded is 20°C. Find the specific heat capacity of the solid. (Take, specific heat capacity of water = 42 J/g°C) ***[2]***

9. (i) How is the transference of heat energy by radiation prevented in a calorimeter?

(ii) You have a choices of three metals A, B and C, of specific heat capacities $900\ \text{Jkg}^{-1}{}^\circ\text{C}$, $380\text{Jkg}^{-1}{}^\circ\text{C}^{-1}$ and $460\ \text{Jkg}^{-1}{}^\circ\text{C}^{-1}$ respectively.

To make a calorimeter, which material will you select? Justify your answer. ***[4]***

10. Calculate the mass of ice needed to cool 150 g of water contained in a calorimeter of mass 50 g at 32°C such that the final temperature is 5° C.

(Take, specific heat capacity of calorimeter = 0.4 J/g°C, specific heat capacity of water = 4.2 J/g° C and latent heat capacity of ice = 330 J/g) ***[3]***

11. (i) Name the radiations which are absorbed by greenhouse gases in the Earth's atmosphere.

(ii) A radiation X is focused by a particular device on the bulb of a thermometer and mercury in the thermometer shows a rapid increase. Name the radiation X.

(iii) Name two factors on which the heat energy liberated by a body depends? ***[3]***

2016

12. Calculate the mass of ice required to lower the temperature of 300 g of water at 40°C to water at 0°C.

(Take, specific latent heat of ice = 336 J/g and specific heat capacity of water = 4.2 J/g°-C) ***[2]***

13. What do you understand by the following statements?

(i) The heat capacity of the body is $60\ \text{JK}^{-1}$

(ii) The specific heat capacity of lead is $130\text{Jkg}^{-1}\text{K}^{-1}$. ***[2]***

2015

14. Rishi is surprised when he sees water boiling at 115°C in a container. Give reasons as to why water can boil at the above temperature? ***[2]***

15. (i) Name a gas caused by the greenhouse effect. ***[1]***

(ii) Which property of water makes it an effective coolant? ***[1]***

16. Water in lakes and ponds do not freeze at once in cold countries. Give a reason in support of your answer.

(i) What is the principle of calorimetry? *[1]*

(ii) Name the law on which this principle is based. *[1]*

(iii) State the effect of an increase of impurities on the melting point of ice. *[1]*

17. A refrigerator converts 100 g of water at 20°C into ice at –10°C in 35 min. Calculate the average rate of heat extraction in terms of watt.
(Take, specific heat capacity of ice = 2.1 $Jg^{-1}°C^{-1}$, specific heat capacity of water = 4.2 $Jg^{-1}°C^{-1}$ and specific latent heat of fusion of ice = 336 Jg^{-1}) *[4]*

2014

18. Specific heat capacity of substance *A* is 3.8 J/gK, whereas the specific heat capacity of substance *B* is 0.4 J/gK.

(i) Which of the two is good conductor of heat?

(ii) How is one led to the above conclusion?

(iii) If substances *A* and *B* are liquid, then which one would be more useful in car radiators? *[3]*

19. (i) State any two measures to minimise the impact of global warming. *[1½]*

(ii) What is greenhouse effect? *[1½]*

20. 50 g of metal piece at 27°C requires 2400 J of heat energy so as to attain a temperature of 327°C. Calculate the specific heat capacity of the metal. *[2]*

21. Heat energy is supplied at a constant rate to 100 g of ice at 0°C. The ice is converted into the water at 0°C in 2 min. How much time will be required to raise the temperature of water from 0°C to 20°C?
(Take, specific heat capacity of water = 4.2 $Jg^{-1}°C^{-1}$ and latent heat of ice = 336 J/g). *[4]*

2013

22. A calorimeter of mass 50 g and specific heat capacity 0.42 $Jg^{-1}°C^{-1}$ contains some mass of water at 20°C. A metal piece of mass 20 g at 100°C is dropped into the calorimeter. After stirring, the final temperature of the mixture is found to be 22°C. Find the mass of water used in calorimeter.
(Take, specific heat capacity of metal piece = 0.3 $Jg^{-1}°C^{-1}$ and specific heat capacity of water = 4.2 $Jg^{-1}°C^{-1}$) *[4]*

23. Define the term heat capacity and state its SI unit. *[2]*

24. How much heat energy is released when 5 g of water at 20°C changes to ice at 0°C? *[2]*

25. How is the heat capacity of the body related to its specific heat capacity? *[3]*

26. A certain amount of heat *Q* will warm 1 g of material *X* by 3°C and 1 g of material *Y* by 4°C. Which material has higher specific heat capacity? *[3]*

27. It is observed that the temperature of the surroundings starts falling when the ice in a frozen lake starts melting. Give a reason for the observation. *[3]*

28. What do you mean by global warming? *[2]*

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 Two bodies of specific heats c_1 and c_2 having same heat capacities are combined to form a single composite body. What is the specific heat of the composite body?

(a) $\frac{c_1 - c_2}{2c_1 c_2}$ (b) $\frac{c_1 + c_2}{2c_1 c_2}$ (c) $\frac{2c_1 c_2}{c_1 + c_2}$ (d) $\frac{2c_1 c_2}{c_1 - c_2}$

2 If 1 g of steam is mixed with 1 g of ice, then the resultant temperature of the mixture is

(a) 270°C (b) 230°C (c) 100°C (d) 50° C

3 A vessel from which the air is rapidly being pumped out contains 100 g of water at 0° C. The intensive evaporation causes a gradual freezing of the water. What part of the original water can be converted into ice by this method?

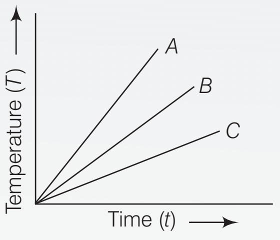
(a) 60 % (b) 86.2 % (c) 78 % (d) 56 %

4 Two identical calorimeters *A* and *B* contain equal quantity of water at 20° C. A 5 g piece of metal *X* of specific heat 0.2 cal $g^{-1}\,°(C)^{-1}$ is dropped into *A* and a 5 g piece of metal *Y* into *B*. The equilibrium temperature in *A* is 22°C and in *B* is 23°C. The initial temperature of both the metals is 40° C. Find the specific heat of metal *Y* in cal $g^{-1}(°C)^{-1}$.

(a) $\frac{27}{85}$ cal / g° c (b) 26 cal / g°C

(c) $\frac{85}{27}$ cal / g° c (d) 27 cal / g°C

5 Which of the substance *A, B* and *C* has the lowest heat capacity, if heat is supplied to all of them at equal rates. The temperature *versus* time graph is shown.



(a) All have equal specific heat
(b) *C*
(c) *B*
(d) *A*

6 A child running a temperature of 101 °F is given an antipyretic (i.e., a medicine that lowers fever) which causes an increase in the rate of evaporation of sweat from his body. If the fever is brought down to 98°F in 20 min. What is the average rate of extra evaporation caused by the drug?

Assume the evaporation mechanism to be the only way by which heat is lost. The mass of the child is 30 kg. The specific heat of human body is approximately the same as that of water and latent heat of evaporation of water at that temperature is about 580 cal g^{-1}

(a) 4.32 g min^{-1} (b) 3.42 g min^{-1}
(c) 0.432 g sec^{-1} (d) 3.42 g sec^{-1}

7 In an industrial process 10 kg of water per hour is to be heated from 20°C to 80°C. To do this, steam at 150°C is passed from a boiler into a copper coil immersed in water. The steam condenses in the coil and is returned to the boiler as water at 90° C, how many kg of steam is required per hour?
(Take, specific heat of steam = 1 cal per g°C and latent heat of vaporisation = 540 cal g^{-1})

(a) 1 g (b) 1 kg
(c) 10 g (d) 10 kg

8 How many grams of ice at –14°C are needed to cool 200 g of water from 25°C to 10°C? (Take, specific heat of ice = 0.5 cal $g^{-1}\,°C^{-1}$ and latent heat of ice = 80 cal g^{-1})

(a) 20 g (b) 27 g
(c) 30 g (d) 31 g

Answers

1. (c)	2. (c)	3. (b)	4. (c)	5. (d)	6. (a)	7. (b)	8. (b)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 245.

CHAPTER

11

Radioactivity and Nuclei

All elements consists of very small invisible particles which are known as atoms. It consist of three elementary particles, electrons, protons and neutrons. Its central core contains entire positive charge which is known as nucleus.

In this chapter, we will study different properties of nucleus and associated phenomena such as radioactivity, nuclear fission and nuclear fusion.

Chapter Objectives

- Composition of Nucleus
- Radioactivity
- Radioactive Decay
- Uses of Radioactivity-Radioisotopes
- Sources of Harmful Radiation
- Background Radiations
- Safety Precautions while Using Nuclear Energy
- Nuclear Energy

Composition of Nucleus

The nucleus was first discovered in 1911 by **Lord Rutherford** and his associates by an experiment of scattering of α-particles by atoms. He found that the scattering results could be explained, if atoms consist of a small, central, massive and positive core surrounded by orbiting electrons.The experimental results indicated that the size of the nucleus is of the order of 10^{-14} m and thus it is 10000 times smaller than the size of atom. Further, the study of radioactivity revealed that nucleus is not a composite body, but it is made of nucleons.The positive charge in the nucleus is that of the protons. A proton carries one unit of fundamental charge.

Atomic Number (Z)

The number of protons present inside the nucleus of an atom of the element is known as its atomic number. It is also equal to the number of electrons revolving in various orbits around the nucleus of the neutral atom.

Atomic number, Z = Number of protons = Number of electrons (in neutral atom)

Mass Number (A)

The sum of total number of protons and neutrons inside the atomic nucleus of the element is known as its mass number.

i.e., Mass number,

$$\begin{aligned} A &= \text{Number of protons} + \text{Number of neutrons} \\ \text{or } &= \text{Number of electrons (in neutral atom)} + \text{Number of neutrons} \\ \text{or } &= \text{Atomic number} + \text{Number of neutrons} = Z + N \end{aligned}$$

The term **nucleon** is also used for neutron and proton. Thus, the number of nucleons in an atom is its mass number A.

Nuclear species or nuclides are shown by the notation ${}_Z^A X$, where X is the chemical symbol of the species.

Isotopes, Isobars and Isotones

The atoms of same elements having same number of protons but different number of neutrons are called **isotopes**. e.g., ${}_1H^1, {}_1H^2, {}_1H^3$, etc.

The atoms of different elements having the same mass number (A) but different atomic number (Z) are called **isobars**. e.g., ${}_1H^3$ and ${}_2He^3$, etc.

The atoms of different elements having equal number of neutrons $(A - Z)$ but different number of protons are called **isotones**. e.g., ${}_3Li^7$ and ${}_4Be^8$, etc.

Example 1. In a nucleus of ${}_{92}U^{238}$, find the number of protons and the number of neutrons.

Sol. Given, mass number, $A = 238$

Number of protons, $Z = 92$

Number of neutrons, $N = A - Z = 238 - 92 = 146$

Radioactivity

A French Physicist **H Becquerel** discovered radioactivity in 1896. A spontaneous nuclear phenomenon in which an unstable nucleus undergoes a decay with the emission of some particles (α, β) and electromagnetic radiation (γ-rays) is called radioactivity.

The elements which show this phenomenon is called radioactive elements.

In nature, three types of radioactive decay occurs which are given below

(i) **α-decay** In this decay, a helium nucleus ${}_2^4He$ is emitted.

(ii) **β-decay** In this decay, electrons or positrons with the same mass as that of electron are emitted.

(iii) **γ-decay** In this decay, high energy $\approx$ 100 keV photons are emitted.

Properties of α-Particles

An α-particle carries $+2e$ charge and mass equal to four times that of proton.

Some important properties of α-particles are as follows

(i) These particles are deflected by electric and magnetic fields.

(ii) The velocity of α-particles varies from 0.01-0.1 times of c (velocity of light).

(iii) These particles have low penetrating power.

(iv) These particles have high ionising power. Their ionising power is 100 times greater than that of β-rays and 10000 times greater than that of γ-rays.

(v) These particles produce fluorescence in substances like zinc sulphide and barium platinocyanide. They produce scintillation on fluorescent screen.

(vi) These particles feebly affect photographic plate. They also produce heating effect, when stopped and cause incurable burns on human body.

Properties of β-Particles

A β-particle $({}_{-1}e^0)$ has a charge of electron. Actually, it is a fast moving electron (not the orbital electron of the atom but is emitted from the nucleus).

Some important properties of β-particles are as follows

(i) These particles are also deflected by electric and magnetic fields. Their deflection is much larger than the deflection of α-particles.

(ii) The velocity of β-particles varies from 1% to 99% of the velocity of light.

(iii) As, the velocity of β-particles is of the order of the velocity of light, its mass increases with increase in their velocity.

(iv) These particles have high penetrating power (100 times larger than the penetrating power of α-particles). They can pass through 1 mm thick sheet of aluminium.

(v) These particles have low ionising power i.e., (1/100)th of the ionising power of α-particles.

(vi) These particles produce fluorescence in calcium tungstate, barium platinocyanide and zinc sulphide. And they affect photographic plate more than α-particles.

Properties of γ-Rays

γ-rays $({}_0\gamma^0)$ are high energy electromagnetic radiation of nuclear origin and short wavelength (≈ 0.01Å). It is about (1/100)th part of the wavelength of X-rays. Radiation of γ-rays is a nuclear property whereas X-rays is due to atomic property.

Some important properties of γ-rays are as follows

(i) As, the γ-rays do not have any charge, they are not deflected by electric and magnetic fields.

(ii) These rays travel with the speed of light $(3 \times 10^8 \text{ms}^{-1})$.

(iii) These rays have highest penetrating power more than that of α and β-particles. They can pass through 30 cm thick iron sheet.

(iv) These rays have least ionisation power as compared to that of α and β-particles.

(v) These rays produce fluorescence. They also affect photographic plate more than β-particles.

(vi) As, the γ-rays have high energy, they can give rise to the phenomenon of pair production. When a photon of γ-rays strikes the nucleus of an atom, its energy is converted into an electron and a positron (positively charged electron).

$$\underset{\text{(photon)}}{\gamma} \longrightarrow \underset{\text{(electron)}}{e^-} + \underset{\text{(positron)}}{e^+}$$

Comparison of the Properties of α, β and γ-radiations

Property	α-particle	β-particle	γ-rays
Nature	Helium nucleus	Fast moving electrons	Electromagnetic waves
Charge	$+2e$	$-e$	zero
Rest mass	6.67×10^{-27} kg	9.1×10^{-31} kg	zero
Speed	1.4×10^7 to 2.2×10^7 ms^{-1}	1 to 99% of c $=3\times10^8$ ms^{-1}	$c=3\times10^8$ ms^{-1}
Ionising power	10^4	10^2	1
Penetrating power	1	10^2	10^4

CHECK POINT 01

1. What are the elementary particles of an atom?
2. In an atom $_{13}Al^{27}$, find the number of electrons, protons and neutrons.
3. What are the three types of decay occurs in nature?
4. In α, β and γ-particles, which have least ionising power?
5. In α, β and γ-particles, which have most penetrating power?

Radioactive Decay

A radioactive nucleus (parent nucleus), decays by particle emission into another nucleus (daughter nucleus), this phenomenon is called **radioactive decay**.

Some radioactive decays are as follows

α-Decay

In α-decay, the mass number of the daughter (product) nucleus is four less than that of parent (decaying) nucleus, while the atomic number decreases by two.

The decay can be written as,

$$^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}_2He^4$$

where, X is the parent nucleus and Y is daughter nucleus.

e.g., $$_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_2He^4$$

α-decay occurs with nuclei that are very heavy, hence unstable. So, emitting alpha particles, mass number decreases and it moves towards stability.

Example 2. $_{86}Rn^{222}$ **is converted into** $_{84}Po^{218}$. **Name the particle emitted in this case and write down the corresponding equation.**

Sol. Let the particle emitted in this case be represented as $_ZX^A$.

Therefore, $_{86}Rn^{222} \longrightarrow {}_{84}Po^{218} + {}_ZX^A$.

Using the law of conservation of mass number and charge number , we get

$$222 = 218 + A$$

and $$86 = 84 + Z$$

$\Rightarrow$ $$A = 4 \Rightarrow Z = 2$$

Now, $A = 4$ and $Z = 2$ correspond to an α-particle ^4_2He. Therefore, emitted particle is an α-particle and the equation is

$$_{86}Rn^{222} \longrightarrow {}_{84}Po^{218} + {}^4_2He$$

β^--Decay

In β-decay, the mass number of the daughter (product) nucleus remains same but atomic number increases by one.

The decay can be written as

$$^{A}_{Z}X \longrightarrow {}_{Z+1}X^A + \beta^-({}_{-1}e^0)$$

It is to be noted here that β-particles are nothing but electrons.

Example 3. How many α and β^--particles will be emitted when $_{90}Th^{232}$ changes to $_{83}Bi^{212}$?

Sol. $_{90}Th^{232} \longrightarrow {}_{83}Bi^{212}$

Decrease in mass number $= 232 - 212 = 20$

Number of α-particles emitted due to the above decrease in mass number $= \frac{20}{4} = 5$

Expected decrease in atomic number due to emission of 5α-particles $= 5 \times 2 = 10$

Expected atomic number of the nucleus formed

$$= 90 - 10 = 80$$

But the atomic number of nucleus formed = 83

Increase in atomic number = 83 – 80 = 3

Number of β^--particles emitted = 3

Thus, 5 α-particles and 3 β^--particles are emitted.

γ-Decay

In γ-decay, there is no change in mass number and atomic number of parent nucleus but energy in form of electromagnetic radiation is related in this decay.

The decay can be written as

$$^{A}_{Z}X \longrightarrow {}^{A}_{Z}X + \gamma \text{ (gamma radiation or energy)}$$

Uses of Radioactivity-Radioisotopes

There are some elements with atomic number $Z < 82$, whose isotopes are also radioactive. These isotopes are called **radioisotopes**.

e.g., Potassium $^{40}_{19}K$ (atomic number = 19, mass number = 40) and Carbon $^{14}_{6}C$ (atomic number = 6, mass number = 14), etc., are the radioisotopes.

Radioisotopes has its applications in different fields, they are discussed as follows

Medical Uses

(i) Diseases like leukemia, cancer, etc., can be cured by radioisotopes.

(ii) γ-rays emitted by $^{60}_{27}Co$ are used to kill the cells in malignant tumour of patient.

(iii) The weak radioactive tracers of isotopes such as radioisotopes of NaCl, I, etc., are used to diagnose the brain tumour, blood clots before they become dangerous.

Industrial Uses

(i) To avoid the accumulation of charge on moving parts of machine due to friction, radioactive isotopes are used. Due to ionisation effect, charges accumulated on moving parts will be taken.

(ii) The radioactive isotopes have such an ionisation effect that they can be used in making luminescent signs.

(iii) Radioactive tracers are used to check the underground pipelines.

(iv) Radioisotopes in the form of nuclear fuel are used to produce power.

Scientific Uses

(i) The radioisotopes are used in determining the age of rocks containing carbon, by measuring the percentage of C^{12} and C^{14} in them.

(ii) The age of old objects not containing carbon can be determined by measuring the percentage of isotopes atom in them.

(iii) These are used in **α-particle gold foil experiment** in order to study the structure of atom.

(iv) Radioactive sources of elements N, P, K are used in agriculture science to study the growth of plants with respect to manure.

CHECK POINT 02

1. How can we see that radioactive decay is a radom phenomena?
2. What is the basic difference between β^- and β^+ decay?
3. How atomic number and mass number changes during γ-decay?
4. What are the medical uses of radioisotopes?
5. How age of rocks can be determined by carbon isotopes?
6. Which elements are used to study the growth of plants?

Sources of Harmful Radiation

Radioactive or nucleus radiation are very harmful for human being, they can cause diseases likes sore throat, loss of hair, cancer, leukemia, etc.

Along withing they have affect on genetics which can appear in later generation.

There are three main sources from where we get the radiations.

Radioactive Fall out from Nuclear Power Plants and Other Resources

It is a fact that now a days, the nuclear power plants are acting as a major source of electricity in the world. In case any accident occured in the reactor of these plants, radioactive radiations will escape into the atmosphere in a large amount. It will not only affect the population around the plant but also affect the life at far off places where they can reach with air currents.

Nuclear Waste

When the activity of the fuel rods used in nuclear power reactor decreases, they get rejected. But still, these rods are quite radioactive in nature. If these are thrown in an open garbage dump, they can contaminate water and soil and can affect the living organisms also.

Cosmic Radiations

Cosmic radiations from the sun enter the Earth's atmosphere from outer space. Out of these radiations, substantial amount of uncharged radiations such as γ-ray and X-ray, etc enter the Earth's atmosphere.

These radiations are also very harmful for human beings.

Background Radiations

All the radiations which are present in the atmosphere, even if there is no radioactive source present are called background radiations.

The sources of these radiations are

(i) cosmic radiations.

(ii) natural and artificial radioactive isotopes.

(iii) products after nuclear explosion.

(iv) traces of radioactive substances present in Earth i.e., rocks.

Safety Precautions while Using Nuclear Energy

Some of the safety precautions which are required to be undertaken while using nuclear energy are as follows

Safety Measures for Handling the Radioactive Materials

(i) Each type of radiations should have some safety limits and that should be known to each and everyone, so that no one get exposed beyond the safety limit in any case.

(ii) People working with radioactive materials should wear special lead lined aprons and lead gloves.

(iii) In order to stop radiations from spreading all round, the radioactive substances must be kept in thick lead containers with a very narrow opening.

Safety Measures for Establishment of Nuclear Plants

When a nuclear power plant is going to be established to generate the electricity, proper care must be taken, so that the working people in it are not exposed to the nuclear radiations.

Given below are some safety measures which are to be followed during the establishment of nuclear power plants.

(i) The housing of nuclear reactor must be done in an air-tight building of strong concrete structure which can with stand earthquakes, fires and explosion.

(ii) For backup the cooling system must be there for the reactor core, for safety in case of failure.

Safe Disposal of Nuclear Waste

Nuclear wastes are the wastes found after use of radioactive material. It is obtained from different places like laboratories, power plants, hospitals, scientific establishment.

So, it must be first kept them in thick casks and then must be buried in the specially constructed deep under ground stores.

These stores must be far from the populated areas. Even the casks can also be buried in useless mines and these mines must be sealed after storing the casks.

Nuclear Energy

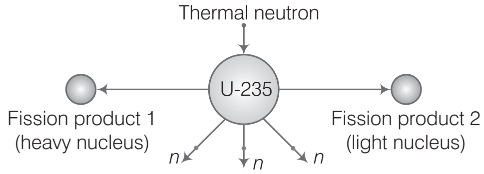
Energy contained in the nucleus of atom is called nuclear energy. It is released during nuclear reaction.

A reaction in which composition of the reacting nuclei changes to form new elements with a simultaneous release of large amount of energy is called a **nuclear reaction**.

Nuclear reactions occur in the following two ways

1. Nuclear Fission

The reaction in which a heavy nucleus splits into two or more smaller nuclei, with the evolution of large amount of energy when it is bombarded with slow moving neutron is called a nuclear fission reaction.



Nuclear fission reaction

Nuclear fission of U-235 as follows

$$\underset{\text{Heavy nucleus}}{{}^{235}_{92}\text{U}} + \underset{\text{Thermal neutron}}{{}^{1}_{0}n} \xrightarrow[\text{fission}]{\text{Nuclear}} \underbrace{{}^{139}_{56}\text{Ba} + {}^{94}_{36}\text{Kr}}_{\text{Fission products}} + \underset{\text{Product neutrons}}{3\,{}^{1}_{0}n} + \underset{\substack{\text{Huge amount}\\ \text{of energy}\\ (220\text{ MeV})}}{Q}$$

The fission of an atom of uranium, e.g., produces 10 million times, the energy produced by the combustion of an atom of carbon from coal. In a nuclear reactor designed for electric power generation, such nuclear fuel can be part of a self sustaining fission chain reaction that release energy at a controlled rate.

Energy released in fission reactions In all fission reactions, a small quantity of matter is lost. This lost matter gets converted into energy which is released in any nuclear fission reaction.

The energy (E) obtained due to loss of matter of mass (Δm) is given by the famous Einstein's equation in 1905,

$$E = \Delta mc^2$$

where, c = velocity of light $= 3 \times 10^8 \text{ m/s}$

Differences between nuclear fission and radioactive decay

Nuclear Fission	Radioactive Decay
It is a reaction in which a heavy nucleus splits into two or more smaller nuclei, with the evolution of large amount of energy when it is bombarded with slow moving neutron.	In this, an unstable nucleus undergoes a decay with the emission of some particles (α, β) and electromagnetic radiations (γ-rays).
It is carried out only when bombarded with neutrons and can be controlled.	It is a spontaneous process and cannot be controlled.

2. Nuclear Fusion

A nuclear reaction in which two or more lighter nuclei fuse to form a heavy nucleus and large amount of energy is released is called nuclear fusion reaction.

Conditions for fusion reaction to take place are as given below

(i) High temperature (~ 4-15 million kelvin)
(ii) High pressure (~ 1 million atmosphere)

Because these reactions require a very high temperature, therefore they are also called **thermonuclear reactions**.

The cause of high heat energy on the Sun is due to fusion of hydrogen nuclei to form helium nuclei.

$$ {}_{1}^{2}\mathrm{H} + {}_{1}^{2}\mathrm{H} \longrightarrow {}_{2}^{3}\mathrm{He} + {}_{0}^{1}n $$

Such nuclear fusion reactions are the source of energy in the Sun and other Stars.

Hydrogen Bomb

The hydrogen bomb is based on **thermonuclear fusion reaction**.
A nuclear bomb based on the fission of uranium or plutonium is placed at the core of the hydrogen bomb. This nuclear bomb is embedded in a substance which contains deuterium and lithium. When the nuclear bomb (based on fission) is detonated, then the temperature of this substance is raised to 10^7 K in a few microseconds. The high temperature generates sufficient energy for the light nuclei to fuse and a devastating amount of energy is released.

Differences between nuclear fission and nuclear fusion

Nuclear Fission	Nuclear Fusion
It involves breaking of a heavy nucleus into lighter nuclei into a heavy two light nuclei.	It involves binding of two nucleuses.
It is carried out by the bombardment of two thermal lighter nuclei upto neutrons over a heavy nucleus.	It is carried out by heating at an extreme temperature.
It is a chain reaction.	It is not a chain reaction.
It is a controlled process.	It is an uncontrolled process.
It produces an enormous amount of energy.	It produces more energy than nuclear fission.
Fission products are hazardous.	It does not cause pollution.

Hazards of Nuclear Power Generation

The major hazards of nuclear power generation are as follows

(i) Storage and disposal of spent/used fuels and the uranium continuously decaying into harmful subatomic particles is a big problem.
(ii) Improper nuclear-waste storage and disposal may lead to environmental contamination.
(iii) There is also a risk of nuclear accidents causing due to leakage of nuclear radiation.

Due to all the above factors, large scale use of nuclear energy is prohibited. The nuclear power reactors in India at **Tarapur** (Maharashtra), **Rana Pratap Sagar** (Rajasthan), **Kalpakkam** (Tamil Nadu), **Narora** (Uttar Pradesh), **Kakrapar** (Gujarat) and **Kaiga** (Karnataka) have the installed capacity of less than 3% of total electricity generation capacity of the country.

However, many industrialised countries are producing more than 30% of their electric power needs from nuclear reactors.

CHECK POINT 03

1 What is source of cosmic radiations in nature? How these radiations can effect us?
2 Why safe disposal of nuclear waste is needed?
3 What is the unit for background radiations?
4 On what type of reaction does a hydrogen bomb depend?
5 When does nucleus of an atom tend to be radioactive?
6 In between nuclear fission and fusion, which is more hazardous?

SUMMARY

- An atom consists of electron, proton and neutron.
- A nucleus consist of proton and neutron.
- Isotopes are the atoms belonging to the same elements, having same atomic number but different mass number, due to difference in neutrons.
- Isotones are the atoms with the same neutron number but different atomic number.
- Isobars are the same mass number but different atomic numbers.
- Radioactivity is a spontaneous nuclear phenomenon in which an unstable nucleus undergoes a decay with the emission of some particles and electromagnetic radiation.
- Becquerel rays are of three types: alpha, beta and gamma rays.
- Energy contained in a nucleus of atom is called nuclear energy.
- Nuclear fission is the reaction in which a heavy nucleus splits into two or more smaller nuclei, with evolution of long amount of energy.
- Nuclear fusion is the reaction in which two or more lighter nuclei fuse to form a heavy nucleus and a large amount of energy.

EXAM PRACTICE

2 Marks Questions

1. Define the term "isotopes". Give an example.

Sol. Isotopes are an atoms of the same element having same atomic number (Z) but different mass number (A), isotopes have the same number of orbital electrons, so their chemical properties are similar.
e.g., Isotopes of hydrogen. ***[1]***

^1_1H (Proton),
^2_1H (Deuterium)
and ^3_1H (Tritium). ***[1]***

2. (i) What are isobars?
(ii) Give one example of isobars. ***[2018]***

Sol. (i) The atoms of different elements which have the same mass number (A), but different atomic number (Z) are called isobars. ***[1]***
(ii) $^{23}_{11}Na$ and $^{23}_{11}Mg$ are isobars having same mass number '23' and different atomic numbers. ***[1]***

3. At what condition does the nucleus of an atom become radioactive?

Sol. The nucleus of an atom becomes radioactive when the number of neutrons exceed the number of protons , present inside the nucleus which thereby increases its instability. ***[2]***

4. When does the nucleus of an atom, tend to be radioactive? ***[2017]***

Sol. Atoms with unstable nuclei are constantly changing as a result to the imbalance of energy within the nucleus. Instability of an atoms nucleus may result from an excess of either neutrons or protons since, nuclear forces become weak, so to become stable some amount mass in form of energy is released. This means, when the nucleus loses a neutron, it gives off energy and becomes radioactive. ***[2]***

5. In heavy nuclei, number of neutrons is greater than the number of protons. Why?

Sol. Electrostatic repulsive forces between number of protons is very high in heavy nuclei due to presence of large number of protons. The attraction due to nuclear forces cannot sustain so much the protons together in the nucleus. Thus, large number of neutrons separate the protons, weakening the repulsion between them. ***[2]***

6. When a radioactive substance is oxidised, will there be any change in the nature of its radioactivity? Give a reason for your answer. ***[2016]***

Sol. There will be no change in the nature of its radioactivity because radioactivity is a nuclear phenomenon and oxidation is a chemical process which does not affects the nucleus of the substance.
If the nucleus has a greater number of protons than neutrons or *vice-versa*, the nuclear forces become weak. So, the nuclei of such an element becomes unstable and has a tendency to disintegrate into a more stable element. ***[2]***

7. A mixture of radioactive substances gives off three types of radiations.
(i) Name the radiation which travels with the speed of light.
(ii) Name the radiation which has the highest ionising power. ***[2011]***

Sol. (i) γ-radiation travels with the speed of light. ***[1]***
(ii) α (^4_2He) particle has the highest ionising power. ***[1]***

8. Point out the comparison for
(i) the ionising powers and
(ii) penetrating powers of α, β and γ-radiations.

Sol. (i) The ionising power of α-radiations is nearly 100 times that of β-radiations and nearly 10000 times that of γ-radiations. The ionising power for the three particles (α, β, γ respectively) is the order of $10^4 : 10^2 : 1$. ***[1]***
(ii) The penetrating power of α-particle is 1/100th times that of a β-particle and 1/10000 times that of γ-radiation. ***[1]***

9. "α and β-particles are deflected in an electric field or a magnetic field, while γ-rays are not deflected in such a field". Comment on this statement.

Sol. Since, α and β-particles are the charged particles (i.e., α-particles carry positive charge and β-particles carry negative charge) due to which, they are deflected in such a field. While γ-rays are not deflected in such a field because they are uncharged. ***[2]***

10. What happens to the atomic number of an element, when it emits
(i) an α-particle and
(ii) a β-particle ?

Sol. (i) When an α-particle is emitted, then atomic number decreases by 2 and mass number decreases by 4. *[1]*

(ii) During β-emission, atomic number increases by 1 as it consists of electron. *[1]*

11. Write two industrial use of radioisotopes.

Sol. Refer to theory (Page 226).

12. Which of the radioactive radiations occurs in the following cases:

(i) That can cause severe genetical disorder.

(ii) Are deflected by an electric field? *[2013]*

Sol. (i) γ- radiation can cause severe genetical disorder. *[1]*

(ii) Since α, β are charged particles, so they get deflected in the electric field. *[1]*

13. (i) Which radiation produces maximum biological damage?

(ii) What happens to the atomic number of an element, when the radiation named by you in part (i) above are emitted? *[2010]*

Sol. (i) γ-radiation produces maximum biological damage as it has maximum penetration power. *[1]*

(ii) There is no change in atomic and mass number of element formed after γ-radiation or emission. *[1]*

14. What is nuclear fission reaction? Give an example equation of explain.

Sol. Refer to theory (Page 227).

15. (i) What do you understand by the term nuclear fusion?

(ii) Nuclear power plants use nuclear fission reaction to produce electricity. What is the advantage of producing by fusion reaction? *[2018]*

Sol. (i) In nuclear fusion two light nuclei are combined to form heavy nucleus with release of energy. *[1]*

(ii) In fusion more energy per unit mass is released than fission, therefore it will be more useful in producing electricity. *[1]*

16. Differentiate between radioactive decay and nuclear fission.

Sol. Refer to theory (Page 227).

b 3 Marks Questions

17. Arrange α, β and γ-rays in ascending order with respect to their

(i) penetrating power (ii) ionising power

(iii) biological effect *[2016]*

Sol. Ascending order arrangement of α, β and γ-particle with respect to their

(i) **penetrating power** α-particle, β-particle, γ-particle.

(ii) **ionising power** γ-particle, β-particle, α-particle.

(iii) **biological effect** γ-particle, β-particle, α-particle. *[3]*

18. The ore of uranium found in nature contains $_{92}U^{238}$ and $_{92}U^{235}$.

Although both the isotopes are fissionable, it is found out experimentally that one of the two isotopes is more easily fissionable.

(i) Name the isotope of uranium which is easily fissionable.

(ii) Give a reason for your answer.

(iii) Write a nuclear reaction when uranium 238 emits an alpha particle of form a Thorium (Th) nucleus. *[2018]*

Sol. (i) $_{92}U^{235}$ is easily fissionable. *[1]*

(ii) Fission of uranium with mass number of 238 is possible by only fast neutron but the fission of uranium with mass number of 235 is also possible by slow neutron. *[1]*

(iii) $^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ (α-particle) *[1]*

19. Write in details about the sources of harmful radiations.

Sol. Refer to theory (Page 226).

20. (i) What is meant by radioactivity?

(ii) What is meant by nuclear waste?

(iii) Suggest one effective process for the safe disposal of nuclear waste.

Sol. (i) Radioactivity is the spontaneous process by which nucleus of an unstable atom decays by emitting radiations such as α, β and γ. *[1]*

(ii) Nuclear waste is the material which remains after the use of radioactive element such as α, β and γ-particles in the form of radiation. *[1]*

(iii) Nuclear waste must be put in a thick casks (dumbell shaped structure), then after buried in the specially constructed deep underground stores reservoirs. *[1]*

21. (i) Explain the term background radiation.

(ii) Name its sources.

(iii) State whether is it possible for us to keep ourselves away from it?

Sol. (i), (ii) Refer to theory (Page 226). *[1+1]*

(iii) No, it is not possible to keep ourselves away from them. *[1]*

22. (i) Mention two important precautions that should be taken while handling radioactive materials.
(ii) State one use of radioisotopes.

Sol. (i) *Two important precautions of handling radioactive materials are as follows*
(a) Put them in a thick lead box.
(b) Wear special protective clates (lead coated) and gloves on the hand. **[2]**
(ii) Refer to theory (Page 226). **[1]**

23. Differentiate between nuclear fission and nuclear fusion.

Sol. Refer to theory (Page 228).

C 4 Marks Questions

24. Explain in brief the given statement: "radioactivity is a nuclear phenomenon."

Sol. The process of spontaneous emission of radiations from the nucleus, is known as radioactivity. The nucleus consists of protons and neutrons. These are bounded inside the nucleus by a strong attractive force called the nuclear force. If in a nucleus, the number of protons is much more than the number of neutron, the nuclear force becomes weak. The nuclei of such element becomes unstable and have a tendency to disintegrate. **[2]**

This happens in the case of nuclei of elements of atomic number higher than 82. These elements are called natural radioactive elements. Any physical or chemical condition such as excessive heating, freezing, magnetic fields, etc., cannot alter the rate of disintegration of such elements. That means the phenomenon cannot be due to the orbital electrons which could be easily affected by such changes. It is the property of the nucleus. Hence, radioactivity is a nuclear phenomenon. **[2]**

25. Describe briefly, two properties of each of α and β-particles. **[2002]**

Sol. Refer to theory (Page 224).

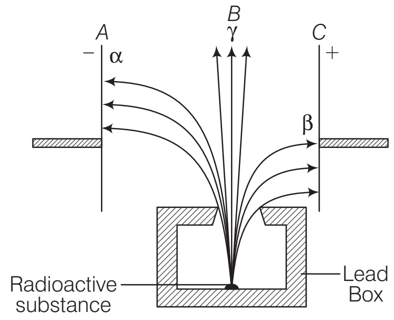
26. Specify two properties of β-particles and γ-rays.

Sol. Refer to theory (Pages 224 and 225).

27. Write a comparison table between α, β and γ-radiations.

Sol. Refer to theory (Page 225).

28. Radiations given out from a source when subjected to an electric field in a direction perpendicular to their path are shown below in the diagram. The arrows show the path of the radiation *A*, *B* and *C*. Answer the following questions in terms *A*, *B* and *C*.



(i) Name the radiation *B* which is unaffected by the electrostatic field.
(ii) Why does the radiation *C* deflect more than *A*?
(iii) Which among the three causes the least biological damage externally?
(iv) Name the radiation which is used in carbon dating. **[2018]**

Sol. (i) Gamma radiations. **[1]**
(ii) The radiation *C* deflect more than *A* because the mass of β-particles is less than that of α, hence radiation deflects more than *A*. **[1]**
(iii) γ-rays **[1]**
(iv) β radiation is used in carbon dating. **[1]**

29. (i) What happen to the atomic number of an element, when it emits
(a) an α-particle and (b) a β-particle?
(ii) Explain, why α-and β-particle are deflected in an electric or a magnetic field but γ-rays are not deflected in such a field. **[2007]**

Sol. (i) (a) When an α-particle is emitted, then atomic number decreases by 2 and mass number decreases by 4.
(b) During β-emission, atomic number increases by 1 as it consists of ${}_{-1}\beta^0$. **[2]**
(ii) Since, α-particle is a helium nuclei $({}_2He^4)$ and is positively charged particle and β-particle is $({}_{-1}\beta^{\circ})$, negatively charged particle.
So, in an electric field they experiences some force so, get deflected. **[2]**

30. (i) Represent the change in the nucleus of a radioactive element when a β-particle is emitted from it.
(ii) What is the name given to elements with same mass number and different atomic numbers?
(iii) Under which conditions the nucleus of an atom tend to be radioactive? **[2016]**

Sol. (i) The emission of β-particle by the nuclei of radioactive substance does not change the mass number of the atom but increases its atomic number by one. *[1]*

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$$ *[1]*

(ii) Isobar is the name give to the elements with the same mass number and different atomic numbers. *[1]*

(iii) Refer to Sol. 2. *[1]*

31. A certain nucleus X has a mass number 14 and atomic number 6. The nucleus X changes to ${}_7Y^{14}$ after the loss of a particle.

(i) Name the particle emitted.

(ii) Represent this change in the form of an equation.

(iii) A radioactive substance is oxidised. What change would you expect to take place in the nature of its radioactivity? Give a reason for your answer. *[2012]*

Sol. (i) β-particle since during the ${}_{-1}\beta^0$- emission, there is gain in atomic number. *[1]*

(ii) $${}_6X^{14} \xrightarrow{-{}_1\beta^0} {}_7\gamma^{14} + {}_{-1}e^0$$ *[1]*

(iii) There is no change in the nature of radioactivity during oxidation. Because oxidation is a phenomena in which involvement of electrons takes place, whereas in radioactivity nucleons takes part in the reaction. *[2]*

32. Write a note on the safety measures to be undertaken during establishment of nuclear power plants.

Sol. Refer to theory (Page 227). *[4]*

33. Briefly explain the term radiation hazards.

Sol. The nuclear radiations such as α, β, γ-rays and neutrons can damage the human body. The radiations produce severe burns on the human body. e.g., When gamma rays pass through a living organism, they knockout the electrons from the organic molecules as a result of which the molecules may breakup. The distortion of the molecules hampers the normal functioning of the living system and may ultimately result in the death of the organism. *[2]*

These radiations causes following two types of damages.

(i) **Genetical Damage** Damages of this type are not evident immediately but appear in the subsequent damages. *[1]*

(ii) **Pathological Damage** If an organism is exposed to high doses of radiation, it might ultimately lead to the death of the organism. Such a damage is known as pathological damage. *[1]*

Numerical Based Questions

34. One isotope of uranium has a mass number 235 and atomic number 92.

(i) What is the number of electrons in the neutral atom of this isotope?

(ii) What is the number of protons and number of neutrons in its nucleus?

(iii) Do all isotopes have the same number of neutrons?

(iv) What is the number of protons and neutrons in ${}^{238}_{92}U$?

Sol. Given, $A = 235$, $Z = 92$

(i) Atomic number, Z = number of protons

= number of electrons = 92

∴ The neutron atom of ${}^{235}_{92}U$ will have 92 electrons. *[1]*

(ii) The number of protons $= Z = 92$

The number of neutrons $= A - Z = 235 - 92 = 143$

The nucleus of ${}^{235}_{92}U$ contains 92 protons and 143 neutrons. *[1]*

(iii) No, isotopes of an element have same atomic number, but different mass number, so they have the same number of protons, but different number of neutrons. *[1]*

(iv) In ${}^{238}_{92}U$, number of protons $= Z = 92$ and number of neutrons $= A - Z = 238 - 92 = 146$. *[1]*

35. The isotope of ${}_{92}U^{238}$ decays by α-emission to an isotope of thorium (Th). The thorium isotopes decays by β- emission to an isotope of protactinium (Pa). Write down the equations to represents these two nuclear charges. *[2003]*

Sol. *The equation for α-emission is as follows*

$${}_{92}U^{238} \xrightarrow{-\alpha\,({}_2He^4)} {}_{90}Th^{234}$$

The equation for β-emission is as follows

$${}_{90}Th^{234} \xrightarrow{-\beta({}_{-1}\beta^0)} \text{(protactinium)}\ {}_{91}Pa^{234}$$ *[4]*

36. An element ${}_ZS^A$ decays to ${}_{85}R^{222}$ after emitting 2α-particles and 1β-particle. Find the atomic number and atomic mass of the element S. *[2016]*

Sol. According to the question,

$${}_{88}S^{230} \longrightarrow {}_{85}R^{222} + 2\alpha + {}^{\circ}_{+1}e + \nu_e$$

Therefore, atomic number, $Z = 88$

Mass number, $A = 230$ *[2]*

37. A nucleus $_{11}Na^{24}$ emits a β-particle to change into magnesium (Mg).

(i) Write the symbolic equation for the process.
(ii) What are numbers 24 and 11 called?
(iii) What is the general name of $^{24}_{12}Mg$ with respect to $^{24}_{11}Na$?

Sol. (i) The symbolic equation of this process is

$$_{11}Na^{24} \longrightarrow {}_{12}Mg^{24} + {}_{-1}e^{0}$$ ***[1]***

(ii) 24 is the mass number and 11 is the atomic number. ***[1]***

(iii) $_{11}Na^{24}$ and $_{12}Mg^{24}$ are isobars. ***[1]***

38. Write nuclear reaction equations for

(i) α-decay of $^{226}_{88}Ra$ (ii) α-decay of $^{242}_{94}Pu$
(iii) β^--decay of $^{32}_{15}P$

Sol. As we know that,

(i) in α-decay, the mass number is reduced by 4 and atomic number is reduced by 2.
(ii) in β-decay, the mass number remains constant and atomic number is increased by 1.
(iii) in a γ-decay, the mass number and atomic number remains same.

The following equations are given

(a) $^{226}_{88}Ra \xrightarrow{-\alpha} {}^{222}_{88}Rn + {}^{4}_{2}He$

(b) $^{242}_{94}Pu \xrightarrow{-\alpha} {}^{238}_{92}U + {}^{4}_{2}He$

(c) $^{32}_{15}P \xrightarrow{-(-\beta)} {}^{32}_{16}S + {}^{0}_{-1}e + \bar{\nu}$

i.e., β^--decay is accompanied by release of antineutrino. ***[3]***

39. A certain nucleus P has a mass number 15 and atomic number 7.

(i) Find the number of neutrons.
(ii) Write the symbol for the nucleus P.
(iii) The nucleus P losses (a) one proton (b) one β-particle (c) one α-particle.
Write the symbol of the new nucleus in each case and express each charge by a reaction.

Sol. Given, for the nucleus P, $A = 15$, $Z = 7$

(i) Mass number, A
= number of protons + number of neutrons
Atomic number, Z = number of protons

$\therefore$ Number of neutrons = mass number, A − atomic number, $Z = 15 - 7 = 8$ ***[1]***

(ii) The nucleus P can be written as $^{15}_{7}P$. ***[1]***

(iii) (a) After the loss of proton, the mass number and atomic number of the nucleus $^{15}_{7}P$ will decrease by 1. The new nucleus will be $^{14}_{6}Q$ (say).
The nucleus $^{15}_{7}P$ changes to $^{14}_{6}Q$ (say) as follows

$$^{15}_{7}P \longrightarrow {}^{14}_{6}Q + {}^{1}_{1}P$$

(b) After the loss of one β-particle, the mass number will remain the same but the atomic number will increase by 1.
The nucleus $^{15}_{7}P$ changes to $^{15}_{8}R$ (say) as follows

$$^{15}_{7}P \longrightarrow {}^{15}_{8}R + {}^{0}_{-1}e$$

(c) After the loss of one α-particle, the mass number decreases by 4 and the atomic number decreases by 2.
The nucleus $^{15}_{7}P$ changes to $^{11}_{5}S$ (say) as follows

$$^{15}_{7}P \longrightarrow {}^{11}_{5}S + {}^{4}_{2}He$$ ***[2]***

40. Complete the following nuclear changes.

(i) $_{11}Na^{24} \longrightarrow {}_{\dots}Mg^{\dots} + {}_{-1}\beta^{0}$

(ii) $_{92}U^{238} \longrightarrow {}_{90}Th^{234} + \dots +$ Energy ***[2010]***

Sol. (i) $_{11}Na^{24} \longrightarrow {}_{12}Mg^{24} + {}_{-1}\beta^{0}$ ***[1]***

(ii) $_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_{2}He^{4}$ (α-particle) + Energy ***[1]***

41. Complete the following nuclear reactions given below:

(i) $^{238}_{92}P \xrightarrow{\alpha} Q \xrightarrow{\beta} R \xrightarrow{\beta} S$

(ii) $^{A}_{Z}X \xrightarrow{\alpha} X_1 \xrightarrow{-\gamma} X_2 \xrightarrow{2\beta} X_3$

Sol. (i) $^{238}_{92}P \longrightarrow {}^{234}_{90}Q + {}^{4}_{2}He$, $^{234}_{90}Q \longrightarrow {}^{234}_{91}R + {}^{0}_{-1}\beta$

$^{234}_{91}R \longrightarrow {}^{234}_{92}S + {}^{0}_{-1}\beta$

Therefore, the complete radiation series can be represented as ***[1]***

$$^{238}_{98}P \xrightarrow{\alpha} {}^{234}_{90}Q \xrightarrow{\beta} {}^{234}_{91}R \xrightarrow{\beta} {}^{234}_{92}S$$

(ii) $^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X_1 + {}^{4}_{2}He$

$^{A-4}_{Z-2}X_1 \longrightarrow {}^{A-4}_{Z-2}X_2 + \gamma$

$^{A-4}_{Z-2}X_2 \longrightarrow {}^{A-4}_{Z}X_3 + 2\,{}^{0}_{-1}\beta$

Therefore, complete radioactive series can be given as

$$^{A}_{Z}X \xrightarrow{\alpha} {}^{A-4}_{Z-2}X_1 \xrightarrow{\gamma} {}^{A-4}_{Z-2}X_2 \xrightarrow{2\beta} {}^{A-4}_{Z}X_3$$ ***[1]***

CHAPTER EXERCISE

2 Marks Questions

1. How can you define the term "isobar"? Give its one example.

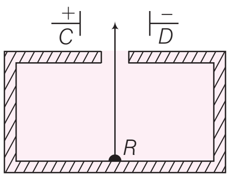
2. The nucleus $_{84}X^{202}$ emits an α-particle and forms the nucleus Y. Represent this change in the form of an equation.

3. In order to form an element C, an element D disintegrates by α-emission and the new element suffers two further disintegrations, both by β-emission. Explain the fact that the new elements P and Q are isotopes.

4. "We usually use isotopes emitting γ-radiations as radioactive tracers in medical science". Justify the statement with the help of a reason.

3 Marks Questions

5. The diagram given below is showing a radioactive source R in a thick walled container having a narrow opening. The radiations pass through an electric field between the plates C and D.



(i) Consider the above diagram and complete it in order to show the paths of α, β and γ-radiations.

(ii) What is the reason of keeping the source R in a thick lead walled container with narrow opening?

6. State any two safety measures that should be taken while establishing a nuclear power plant.

4 Marks Questions

7. (i) Briefly explain the two main sources of nuclear radiations.

   (ii) How are these radiations harmful?

8. Briefly mention any three precautions while handling the source of γ-radiation?

Numerical Based Questions

9. If a nucleus $^{234}_{90}$Th decay to $^{206}_{82}$Pb, find the number of α and β-particles emitted.

10. Uranium nucleus $^{238}_{92}$U undergoes several disintegrations and ultimately decays to lead nucleus $^{206}_{82}$Pb . How many α and β-particles are emitted?

Ans. 8 α-particles, 6 β-particles

ARCHIVES* *(Last 5 Years)*

Collection of Questions Asked in Last 5 Years' (2018-2014) ICSE Class 10th Examinations

2018

1. (i) What are isobars?

(ii) Give one example of isobars. ***[2]***

2. (i) What do you understand by the term nuclear fusion?

(ii) Nuclear power plants use nuclear fission reaction to produce electricity. What is the advantage of producing by fusion reaction? ***[2]***

3. The ore of uranium found in nature contains $_{92}U^{238}$ and $_{92}U^{235}$

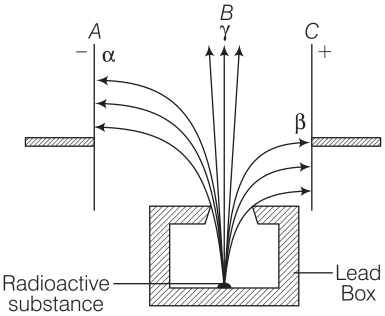
Although both the isotopes are fissionable, it is found out experimentally that one of the two isotopes is more easily fissionable.

(i) Name the isotope of uranium which is easily fissionable.

(ii) Give a reason for your answer.

(iii) Write a nuclear reaction when uranium 238 emits an alpha particle of form a Thorium (Th) nucleus. ***[3]***

4. Radiations given out from a source when subjected to an electric field in a direction perpendicular to their path are shown below in the diagram. The arrows show the path of the radiation *A*, *B* and *C*. Answer the following questions in terms *A*, *B* and *C*.



(i) Name the radiation *B* which is unaffected by the electrostatic field.

(ii) Why does the radiation *C* deflect more than *A*?

(iii) Which among the three causes the least biological damage externally?

(iv) Name the radiation which is used in carbon dating. ***[4]***

2017

5. When does the nucleus of an atom tend to be radioactive? ***[2]***

2016

6. A element $_{Z}S^{A}$ decays to $_{85}R^{222}$ after emitting 2α-particles and β-particle. Find the atomic number and atomic mass of the elements. ***[2]***

7. A radioactive substance is oxidised. Will there be any change in the nature of its radioactivity? Given reason for your answer. ***[2]***

8. Arrange α, β and γ-rays in ascending order with respect to their

(i) penetrating power (ii) ionising power

(iii) biological effect ***[3]***

9. (i) Represent the change in the nucleus of a radioactive element when a β-particle is emitted.

(ii) What is the name given to elements with same mass number and different atomic numbers?

(iii) Under which conditions does the nucleus of an atom tend to be radioactive? ***[3]***

2015

10. (i) Complete the diagram as given below drawing the deflection of radioactive radiations in an electric field. ***[2]***

(ii) State any two precautions to be taken while handling radioactive substance. ***[2]***

11. An atomic nucleus *A* is composed of 84 protons and 128 neutrons.

(i) The nucleus *A* emits an α-particle and is transformed into the nucleus *B*. What is the composition of nucleus *B* ? ***[1]***

(ii) The nucleus *B* emits a β-particle and is transformed into a nucleus *C*. What is the composition of nucleus *C*? ***[1]***

(iii) Does the composition of nucleus change, if it emits γ-radiations? ***[1]***

2014

12. A nucleus $_{11}Na^{24}$ emits a β-particles to change into magnesium (Mg).

(i) Write the symbolic equation for the process.

(ii) What are numbers 24 and 11 called? ***[1+1]***

(iii) What is the general name of $^{24}_{12}Mg$ with respect to $_{11}Na^{24}$? ***[1]***

* Explanations/Answers to all these questions are given in the chapter Theory and Exam Practice.

CHALLENGERS*

A Set of Brain Teasing Questions for Exercise of Your Mind

1 In fission of one uranium-235 nucleus, the loss in mass is 0.2 amu. Calculate the energy released.

(a) 186.2 MeV

(b) 182.6 MeV

(c) 156.4 MeV

(d) 189.1 MeV

2 When four hydrogen nuclei combine to form a helium nucleus in the interior of sun, what amount of energy released per nucleon in this process?

(a) 46.3 MeV

(b) 24.5 MeV

(c) 18.5 MeV

(d) 26.7 MeV

3 When a nucleus in an atom undergoes a radioactive decay, then the electronic energy levels of the atom

(a) do not change for any type of radioactivity

(b) change for α and β-radioactivity but not for γ-radioactivity

(c) change for α-radioactivity but not for others

(d) change for β-radioactivity but not for others

4 Heavy stable nuclei have more neutrons than protons. This is because of the fact that

(a) neutrons are heavier than protons

(b) electrostatic force between protons are repulsive

(c) neutrons decay into protons through beta decay

(d) nuclear forces between neutrons are weaker than that between protons

5 M_x and M_y denote the atomic masses of the parent and the daughter nuclei respectively, in radioactive decay. The Q-value for a β^--decay is Q_1 and that for a β^+-decay is Q_2.

If m_e denotes the mass of an electron, then which of the following statements is correct?

(a) $Q_1 = (M_x - M_y)\,c^2$ and $Q_2 = (M_x - M_y - 2m_e)\,c^2$

(b) $Q_1 = (M_x - M_y)\,c^2$ and $Q_2 = (M_x - M_y)\,c^2$

(c) $Q_1 = (M_x - M_y - 2m_e)\,c^2$ and $Q_2 = (M_x - M_y + 2c_e)\,c^2$

(d) $Q_1 = (M_x - M_y + 2m_e)\,c^2$ and $Q_2 = (M_x - m_y + 2m_e)\,c^2$

6 The gravitational force between a H-atom and another particle of mass m will be given by Newton's law $F = G\dfrac{M \cdot m}{r^2}$, where r is in metre and

(a) $M = m_{\text{proton}} + m_{\text{electron}}$

(b) $M = m_{\text{proton}} + m_{\text{electron}} - \dfrac{B}{c^2}\,(B = 13.6 \text{ eV})$

(c) M is not relate to the mass of the hydrogen atom

(d) $M = m_{\text{proton}} + m_{\text{electron}} - \dfrac{|V|}{c^2}$ ($|V|$ = magnitude of the potential energy of electron in the H-atom)

7 A stationary radioactive nucleus of mass 210 units disintegrates into an α-particle of mass 4 units and residual nucleus of mass 206 units. If the kinetic energy of the α-particle is E, then the kinetic energy of the residual nucleus is

(a) $\left(\dfrac{2}{105}\right)E$

(b) $\left(\dfrac{2}{103}\right)E$

(c) $\left(\dfrac{103}{105}\right)E$

(d) $\left(\dfrac{103}{2}\right)E$

8 The Sun radiates energy in all directions. The average radiation received on the earth surface from the Sun 1.4 kW/m^2. The average Earth-Sun distance 1.5×10^{11} m. The mass lost by the Sun per day is (1 day = 86400 s)

(a) 4.4×10^9 kg

(b) 7.6×10^{14} kg

(c) 3.8×10^{12} kg

(d) 3.8×10^{14} kg

Answers

1. (a) 2. (d) 3. (b) 4. (b) 5. (a) 6. (b) 7. (b) 8. (d)

* These questions may or may not be asked in the examination, have been given just for additional practice required for olympiads Scholarship Exams etc. For detailed explanations refer Page No. 247.

Explanations of Challengers

Chapter 1. Force

1. (a) Mass of the particle = m

As, the particle is executing a uniform circular motion, it will be accelerated with $\frac{v^2}{r}$ directed towards the centre as it is moving with a circle of radius r and moving with uniform speed v.

According to Newton's second law of motion,

centripetal force, $F_c = \frac{mv^2}{r}$.

Rearranging, it can be written as, $F_c = \frac{mv^2}{r} \cdot \frac{m}{m}$

$$= \frac{(mv)^2}{mr} = \frac{p^2}{mr}$$

Hence, option (a) is correct.

2. (d) When a car of mass M passes through a convex bridge of radius r with velocity v, it exerts a force on it, in following ways

(i) The weight mg of the car acting vertically downwards.

(ii) Normal reaction R of the road on the car, acting vertically downwards. As the radius of the bridge is r, hence the centripetal force is along the surface of the road, towards the centre of turn.

Hence, the magnitude of force $= Mg - \frac{Mv^2}{r}$.

3. (b) As the vehicle is moving in forward direction, but wheels are revolving *i.e.*, executing circular motion.

Hence, option (b), a vehicle and its wheels execute translatory and rotatory motion.

4. (c) A nut cracker is an example of second class of lever, where fulcrum is one side and load (nut) is between fulcrum and effort.

According to the question,

moment of force $= F \times d$

$$= 120 \times \frac{50}{100} = 60 \text{ N-m}$$

As the same moment of force acts on the nutcracker by applying a force of 40N, then applying formula

moment of force $= F \times d$

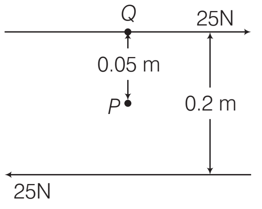
$$60 = 40 \times d$$

$$\Rightarrow \quad d = \frac{60}{40} = \frac{3}{2} = 1.5 \text{ m}$$

5. (d) Torque required to open the door will remain constant.

$$r_1 \times F_1 = r_2 \times F_2$$
$$3 \times 100 = 6 \times F_2$$
$$F_2 = \frac{3 \times 100}{6} = 50 \text{ N}$$

6. (c) From the given figure,



(i) **At point P** Two torques τ_1 and τ_2 acting from distances 0.05 m and $(0.2 - 0.05 = 0.15)$ 0.15 m.

Hence, torque, τ_1 = force $\times$ distance

$= 25 \times 0.05$

= 1.25 N clockwise

and torque, $\tau_2 = 25 \times (0.2 - 0.05)$

$= 25 \times 0.15$

= 3.75 N clockwise

Hence, (net) total torque $= \tau_1 + \tau_2$

$= 1.25 + 3.75$

= 5 N-m, clockwise

(ii) **Now, at point Q** Two torques τ_1 and τ_2 will be

$$\tau_1 = F_1 \times 0 = 0$$

$$\tau_2 = 25 \times 0.2 = 25 \times \frac{2}{10} = 5 \text{ N, clockwise}$$

Hence, net torque $= \tau_1 + \tau_2 = 0 + 5 = 5$ N-m, clockwise

7. (b) Force in linear motion has its analogue with torque in rotational motion, because moment of force = force $\times$ the perpendicular distance of the line of action of the force moving towards the point.

8. (a) According to the definition of centripetal force,

$$F_C = \frac{mv^2}{r}$$

Hence, $F_1 = \frac{m_1 v_1^2}{r_1^2}$ for mass m_1 ...(i)

and $F_2 = \frac{m_2 v_2^2}{r_2^2}$ for mass m_2 ...(ii)

Hence, the ratio of their centripetal force is obtained dividing Eqs. (i) and (ii). Hence,

$$\frac{F_1}{F_2} = \frac{\frac{m_1 v_1^2}{r_1}}{\frac{m_2 v_2^2}{r_2}}$$

But as the masses of both the particles are same *i.e.*, $m_1 = m_2 = m$ and speeds are same *i.e.*, $v_1 = v_2 = v$

Then, $$\frac{F_1}{F_2} = \frac{mv^2}{r_1} \times \frac{r_2}{mv^2} = \frac{r_2}{r_1}$$

9. (b) Essential characteristics of equilibrium is the total force *i.e.*, the vector sum of all forces acting on the rigid body is r.

i.e., $$\sum_{i=1}^{n} F_i = 0 = F_1 + F_2 + \ldots + F_n$$

As, mass cannot be 0, hence acceleration equals to zero.

10. (b) Length of seconds hand of a clock = 10 cm.

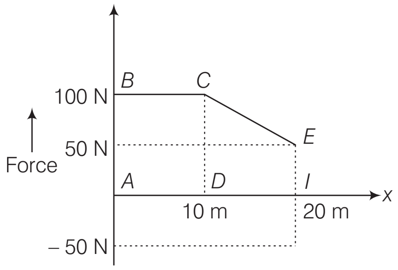
$\therefore$ Angular speed, $\omega = \frac{\theta}{t}$

But $\theta = 2\pi$, $t = 60$ s

$\therefore$ $$\omega = \frac{2\pi}{60} = \frac{\pi}{30} \text{ rads}^{-1}$$

Chapter 2. Work, Power and Energy

1. (c) The graph given below gives the force- distance variation.



Its given frictional force = 50 N

As it opposes motions, acts in opposite direction.

Work done by the woman $= W_F$ = Area of rectangle *ABCD* + Area of trapezium *CEID*

$$= 100 \times 10 + \frac{1}{2} \times (100 + 50) \times 10$$

$$= 1000 + 750 = 1750 \text{ N}$$

Work done by the frictional force is -1000 N.

Hence, net work done $= 1750 - 1000$

$$= 750 \text{ J}$$

Hence, option (c) is correct.

2. (c) Given, $m = 0.5$ kg, $v = ax^{\frac{3}{2}}$

where, $a = 5\text{ms}^{-2}$

As we know, from work-energy theorem, work done by net force acting on a body is equal to its change in KE. If velocity of the body corresponds to $x = 0$ and $x = 2$ m and represented as u and v, then

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = \frac{1}{2}m(v^2 - u^2)$$

$$u = a \cdot (0)^{3/2} = 0 \qquad (\because v = u + at)$$

$$= a \cdot (2)^{3/2} = a\,2^{3/2}$$

$$W = \frac{1}{2} \times 0.5 [\{a(2)^{3/2}\}^2 - 0]$$

$$= \frac{1}{2} \times 0.5 \times a^2 \times (2)^3$$

$$= \frac{1}{2} \times 0.5 \times (5)^2 \times 8 = 50 \text{ J}$$

3. (b) For P, $m = 20$ kg, $v = 5$ m/s

For Q, $m = 5$ kg, $v = 20$ m/s

$\therefore$ $$\frac{\text{Momentum of } P}{\text{Momentum of } Q} = \frac{20 \times 5}{5 \times 20} = \frac{1}{1}$$

4. (c) Given, mass of boy = 40 kg

Vertical distance, $h = 12$ m

Time interval = 40 s

Hence, power $= \frac{\text{work done}}{\text{time}}$

$$= \frac{mgh}{t} = \frac{40 \times 10 \times 12}{40} = 120 \text{ W}$$

5. (c) Given, kinetic energy of electron = 10 keV

Kinetic energy of proton = 100 keV

Mass of electron, $m_e = 9.11 \times 10^{-31}$ kg

Mass of proton, $m_p = 1.67 \times 10^{-27}$ kg

As, $K = \frac{1}{2}mv^2$ or $v = \sqrt{\frac{2K}{m}}$

Hence, $$\frac{v_e}{v_p} = \sqrt{\frac{K_e}{K_p} \times \frac{m_p}{m_e}}$$

$$= \sqrt{\frac{10 \times 1.67 \times 10^{-27}}{100 \times 9.11 \times 10^{-31}}}$$

$$= \sqrt{\frac{167}{911} \times 10^3} = 13.54$$

$\Rightarrow$ $v_e = 13.54\, v_p$

Hence, electron is travelling faster.

6. (a) From work-energy theorem or work-energy principle, total work done by the net force acting on a body is equal to change produced in KE of the body for constant force.

7. (c) As the body is moving along a straight line, delivering constant power, distance moved by the body,

$$s = ut + \frac{1}{2}at^2 \Rightarrow s = \frac{1}{2}at^2 \qquad [\because u = 0]$$

$$\Rightarrow \qquad s^2 = \frac{1}{4}a^2t^4 \qquad \ldots(i)$$

But we know, power $= \dfrac{\text{work}}{\text{time}}$

$$= \frac{F \times s}{t} = F \times v \qquad \left(\because v = \frac{s}{t}\right)$$

$$P = F \times v \quad [\because v = u + at \text{ for } u = 0, v = at]$$

$$= ma \times at \Rightarrow P = ma^2t$$

$$\Rightarrow \qquad a^2t = \frac{P}{m} \qquad \ldots(ii)$$

Substituting $a^2t = \dfrac{P}{m}$ in Eq. (i), we get

$$s^2 = \frac{1}{2}a^2t \cdot t^3$$

Now, $\quad a^2t = \dfrac{P}{m}$, substituting above equation,

$$s^2 = \left(\frac{1}{2} \cdot \frac{P}{m}\right)t^3 \Rightarrow s = \text{constant } t^{3/2}$$

Hence, $\quad s \propto t^{3/2}$

8. (d) Given, power of the pump = 200 W

Mass of water = 2 kg

Depth, $\quad h = 10$ m

$\therefore$ Power = Force × Velocity

$$\text{Velocity} = \frac{\text{Power}}{\text{Force}} = \frac{200}{mg} = \frac{200}{2 \times 9.8}$$

$$= \frac{1000}{98} \text{ m/s} = 10.2 \text{ m/s}$$

9. (a) As the force is inversely proportional to speed in this question, KE $= \dfrac{1}{2}mv^2$

As $F = ma = \dfrac{m(v-u)}{t}$, as F increases v decreases,

as $\quad v = \dfrac{s}{t}$, hence KE in linearly related with time.

10. (c) Power = Force × Velocity

Velocity has to be increased by twice mass of water flowing from same pipe, hence

$$\frac{\text{mass}}{\text{time}} = \frac{\text{volume} \times \text{density}}{\text{time}} = \frac{v \times d}{t}$$

$$= \frac{\text{area} \times \text{length} \times \text{density}}{\text{time}}$$

$$= a \times \rho \times \text{velocity}$$

Rate of increase of KE $= \dfrac{mv^2}{2 \times \text{time}}$

$$= \frac{A \times \rho \times \text{velocity} \times v^2}{2} = \frac{A \times \rho \times v^2}{2}$$

Mass m flowing out per second can be increased to m_1, by increases v to v_1, then power increases for P to P_1.

$$\therefore \qquad \frac{P_1}{P} = \frac{A \times \rho \times v_1^3}{A \times \rho \times v^3} = \frac{v_1^3}{v^3}$$

But given, $m_1 = 2\,m$, $v_1 = 2v$, then

$$\frac{P_1}{P} = 2^3 = 8$$

$$P_1 = 8P$$

Chapter 3. Machines

1. (b) The mechanical advantage of a fixed pulley

$$= \frac{\text{Load } (L)}{\text{Effort } (E)}$$

Effort (force applied), $E = 70$ N

Weight of the bucket $= mg$

$= 6 \times 9.8 = 60$ N

Hence, mechanical advantage $= \dfrac{60}{70}$

Hence, mechanical advantage = 0.86

2. (c) Mechanical advantage (MA) given as,

$$\text{MA} = \frac{\text{Load } (L)}{\text{Effort } (E)}$$

Hence, MA and efforts are inversely proportional to each other.

The MA of single fixed pulley = 1

For single movable pulley, MA = 2

Load on both the pulleys = 50 kgf

$\therefore$ Effort for single fixed pulley

$$= \frac{\text{Load}}{\text{MA}} = \frac{50}{1} = 50 \text{ kgf} \qquad \ldots(i)$$

Effort for single movable pulley $= \dfrac{\text{Load}}{\text{MA}} = \dfrac{50}{2}$

$$= 2.5 \text{ kgf} \qquad \ldots(ii)$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{\text{Effort single fixed pulley}}{\text{Effort single movable pulley}} = \frac{50}{25} = \frac{2}{1}$$

Hence, $\quad \dfrac{\text{effort single movable pulley}}{\text{effort single fixed pulley}} = \dfrac{1}{2}$

3. (b) As, velocity ratio $= \dfrac{\text{distance travelled by effort}}{\text{distance travelled by load}}$

Efficiency $= \dfrac{\text{MA}}{\text{VR}} = \dfrac{\text{Mechanical advantage}}{\text{Velocity ratio}}$

Given, VR $= 5$, efficiency $= 75\%$

$$\Rightarrow \frac{75}{100} = \frac{\text{MA}}{5}$$

$$\text{MA} = 5 \times \frac{75}{100}$$

But, $\text{MA} = \dfrac{\text{load}}{\text{effort}} = \dfrac{L}{150\text{ kgf}}$

$$L = 5 \times \frac{75}{100} \times 150 = \frac{1125}{2} = 562.5$$

4. (d) Given, VR $= 5$, efficiency $= 80\%$

$$\therefore \frac{\text{MA}}{\text{VR}} = \text{Efficiency}$$

$$80 = \frac{\text{MA}}{5} \Rightarrow \text{MA} = \frac{80}{100} \times 5 = 4$$

5. (d) Given, MA $= 4$, load $= 10$ kgf $= 10 \times 9.8$ N

Distance $= 2$ m, time $= 10$ s

$\therefore$ Power $= \dfrac{\text{Work done}}{\text{Time taken}}$

$$\text{MA} = 4 = \frac{\text{Load}}{\text{Effort}} = \frac{10 \times 9.8}{E}$$

$$\text{Effort} = \frac{10 \times 9.8}{4}$$

Now, power $= \dfrac{\text{Work}}{\text{Time}} = \dfrac{F \times s}{t}$

$$= \frac{10 \times 9.8}{4} \times \frac{2}{10} = \frac{49}{10} = 4.9\text{ W}$$

6. (c) As, clockwise moment $=$ anti-clockwise moment

Load $\times$ Load arm $=$ Effort $\times$ Effort arm

Let load arm $= x$

As given, effort $= 100$ N, effort arm $= 3x$

Hence, $3x \times 100 = x \times \text{load}$

$$\therefore \text{Load} = \frac{3x \times 100}{x} = 300\text{ N}$$

7. (a) $\therefore$ MA $= \dfrac{\text{Load}}{\text{Effort}}$

In case of sugar tongs, its a 3rd class lever, effort lies between fulcrum arm and load, hence MA < 1, effort is greater than load

and $\text{VR} = \dfrac{dE}{dL}$, $d_E < d_L$

Hence, MA < 1

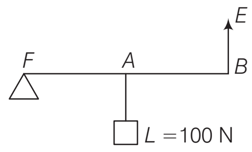
8. (a) As we know, power $= \dfrac{\text{work done}}{\text{time taken}} = \dfrac{F \times s}{t}$

Given, $m = 100$ kg, $g = 10$ m/s^2, $t = 4$ s, $h = 8$ m

Hence, power $= \dfrac{mgh}{t}$

$$= \frac{100 \times 10 \times 8}{4} = 2000\text{ W}$$

9. (d) Given, load $L = 100$ N, $FA = 40$ cm (load arm), $AB = 60$ cm



Hence, $FB = FA + AB$

$= 40 + 60$

$= 100$ cm (effort arm)

As we know, load $\times$ load arm

$=$ effort $\times$ effort arm

$$100 \times 40 = E \times 100$$

$$\Rightarrow E = 40\text{ N}$$

Hence, mechanical advantage $= \dfrac{\text{load}}{\text{effort}} = \dfrac{100}{40} = 2.5$

10. (c) Given, efficiency $= 80\%$

Load $= 200$ kgf $= 200 \times 10$ N

Mechanical advantage $= 5$

$$\therefore \text{MA} = \frac{\text{Load}}{\text{Effort}}$$

$$5 = \frac{200 \times 10}{E}$$

$$\Rightarrow E = \frac{200 \times 10}{5}$$

$$= 400\text{ N} = 40\text{ kgf}$$

Chapter 4. Refraction of Light

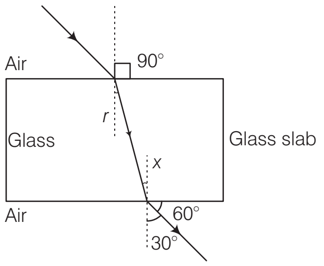
1. (b) As we know, whenever incident light falls on the interface of glass slab for different values of i,

the ratio $\dfrac{\sin i}{\sin r} =$ constant $=$ refractive index. Thus, refractive index measures the light bending capacity or is measures ability of bending of light when it travels from one transparent medium to another medium.

If the light enters obliquely and angle of incidence is more, then angle of refraction will also increase, Hence, bending is directly proportional to the angle of incidence.

2. (a) Using the principle of reversibility of light and considering the air-glass interface,

$$\angle i = \angle e = 90° - 60° = 30°$$



As, $\angle r = \angle x \Rightarrow \mu = \dfrac{\sin r}{\sin x} \Rightarrow 1.5 = \dfrac{\sin r}{\sin x}$

$\Rightarrow \sin x = \dfrac{\sin r}{1.5} = \dfrac{\sin 30°}{1.5} = \dfrac{1/2}{1.5} = 0.333$

$\Rightarrow x = \sin^{-1}(0.333) \quad \therefore \quad x = 19.5°$

3. (c) As glass is an optically denser medium, it bends the light rays towards the normal. After refraction, when light emerge out of the denser medium like glass to the rarer medium like air, it bends away from the normal which is not shown in figure (c). Hence, it is not following rules of refraction.

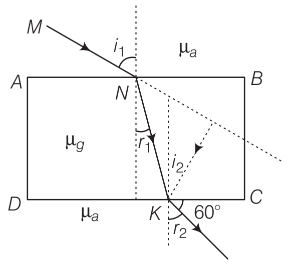
4. (d) As the ray of light is entering a semi-circular glass block normal to curved surface, part of the light will be reflected following laws of reflections *i.e.*, $\angle i = \angle r$.

Part of the light will be refracted following laws of refraction at the glass-air interface.

5. (b) As medium *B* has least refractive index *i.e.*, 1.33, hence light travels fastest in medium *B* because least refractive index indicates that *B* is much optically rarer than all other medium, hence light travels fastest in medium *B*.

6. (a) According to the definition of refractive index, $\mu = \dfrac{\sin i}{\sin r}$. As we know, when $\angle i$ increases, $\angle r$ also increases to keep the value of μ constant. Hence, it will show a linear increase, so graph (b), (c) are showing decrease, hence cannot be the possibilities. Graph (d) is not justified as value of $\sin i$ can be between 0 and 1.

7. (a) In case of refraction of light through glass slab, $\angle i = \angle e$



Applying Snell's law at *N*,

$$\mu_a \times \sin i_1 = \mu_g \times \sin r_1$$

$$\frac{\sin i_1}{\sin r_1} = \frac{\mu_g}{\mu_a} = {}^a\mu_g \quad \text{...(i)}$$

Again, applying Snell's law at *K*,

$$\mu_g \sin i_2 = \mu_a \sin r_2$$

$$\frac{\mu_g}{\mu_a} = \frac{\sin r_2}{\sin i_2} \quad \text{...(ii)}$$

$$\Rightarrow \frac{\mu_a}{\mu_g} = \frac{\sin i_2}{\sin r_2} = {}^g\mu_a \quad \text{...(iii)}$$

Now, Eq. (ii) and (iii), we get

$$\frac{\sin i_2}{\sin r_2} \times \frac{\sin r_2}{\sin i_2} = {}^a\mu_g \times {}^g\mu_a$$

$$1 = {}^a\mu_g \times {}^g\mu_a$$

$${}^a\mu_g = \frac{1}{{}^g\mu_a}$$

From Eqs. (i) and (iii), we have

$$\frac{\sin i_1}{\sin r_1} = \frac{\sin r_2}{\sin i_2}$$

As, $\angle i_2 = \angle r_1$ (alternate angle)

$\therefore \sin i_2 = \sin r_1$

From Eq. (iv), we get

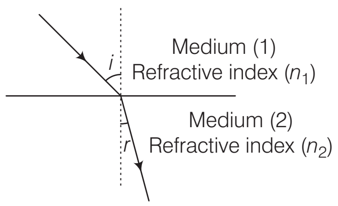
$$\sin i_1 = \sin r_2$$

$$\Rightarrow i_1 = r_2$$

Hence, angle of incidence = angle of emergence.

Reason given for the statement in assertion is correct.

8. (c) According to Snell's law,



$$n_1 \times \sin i = n_2 \times \sin r$$

$$\therefore \frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

Chapter 5. Lenses

1. (a) For rays coming from infinity to a lens having different refractive indices μ_1 and μ_2 will form two images at two different foci.

2. (d) Given, $P_1 = -3.5$ D, $P_2 = +1.0$ D

As, both the lenses are in contact, combination of lenses will have power $= P_1 + P_2 = -3.5 + 1.0 = -2.5$ D.

Hence, focal length, $f = \dfrac{1}{P_{\text{comb}}} = +\dfrac{1}{2.5}$ D

$$= +\frac{1000}{25} = +40 \text{ cm}$$

3. (a) Using the lens formula,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{u}{v} - 1 = \frac{u}{f} \quad \ldots\text{(i)}$$

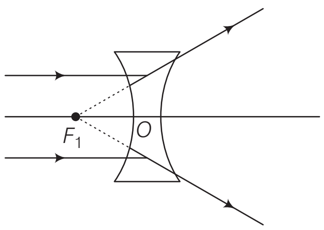
As, $m = \dfrac{v}{u} = n$ (given)

$\Rightarrow \quad \dfrac{u}{v} = \dfrac{1}{n}$

Substituting the above values in Eq. (i), we get

$$\Rightarrow \left(\frac{1}{n} - 1\right) = \frac{u}{f} \Rightarrow u = \left(\frac{1-n}{n}\right) f$$

4. (d) When an object is at infinity, the nature of image formed by concave lens is virtual, erect and highly diminished.



5. (d) Given, f_1 of convex lens = 40 cm

f_2 of first concave lens = – 40 cm

f_3 of second concave lens = –15 cm

Hence, total focal lengths of the combination

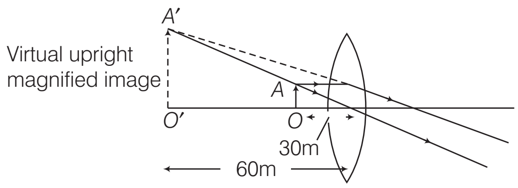
$$= f_1 - f_2 - f_3$$
$$= 40 - 40 - 15$$
$$= -15 \text{ cm}$$

As, $P = \dfrac{1}{f}$

$$= -\frac{1}{15} = -\frac{100}{15}$$
$$= -6.67 \text{ D}$$

6. (c) According to the given diagram, focal length of the lens = 6 cm.

As, the object is between optic centre and focus, the image formed will be virtual, erect (upright) and magnified.



7. (c) Given, $u = -45$ cm

Applying lens formula, $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{90} - \frac{1}{(-45)} = \frac{1}{f}$$

$$\frac{1}{90} + \frac{1}{45} = \frac{1}{f} \Rightarrow \frac{1+2}{90} = \frac{1}{f}$$

$\therefore \quad f = \dfrac{90}{3} = 30$ cm

$\therefore \quad$ Power, $P = \dfrac{1}{f} = \dfrac{100}{30}$ D $= 3.33$ D

8. (a) All the distances are measured from the optic centre of the lens according to the sign convention of lens.

9. (b) If two convex lenses are in contact with each other, the equivalent focal length (f) and power of the combination (P) can be calculated as

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \text{ and } P = P_1 + P_2$$

It increases the sharpness of image and converging power.

10. (d) As $\mu_2 > \mu_1$, hence in the interface of material of refractive index μ_1 and convex lens *i.e.*, from denser to rarer medium parallel ray will bend away from normal and for $\mu_1 > \mu_3$ *i.e.*, interface of material of refractive index μ_1 and μ_3, ray will become convergent, towards the normal, hence a convergent and a divergent beam is produced.

Chapter 6. Spectrum of Light

1. (b) Yes, but may see a rainbow as concentric circles. Sometimes many people confuse this phenomena of rainbow with glory which is caused by interference effects between particles in a cloud, not reflection and refraction in raindrops from a storm.

2. (c) Though violet has the smallest wavelength, but colour of sky is blue because our eyes are more sensitive to blue colour less sensitive to violet colour and most of the violet rays are absorbed by the atmosphere.

3. (d) According to the Snell's law,

Refractive index, $\mu = \dfrac{\text{Speed of light in air}}{\text{Speed of light in medium}}$

$$1.5 = \frac{3 \times 10^8}{v} \Rightarrow v = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ m/s}$$

4. (a) As, $\lambda_{\text{red}} > \lambda_{\text{blue}}$

and $v = \nu\lambda$ (ν is same for red and blue)

Then, $v_{\text{red}} > v_{\text{blue}}$, so red light is slowed down less and refracted less.

5. (c) When white light comprising of seven colours refract through glass prism, violet refracts or bends maximum and form a band of seven colours known as spectrum in which red bends the least, has maximum velocity.

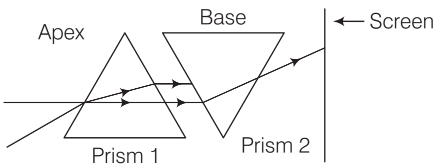
6. (d) All the statements given are correct because sky appears blue due to scattering of light due to atmosphere. Smoke and dust particles in the atmosphere cause greyish appearance of sky.

Red has the maximum wavelength in the visible spectrum, hence velocity of red is more than other primary colour, according to Rayleigh's scattering, amount of scattering $\propto \frac{1}{\lambda^4}$, hence red scatters the least.

7. (b) As the swimmer is inside the water doing backstroke swimming, so the object is in denser medium. Water is a denser medium, so when light travels from water to air *i.e.*, denser to rarer, it will bend away from the normal, as a result of which aeroplane will appear to be higher than its actual position.

8. (b) One of the condition for formation of rainbow is to looking at the sky through water with sun (source) behind observer, total internal reflection can take place in rainbow formation.

9. (b) To get white light from recombination of prism, both the prism should be placed apex to base.



Statement I is incorrect (false).

Statement II is correct as dispersive power,

$$\omega = \frac{\mu_V - \mu_R}{(\mu - 1)}$$

It depends on (a) angle of prism, (b) nature of material used.

Hence, water's refractive index is more than air, so dispersive power decreases.

Statement III Tyndall effect is scattering, of light when it passes through colloidal solution, where size of the particles is relatively larger.

Sunlight comes down through the clouds, showing Tyndall effect because earth's atmosphere is a heterogeneous, mixture of minute particles of smoke.

Statement IV is also correct as yellow light scatters comparatively less and has comparatively low wavelength, visibility also more. Tiny water droplets, suspended particles of dust and molecules of air which becomes visible during scattering.

Chapter 7. Sound

1. (d) An explosion in outer space because sound needs a medium to travel. As in outer space, there is no atmosphere, sound of explosion will not be heard.

2. (a) As the frequency of source 20 kHz, frequency of sound produced by it in water and air will be constant 20 kHz, its the number of waves product.

3. (b) Sound is louder at night due to change in direction of sound due to refraction. During night, sound bends towards the ground, whereas in day bends away from ground. Hence, at night ground starts releasing heat, hot air rises, the air closer to the ground is cooler. Hence, change of direction is caused by the reversal of temperature gradient from day to night.

4. (d) The sound level in dB is

$$\beta = 10 \log_{10}\left(\frac{I}{I_0}\right)$$

If β_1 and β_2 are the sound levels; and I_1 and I_2 are the intensities in the two cases,

$$\beta_2 - \beta_1 = 10\left[\log_{10}\left(\frac{I_2}{I_0}\right) - \log_{10}\left(\frac{I_1}{I_0}\right)\right]$$

or $$30 = 10 \log_{10}\left(\frac{I_2}{I_1}\right) \quad \text{or} \quad \frac{I_2}{I_1} = 10^3$$

As, the intensity is proportional to the square of the pressure amplitude, we have

$$\frac{p_2}{p_1} = \sqrt{\frac{I_2}{I_1}} = \sqrt{1000} \approx 32$$

Relation between intensity and pressure amplitude of sound waves $I \propto p_0^2$

where, p_0 = pressure amplitude.

5. (d) Statements I, III, IV are incorrect about note with high pitch. Pitch is the characteristics of sound by which we can distinguish between different sounds of the same loudness. High pitch sound corresponds to more number of compressions and rarefactions *i.e.*, higher the pitch, higher is the frequency. As $v = \nu\lambda$, hence higher is the frequency lower will be the wavelength.

6. (d) Percussion instruments produce sound when its membrane is struck, sound will be louder when struck with greater force. When vibrating surface is touched, then the sound will stop.

7. (c) The reflected wave would have a lower amplitude (since wall absorbs some of the sound energy), same frequency wavelength and speed but different velocities, since the direction of the wave has changed.

8. (c) Initially, sound wave has wavelength $= \lambda$.

Now, speed $\Rightarrow v = \nu\lambda$ ...(i)

where, ν is the frequency of sound wave.

Now, in another medium, let the speed $= 2v$

Then, $v_1 = 2v = \nu\lambda_1$ ...(ii)

On dividing Eq. (ii) by Eq. (i), we get

$$\frac{v_1}{v} = \frac{2v}{v} = \frac{\nu\lambda_1}{\nu\lambda}$$

$$\lambda_1 = 2\lambda$$

9. (b) The source of sound creates a disturbance in the medium which travels through the medium. The particles of the medium do not move forward but the disturbance is carried forward. Hence, **statement I** is false.

Progressive wave or travelling wave moves away from the source *i.e.*, it moves relative to a coordinate system in a fluid, represented by wave equation,

$$\frac{d^2u}{dt^2} = c^2\frac{d^2u}{dx^2}$$

where, $u =$ particle displacement at a distance x from fixed point along the direction of propagation, $c =$ wave velocity, $t =$ time.

Statement II is true.

In compression, density of particles is more in a longitudinal wave. Hence, statement III is true. During tsunami, shock waves propagate.

Statement IV is false.

In water waves ripples are created by the oscillatory movement of particles.

10. (b) As, $I = \dfrac{p^2}{2\rho v}$

where, $p =$ pressure amplitude, $I =$ intensity, $\rho =$ density and $v =$ velocity.

i.e., $I \propto p^2$

$$\Rightarrow \frac{I_1}{I_2} = \frac{p_1^2}{p_2^2}$$

$$\Rightarrow I_2 = \frac{p_2^2}{p_1^2} \cdot I_1$$

$$= \frac{2.5\times10^{-2}\times2.5\times10^{-2}\times5\times10^{-7}}{2\times10^{-2}\times2\times10^{-2}\times100}$$

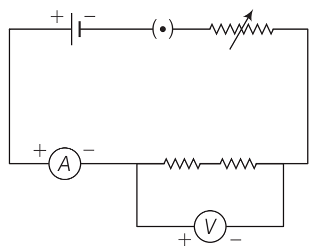
$$= \frac{25\times25}{80}\times10^{-7}$$

$$= \frac{625}{80}\times10^{-7}$$

$$= 7.8\times10^{-7}\ \text{W/m}^2$$

Chapter 8. Electricity

1. (c) According to the diagram, student has connected the apparatus, but terminals of the ammeter is wrongly connected because ammeter is in series. Hence, positive terminal of ammeters should be connected with positive terminal of cell. Diagram is given below,



2. (b) For the given circuit diagram, the components R_1, R_2 and V are connected in parallel combination.

Because terminals of the resistance and voltmeter are connected together.

3. (c) If two unequal resistances are connected in parallel by a student, then voltage drop is same across both because in parallel combination,

$$\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\Rightarrow \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Potential difference across each resistor is same.

4. (c) Only statement I because resistances are connected in series not in parallel.

5. (d) Reading of ammeter in terms of amperes,

$$I = 180\ \text{mA} = 0.18\ \text{A}$$

Reading of voltmeter, $V = 1.8$ V

$\therefore$ Resistance of the resistor, $R = \dfrac{V}{I}$

$$= \frac{1.8}{0.18} = \frac{180}{18} = 10\,\Omega$$

Chapter 9. Electromagnetism

1. (a) A straight wire lying in a horizontal plane carries a current from North to South. Magnetic field at a point directly below the wire is towards East according to Ampere's swimming rule or SNOW rule. If current flows from south to North, magnetic field will be towards West but if current flows from North to South, magnetic field will be towards East.

2. (a) On reversing the direction of current in a wire, the magnetic field produced by it get reversed in direction because magnetic field $= \frac{\mu_0}{4\pi} \frac{I\, dl \sin\theta}{r^2}$.

The direction of magnetic field is perpendicular to both Idl and r.

where, I is the current flowing through a conductor of length dl, μ_0 = permeability in free space =`$4\pi \times 10^{-7}$ Tm/A.

3. (d) As the loop of the wire is held near the magnet but the loop and the magnets are not moving, hence no emf will be induced.

4. (c) The spring is being pulled downwards by the magnet, hence elastic spring force is acting upwards. The magnetic force is acting upwards to attract the ball to the magnet. But gravitational force is pulling the ball downwards. Since, the ball is kept floating, the sum of elastic spring force and magnetic force must be equal to gravitational force.

5. (d) AC current in Figs. (c) and (d) are applied AC current is applied to demagnetise a magnet and DC current is applied to magnetise a magnetic material.

If magnet is withdrawn before switching off the DC power supply, then dipoles will remain aligned and magnetisation will be retained by the magnet.

6. (d) As the beam of electrons are entering a magnetic field, horizontally and perpendicular to magnetic field, according to right hand thumb rule, electrons are deflected towards the top of the diagram.

7. (b) P, Q must not retain induced magnetism and they must be of soft iron. R must return the striker back to its original position when P and Q lose their magnetism.

8. (a) Since, the speed is doubled, the amplitude of AC voltage is doubled and the period of the voltage is halved.

Chapter 10. Heat

1. (c) As the heat capacities are equal, so

$$m_1 c_1 = m_2 c_2 \quad \ldots\text{(i)}$$

where, m_1, m_2 are the masses of two bodies, c_1, c_2 are their specific heats.

Let c be the specific heat of the composite body.

Then, $(m_1 + m_2)c = m_1 c_1 + m_2 c_2$

$\Rightarrow$ $(m_1 + m_2)c = 2\, m_1 c_1$ [from Eq. (i)]

$$\Rightarrow \quad c = \frac{2\, m_1 c_1}{m_1 + m_2} = \frac{2\, m_1 c_1}{m_1 + m_1 \frac{c_1}{c_2}} = \frac{2 c_1 c_2}{c_1 + c_2}$$

2. (c) Heat required by 1g ice at 0°C to mix with 1 g water at 0°C,

$$Q_1 = mL = 1 \times 80 = 80 \text{ cal}$$

(latent heat of fusion of ice, $L = 80$ cal/g)

Heat required by 1 g of water of 0°C to boil at 100°C,

$$Q_2 = mc\,\Delta T = 1 \times 1 \times (100 - 0)$$

(specific heat of water, $c = 1$ cal/g°C)

$$= 100 \text{ cal}$$

Thus, total heat required by 1 g of ice to reach a temperature of 100°C,

$$Q = Q_1 + Q_2 = 80 + 100 = 180 \text{ cal}$$

Heat available with 1 g of steam to condense into 1 g of water at 100°C,

$$Q' = mL' = 1 \times 536$$

(latent heat of vaporisation, $L' = 536$ cal/g)

$$= 536 \text{ cal}$$

Obviously, the whole steam will not be condensed and ice will attain temperature of 100°C. Out of 536 cal, 80 cal used in fusion of ice, while remaining 456 cal will raise the temperature of mixture upto 100°C.

3. (b) As latent heat of vaporisation of water at 0°C,

$$L_1 = 2.10 \times 10^6 \text{ J/kg} = 2.10 \times 10^3 \text{ J/g}$$

Latent heat of fusion of ice

$$= 3.36 \times 10^5 \text{ J/kg} = 3.36 \times 10^2 \text{ J/g}$$

Let mass of ice formed $= mg$

Then, mass of water evaporated $= (100 - m)g$

As, no water is left in the vessel.

Heat gained by water in evaporation = Heat lost by water in freezing

$$(100 - m)L_1 = m L_2$$

$$(100 - m) \times 2.10 \times 10^3 = m \times 3.36 \times 10^2$$

$$\Rightarrow \quad m = 86.2 \text{ g}$$

If we write in terms of %, it will be 86.2%.

4. (a) Given, A, B = calorimeters are identical in size.

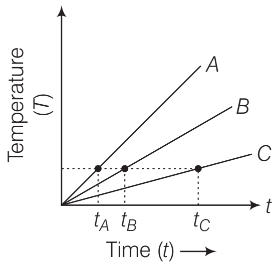
Quality of water is same in both the calorimeters $= x$
Temperature of water $= 20°C$
For metal X, mass $= 5$ g
Specific heat, $c_1 = 0.2$
Initial temperature $= 40°C$
Final temperature $= 22°$ C
For metal Y, mass $= 5$ g
Specific heat, $c_2 = c$
Initial temperature $= 40°$ C
Final temperature $= 23°$ C
Now, for metal X,
heat lost by X = heat gained by water

$$\Rightarrow \quad 5 \times 0.2 \times (40 - 22) = x \times 1 \times (22 - 20)$$
$$\Rightarrow \quad 5 \times 0.2 \times 18 = x \times 2$$
$$\Rightarrow \quad x = \frac{5 \times 0.2 \times 18}{2} = \frac{5 \times 2 \times 18}{2 \times 10} = 9 \text{ g}$$

As, calorimeter B also contain equal of water *i.e.*, 9 g.
Heat lost by metal Y = Heat gained by water

$$5 \times Y \times (40 - 23) = 9 \times 1 \times (23 - 20)$$
$$5 \times Y \times 17 = 9 \times 3$$
$$\Rightarrow \quad Y = \frac{9 \times 3}{5 \times 17} = \frac{27}{85} \text{ cal/g°C}$$

5. (d) Substances having more heat capacity take longer time to get heated to a higher temperature and longer time to get cooled.



If we draw a line parallel to time axis, then it cuts the given graphs at three different points corresponding points on the time axis, show that $t_C > t_B > t_A$

$$\Rightarrow \quad C_C > C_B > C_A$$

So, option (d) is correct.

6. (a) Given, mass of child,

$$M = 30 \text{ kg} = 30 \times 10^3 \text{ g}$$

Fall in temperature from fever,

$$\Delta\theta = 101° - 98° = 3° \text{F}$$
$$= 3 \times \frac{5}{9} = \frac{5}{3} \text{ °C}$$

Specific heat of human
$= $ Specific heat of water $= 1 \text{ cal g}^{-1} \text{ °C}^{-1}$
Heat lost by child in the form of evaporation (sweat),

$$Q = mc\,\Delta\theta$$
$$= 30 \times 10^3 \times 1 \times \frac{5}{3} = 50000 \text{ cal}$$

If m'g of sweat evaporates from the body of the child, heat gained by sweat $= m'L = m' \times 580$
(given, $L_{vap} = 580$ cal/g)
$\therefore$ Heat gained by sweat = Heat lost by child

$$m' \times 580 = 50000$$
$$m' = \frac{50000}{580} = 86.2 \text{ g}$$

Time taken by sweat to evaporate = 20 min

$\therefore$ Rate of evaporation of sweat $= \frac{86.2}{20} = 4.32 \text{ g min}^{-1}$

7. (b) Let steam required per hour $= m$ kg

Heat released by steam in following three steps

(i) When steam at $150°C \xrightarrow[Q_1]{}$ Steam at $100°C$

$$Q_1 = mc_s\,\Delta t = m \times 1(150 - 100) = 50 \text{ m cal}$$

(ii) When steam at $100°$ C $\xrightarrow[Q_2]{}$ Water at $100°C$

$$Q_2 = m\,L_v = m \times 540 = 540 \text{ m cal}$$

(iii) When water at $100°C \longrightarrow$ Water at $90°C$

$$Q_3 = m\,c_w\,\Delta t = m \times 1 \times (100 - 90) = 10 \text{ m cal}$$

Hence, total heat lost by the steam,

$$Q = Q_1 + Q_2 + Q_3 = 600 \text{ m cal}$$

Heat absorbed by 10 kg water,

$$Q' = mc_w\,\Delta t$$
$$= 10 \times 10^3 \times 1 \times (80 - 20)$$
$$= 600 \times 10^3 \text{ cal}$$

Hence, $\quad Q = Q'$

$$\Rightarrow \quad 600\,m = 600 \times 10^3 \Rightarrow m = 10^3 \text{ g} = 1 \text{ kg}$$

8. (b) Heat gained by ice = Heat lost by water

Let $\quad m_1$ = mass of ice
$L_{ice} = 80$ cal/g
$c_{ice} = 0.5$ cal/g/°C
Temperature of ice $= -1.4°$ C

Heat gained by ice

$$= m_1 L + m_1 c_{ice}\ \Delta t + m_1\ c_{water}\ \Delta t$$
$$= m[L + c_{ice}\ \Delta t + c_{water}\ \Delta t]$$
$$= m[80 + 0.5(0+14) + 1\times(0+25)]$$
$$= m[80+7+25]$$
$$= m\times 112 \quad \ldots(i)$$

Heat lost by water

$$= 200\times 1\times(25-10)$$
$$= 200\times 15 \quad \ldots(ii)$$

From Eqs. (i) and (ii), we get

$$m\times 112 = 200\times 15$$
$$\Rightarrow \quad m = \frac{200\times 15}{112} = 26.7 = 27\text{ g}$$

Chapter 11. Radioactivity and Nuclei

1. (a) In fission of U-235 nucleus, the loss of mass, $\Delta m = 0.2$ amu.

Energy released, $\Delta E = \Delta mc^2$

$$= 0.2\times 931.5\text{ MeV} = 186.2\text{ MeV}$$

2. (d) When four hydrogen nuclei combine to form a helium nucleus in the interior of the sun, nuclear fusion takes place its a multi-step process in which hydrogen is fused into helium. The proton-proton (p, p) cycle by which this occurs is represented as

$$4{}_1^1\text{H} + 2e^- \rightarrow {}_2^4\text{He} + 2\nu + 6\nu + 26.7\text{ MeV.}$$

Hence, energy released per nucleon is 26.7 MeV.

3. (b) γ-decay occurs due to deexcitation of a nucleus and electronic energy levels involved is essentially in MeV.

Electronic energy levels have values only in eV.

Energy released per nuclcon is 26.7 MeV

4. (b) Heavy stable nuclei have more neutrons than protons because protons are positively charged and repel each other. This repulsion force is more, so that an excess of neutrons are required to reduce this repulsion. Nuclear forces are strongest attractive forces between nucleons, whereas electrostatic force between protons is repulsive.

5. (a) For a β^--decay, ${}_Z^AX \longrightarrow {}_{Z+1}^{A}Y_1 + {}_{-1}^{0}e + \nu^-$

$\therefore$ Q_1-value of decay

$$= [(M_X - ZM_e) - \{M_Y - (Z+1)M_e\} - M_e]c^2$$
$$= (M_X - M_Y)c^2$$

For β^+-decay,

$${}_Z^AX \longrightarrow {}_{Z-1}^{A}Y_2 + {}_1^0e + \nu$$

$\therefore$ Q_2-value of decay

$$= [(M_X - ZM_e) - \{M_Y - (Z-1)M_e\} - M_e]c^2$$
$$= (M_X - M_Y - 2M_e)c^2$$

6. (b) Given, $F = \dfrac{GMm}{r^2}$

M = effective mass of hydrogen atom

$$= \text{mass of electron} + \text{mass of proton} - \frac{B}{c^2}$$

where, B = binding energy of hydrogen atom = 13.6 eV.

7. (b) Momentum remains constant, $K = \dfrac{p^2}{2m}$

$$K \propto \frac{1}{m}$$

Now, for α-particle, KE = K_n

$$\text{Mass} = m_\alpha = 4$$

For residual nucleus, KE $= K_\alpha$

$$\text{Mass} = m_n = 210 - 4 = 206$$
$$\frac{K_n}{K_\alpha} = \frac{m_\alpha}{m_n} = \frac{4}{206} = \frac{2}{103}$$
$$K_n = \left(\frac{2}{103}\right)K_\alpha$$

Given, energy of α-particle is E.

Hence, $K_n = \left(\dfrac{2}{103}\right)E.$

8. (d) Energy radiated by Sun $= 1.4\text{ kW/m}^2$

$$= 1.4\text{ kJ/sm}^2 \qquad \left(\because P = \frac{\text{energy}}{\text{time}}\right)$$
$$= \frac{1.4}{\frac{1}{86400}} = \frac{1.4\times 864000}{\text{day}\ \ \text{m}^2}\text{ kJ}$$

Total energy radiated per day

$$E = \frac{4\pi\times(1.5\times 10^{11})^2\ \times 1.4\times 86400}{1} = \frac{\text{kJ}}{\text{day}}$$

$\therefore$ We have, $E = mc^2$

$$\Rightarrow \quad m = \frac{E}{c^2} = \frac{4\pi\times(1.5\times 10^{11})^2\ \times 1.4\times 86400\times 10^3}{(3\times 10^8)^2}$$
$$= 3.8\times 10^{14}\text{ kg}$$

Internal Assessment of Practical Work

Experiment 1-A

Aim

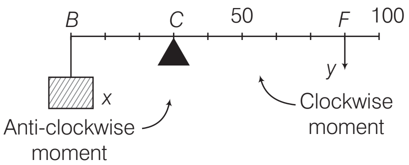
To determine the mass of a meter scale using it as a lever.

Apparatus Required

A wooden wedge, thin thread of negligible mass, a set of weights (10 gf and 20 gf), a meter scale of uniform thickness and a half meter ruler.

Theory/Principle Used

In order to achieve the aim of this experiment, the **law of lever** will be followed. According to which, **"in equilibrium condition, the clockwise moment of the load about the fulcrum is equal to the anti-clockwise moment of the effort about the fulcrum".** It then behaves like a lever of first kind.



Load × Load arm = Effort × Effort arm

Or $x \times BC = y \times FC$

Important Terms

Mechanical advantage It is defined as the ratio of length of effort arm to the length of load arm.

i.e., Mechanical advantage

$$(\text{MA}) = \frac{\text{Load}\,(x)}{\text{Effort}\,(y)} = \frac{\text{Effort arm}\,(FC)}{\text{Load arm}\,(BC)} \quad \text{or} \quad \text{MA} = \frac{FC}{BC}$$

Velocity ratio It is defined as the ratio of velocity of effort to the velocity of the load.

i.e., Velocity ratio (VR)

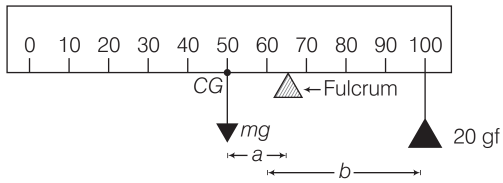
$$= \frac{\text{Velocity of effort}\,(v_y)}{\text{Velocity of load}\,(v_x)}$$

$$= \frac{\text{Displacement of effort}}{\text{Displacement of load}}$$

$$= \frac{\text{Effort arm}\,(FC)}{\text{Load arm}\,(BC)} \quad \text{or} \quad \text{VR} = \frac{FC}{BC}$$

Procedure

1. First of all, make a loose loop of thread.
2. Tie the slotted weight at the other end of loop of thread.
3. Now, put the meter scale on the wooden wedge and try to adjust the position of scale on the wedge such that it gets balanced horizontally.
4. Record the position of wedge on the scale as centre of gravity (CG) of meter scale. It should lie nearly about 50 cm mark on the scale.
5. Choose a weight of 20 gf and suspend it on the one side of centre of gravity.



6. By taking the reference from the figure (given above), place the wedge between centre of gravity and weight hanged.
7. After holding the meter scale, adjust it on wedge by shifting it either left or right.
8. The moment, the scale gets balanced in a horizontal position, record the position of wedge and weight hanged on scale. (it will be the distance between CG and wedge i.e., '*a*' cm and the distance between wedge and weight hanged i.e., '*b*' cm in observation table)
9. By changing the position of hanged weight on meter scale, repeat the experiment.
10. After this, note down the position of wedge.

Observations

Least count of the meter scale = ... cm.

Observation table to determine the mass of a meter scale

Weight suspended on the scale w (in gf)	Distance of a (in cm)	Distance of b (in cm)	Mass of meter scale, $m' = \frac{wb}{a}$ (in gf)
20			$m_1' =$
30			$m_2' =$
40			$m_3' =$

Calculations

The mass of a meter scale can be calculated by using,

$$m' = \frac{b}{a} w$$

where, m' = mass of meter scale,

w = mass of suspended weight,

a = distance between centre of gravity (CG) and fulcrum and

b = distance of known weight from fulcrum.

Mean mass of meter scale,

$$m' = \frac{m_1' + m_2' + m_3'}{3} = \text{.........} \text{ gf.}$$

Result

The mass of a given meter scale = ... g.

Precautions

1. Meter scale should be in a horizontal equilibrium position while taking observations.
2. It should be ensured that while shifting the position of weight, the position of fulcrum should be same.
3. Scale of uniform thickness should be used.

Experiment 1-B

Aim

To find out the mass of the given meter scale by using spring balance.

Apparatus Required

A thin thread of negligible mass, meter scale of uniform thickness, a wooden wedge and a set of weights (10 gf, 20 gf, etc.) and spring balance.

Theory/Principle Used

In the case of a spring balance, extension in the spring is always directly proportional to the force applied on it.

i.e., $F \propto x \Rightarrow F = kx$

where, k is the proportionality constant.

On the basis of above equation, it can be said that in spring balance, length of spring increases on increasing the weight suspended on it. Here, the meter scale whose mass is to be determined with the help of a spring balance is suspended on the hook of the spring balance. Due to the weight of the meter scale, it stretches the spring of spring balance. Ultimately, the pointer of the spring balance reads the weight (or gravitational mass) of the meter scale either in the terms of newton or gf (gram force).

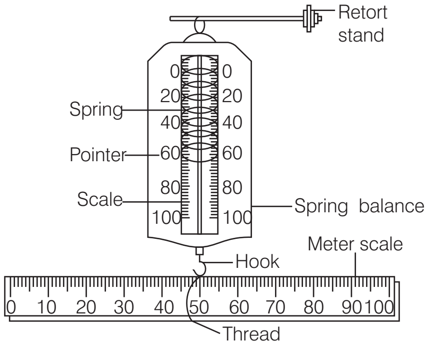
If mass of scale $= m$. This can be calculated by the formula,

$$\text{Mass of the body} = \frac{\text{Gravitational mass}}{\text{Acceleration due to gravity}}$$

Or $$m = \frac{m'_g}{g}$$

Procedure

1. Firstly, suspend the spring balance to a rigid support like retort stand.
2. Record the least count of the spring balance.
3. Now, note down the zero error of spring balance.
4. Suspend the scale horizontally at 50 cm mark on meter scale with the help of loop of thread as shown in figure.



5. Now, note down the reading of spring balance.

6. After noting down the reading of spring balance, repeat the above steps for atleast two times.
7. At last, take the mean of the observations.

Observations

Least count of spring balance = ... gf.

Error in the spring balance = ±......... gf.

Correction to be applied in reading = ∓ .... gf.

Observed gravitational mass,

(i) m_1 = ... gf. (ii) m_2 =......... gf.

(iii) m_3 = ... gf. (iv) m_4 = ... gf.

Calculations

Mean observed gravitational mass,

$$m' = \frac{m_1 + m_2 + m_3 + m_4}{4} = \ldots \text{ gf.}$$

Corrected gravitational mass, m'' = ... gf

Therefore, mass of meter scale = $\frac{m''_g}{g}$

Result

Mass of meter scale = ... g.

Precautions

1. The position of scale, i.e., up or down should be properly adjusted, so as to bring the pointer at zero mark of scale.
2. The value of acceleration due to gravity varies from place to place. Since, the spring balance depends on the value of g, so in order to determine the inertial mass at a given place, the standard value of g must be used.
3. To get the final reading, displace the suspended weights slightly upward or downward.

Experiment 1-C

Aim

To prove that MA < VR, MA = VR and MA > VR using meter scale as a lever where, MA is mechanical advantage and VR is velocity ratio of the lever.

Apparatus Required

Wooden wedge, known weight, a meter scale and thin thread.

Theory/Principle Used

According to the law of lever/principle of moments, **"in equilibrium position, the clockwise moment of the load about the fulcrum is equal to the anti-clockwise moment of the effort about the fulcrum".**

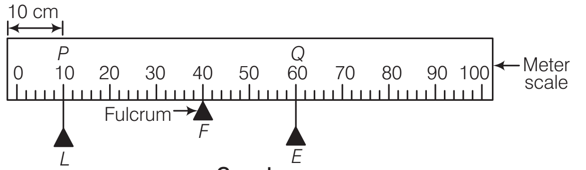
i.e., Load × load arm = Effort × Effort arm

Procedure

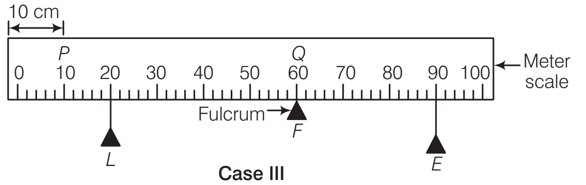
1. Put the meter scale on a wooden wedge at 40 cm mark.
2. Suspend a known weight w_1 gf at 10 cm mark at LHS of fulcrum and another known weight w_2 gf at 60 cm mark on RHS of fulcrum, such that the meter scale balance in horizontal equilibrium.
3. Now, shift the fulcrum at 50 cm mark and then adjust the weights by moving to and fro such that the meter scale is balanced in horizontal equilibrium.
4. Again, repeat step 3 but now shift the fulcrum at 60 cm mark.
5. In each case calculate MA and VR using the relation,

$$\text{MA} = \frac{\text{Load } (L)}{\text{Effort } (E)} = \frac{\text{Effort arm } (QF)}{\text{Load arm } (PF)}$$

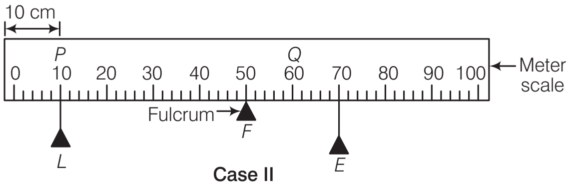
$$\text{VR} = \frac{\text{Distance of effort from fulcrum } (QF)}{\text{Distance of load from fulcrum } (PF)}$$



Case I



Case III



Observations

Mass of meter scale, $m =$ .... gf.

Observation table to prove MA < VR, MA = VR and MR > VR

S.No.	Load, L (gf)	Effort, E (gf)	Position of fulcrum, F (cm)	Position of Load, P (cm)	Position of Effort, Q (cm)	Load arm PF (cm)	Effort arm QF (cm)	$\text{MA} = \frac{L}{E}$	$\text{VR} = \frac{QF}{PF}$
1.		40							
2.		50							
3.		60							

Result

Case I When $F = 40$ cm, then MA > VR

$\therefore$ In equilibrium position,

Load × load arm = Mass of meter scale × 10 + effort × effort arm

$\Rightarrow \quad L \times PF = m \times 10 + E \times QF$

Case II When $F = 50$ cm, then MA = VR

$\therefore L \times PF = E \times QF$

Case III When $F = 60$ cm, then MA < VR

$\Rightarrow L \times PF + m \times 10 = E \times QF$

Precautions

1. The scale of uniform thickness should be used.
2. The position of fulcrum should not be changed while shifting the position of known weight.
3. Balancing of scale on the wedge should be done properly.

Viva-Voce Based Questions

Q 1. How can you define the term "centre of gravity"?

Ans. The point at which the whole weight of the body is supposed to be concentrated, is known as centre of gravity.

Q 2. Define the term "lever".

Ans. A simple machine which turns about a fixed point (called the turning point) due to a load and efforts applied on it, is known as lever. So, it is a simple machine having three points, fulcrum, effort and load.

Q 3. State "principle of moments".

Ans. According to the principle of moments, "when a body is in equilibrium under the action of number of forces, then sum of the clockwise moments is equal to sum of the anti-clockwise moments.

Q 4. What is "least count of an instrument"?

Ans. Least count of an instrument can be defined as the minimum reading which that instrument can record accurately.

Q 5. State the difference between mass and weight.

Ans. The quantity of matter contained in a body defines its mass, while the weight of the body is the force with which it is attracted towards the centre of Earth.

Q 6. What is the weight of the body at the centre of Earth?

Ans. The weight of the body is always zero at the centre of the Earth.

Q 7. Mention the class of lever which is used as force multiplier.

Ans. IInd class of lever is used as a force multiplier.

Q 8. State whether the mechanical advantage of the experiment can be changed or not? If yes, then explain how?

Ans. Yes, the mechanical advantage (MA) of the experiment can be changed by changing the position of fulcrum between the load and effort point.

Q 9. Mention whether the weight of a body is a constant quantity.

Ans. No, the weight of a body is not a constant quantity as it varies from place to place due to the varying value of acceleration due to gravity (g).

Q 10. Distinguish between effort and effort arm.

Ans. The force applied on the lever to overcome the resistance due to load is known as effort.

While the distance of the effort point from fulcrum is known as effort arm.

Q 11. Give the name of SI unit of weight.

Ans. The SI unit of weight is newton (N).

Q 12. Mention the least count of a meter scale.

Ans. The least count of a meter scale is 1 mm or 0.1 cm.

Q 13. What does the weight gf imply?

Ans. It means the force exerted by body towards the centre of Earth on an object of 1 g due to force of gravity.

Q 14. Define the term "velocity ratio" of a machine.

Ans. The velocity ratio of a machine can be defined as the ratio of velocity or displacement of effort point to load point.

Experiment 2

Aim

To determine the velocity ratio (VR) and mechanical advantage (MA) of a given pulley system.

Apparatus Required

Block and tackle, scalepan, threads, weights, pulley, spring balance and rigid stand.

Theory/Principle Used

A simple machine which can change the direction of force or can multiply the force is known as pulley. In appearance, it is a flat circular disc having a groove in its edge and capable of rotation about a fixed axis which passes through its centre called the axle as shown in Fig. a.

A single fixed pulley has mechanical advantage (MA) = 1, due to which it does not multiply force. But it helps to change the direction of applied force.

In a system of two pullies one is fixed and the other is movable, having a mechanical advantage (MA) of 2.

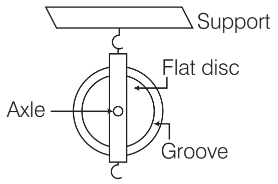


Fig.a

In order to achieve a large mechanical advantage, we usually use a block and tackle system of pulleys. This system consists of two blocks carrying the pulleys. In this, the lower block is movable and upper block is fixed. Moreover, the number of pulleys in the upper block is either equal to or is more than the number of pulleys in the lower block. A massless and a single inextensible rope passes over all the pulleys and the load which is to be lifted, is attached to lower movable pulley. The mechanical advantage or velocity ratio of an ideal pulley and tackle is equal to the total number of pulleys in the two blocks. Mechanical advantage (MA) is slightly less than velocity ratio (VR) in actual system of block and tackle, it is due to the weight of the lower block and the friction in pulley.

Efficiency of pulley block and tackle system of pulleys is $= \frac{MA}{VR} \times 100$

If n be the number of pulleys which is used in block and tackle arrangement and effort (E) is applied in the downward direction then,

Load $(L) = nT$

Effort (E) = Tension in string (T) as shown in Fig. (b).

$\therefore$ Mechanical Advantage $= \frac{\text{Load}}{\text{Effort}}$

Or $$MA = \frac{L}{E} = \frac{nT}{T} = n \quad ...(i)$$

On applying effort (E), if load moves a distance d, the effort moves by nd.

$$\therefore \text{Velocity Ratio} = \frac{\text{Distance travelled by effort}}{\text{Distance travelled by load}}$$

Or $$\text{VR} = \frac{nd}{d} = n \quad \text{...(ii)}$$

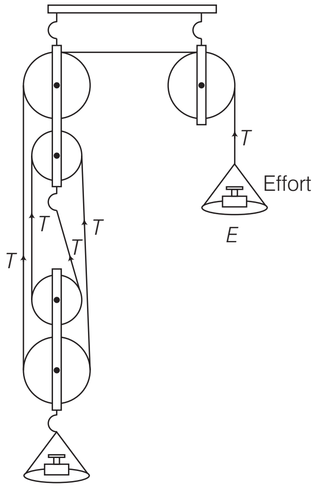


Fig. b

In an ideal pulley system, VR = MA ...(iii)

If total weight of pulleys in the lower block be w, then

$$L + w = nT$$

and $$E = T$$

$$\therefore \quad \text{MA} = \frac{L}{E} = \frac{nT - w}{T} = n - \frac{w}{T} \quad \text{...(iv)}$$

$$\therefore \quad \text{VR} > \text{MA}$$

From Eqs. (ii) and (iv), we get

$$\therefore \text{Efficiency, } \eta = \frac{\text{MA}}{\text{VR}}$$

$$= \frac{\left(n - \frac{w}{T}\right)}{n} = \left(1 - \frac{w}{nE}\right) \quad \text{...(v)}$$

(As, $E = T$)

Procedure

1. Firstly, take a pulley block and tackle in which the number of pulley can be adjusted.
2. It should be ensured that there is no friction at the pulleys axle.
3. If required, oil the pulleys.
4. Now, try to support a weight of 500 g from the lower block to serve as load x.

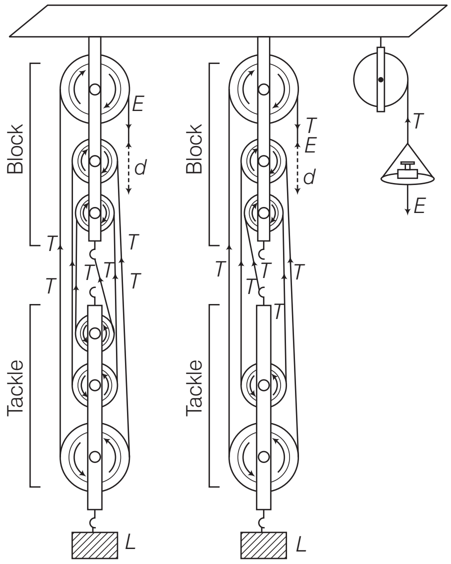


Fig. c

5. Attach one end of a string of suitable length to a hook in the lower block and pass it around the pulleys in such a way that free end of the string passes around the pulley in the upper block.
6. Determine the weight of the scale pan with the help of a spring balance.
7. Suspend the pan with string and at upmost pulley as shown in Fig. c.
8. Place the suitable weights in the scale pan in such a way that the load x from the lower block is supported.
9. Carefully observe that the scale pan does not touch the pulley or the block.
10. Record the weights in the pan.
11. Repeat the experiment with the same load.
12. To have sets of different readings, repeat the experiment with atleast three different loads.

Observations

Least count of spring balance = ...gf.

Zero error in the spring balance = ±.........gf.

Correction to be applied to the weight in observed reading = ∓.....gf.

Corrected weight of the pan as measured with the spring balance, $y = \mp$ .... gf.

Observation table to obtain mechanical advantage and velocity ratio of a given pulley system

S.No.	Load, x	Weights in the pan in equilibrium m position F_1 (gf)	F_2 (gf)	Mean $F(gf)$	Effort $E = F + y$ (gf)	MA	VR	$\eta = \frac{MA}{VR} \times 100$
1.								
2.								
3.								

Calculations

Mean MA = ...

Mean VR = ...

It should be noted that the above experiments can be performed by taking different number of pulleys.

Mean efficiency = ...

Result

MA of given system of pulleys = ...

VR of given system of pulleys = ...

Efficiency of given system of pulleys = ...

Precautions

1. Carefully measure the displacement of effort and load point with the help of meter scale.
2. The scale pan should not be touched any part of the apparatus.
3. It should be ensured that the friction in the pulleys is minimum.
4. If required, then only the correction of the spring balance must be used properly.

Viva-Voce Based Questions

Q 1. What do you mean by the term "pulley"?

Ans. A grooved wheel that can turn readily on an axle is known as pulley.

Q 2. State the factors on which the weight of the string lifted depends?

Ans. The weight of string lifted depends on the distance between the pulley blocks, but the weight of the lower block remains constant.

Q3. Is it possible that mechanical advantage can be less than 1?

Ans. Yes, the mechanical advantage can be less than one in class III lever.

Q 4. State the principle of a machine?

Ans. The principle of a machine states that, "work done by a machine is always equal to the work done on the machine".

Q 5. What is single movable pulley and its mechanical advantage?

Ans. A pulley whose axis of rotation can change is known as single movable pulley. Its mechanical advantage is 2, i.e., it can multiply force.

Q 6. Define "efficiency" of a machine?

Ans. The ratio of the work done by the machine to the work done on the machine is known as efficiency of a machine.

Q 7. Mention the relation between mechanical advantage (MA), velocity ratio (VR) and efficiency (η) ?

Ans. The relation between MA, VR and η can be given as, $MA = (\eta \times VR)/100$

Q 8. Give a reason, why the efficiency of an actual machine can never be equal to one?

Ans. Since, frictional forces acts with in the parts of a machine which decreases the output of work. As, we know that,

$$\eta = \frac{\text{Output work}}{\text{Input work}}$$

So, if input work is larger than the output work, then η for the actual machine will be always less than one.

Q 9. Give a relation between mechanical advantage (MA) and velocity ratio (VR) in the case of

(i) ideal machine (ii) real machine

Ans. (i) In an ideal machine, VR = MA

(ii) In a real machine, MA < VR

Q10. Define a single fixed pulley?

Ans. A pulley whose axis of rotation is fixed is known as a single fixed pulley.

Q11. What is the mechanical advantage of a single fixed pulley?

Ans. The mechanical advantage of a single fixed pulley is 1.

Q12. What does the term "useless load" means?

Ans. The useless load is the combination of the weight or force of lower block, string and friction in the string and bearing in axle and pulleys.

Experiment 3

Aim

To trace the course of different rays of light through a rectangular glass prism at different angles of incidence and measure and an angles of incidence, refraction and emergence. Also, measure the lateral displacement.

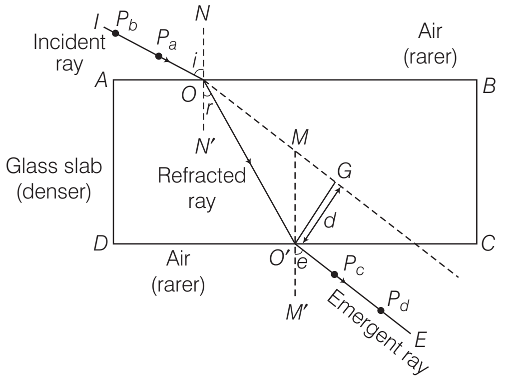
Apparatus Required

A rectangular glass slab, a drawing board, sharp alpins, a sharp pencil, eraser, protractor, drawing thumb pins, white drawing sheets and 15 m scale.

Description of Apparatus

Figure given below is representing a rectangular glass slab *ABCD*. When a ray of light *OI* is incident at an angle of incidence *i* with the normal *NON′* at the point of incidence O. After suffering the refraction from the surface *AB* of the rectangular glass slab, this ray gets refracted along *OO′* and bent towards the normal. It is because it is travelling from air (rarer) to the glass (denser medium). This refracted ray agains suffers the refraction at surface *CD* of glass slab and it gets bent away from the normal *MOM′* and emerges along *OE* (i.e., emergent ray).

The emergent ray becomes parallel to the incident ray (which is laterally displaced). The distance between the emergent ray and extended incident ray is known as lateral displacement.



Theory/Principle Used

The phenomenon of bending of light when the ray of light passes from an optical medium to another medium when incident obliquely is known as refraction. There are following observations which are usually noticed when a ray of light passes through rectangular glass slab.

(i) Incident and emergent rays are parallel to each other but laterally shifted.

(ii) Angle of incidence and angle of emergence are always equal.

(iii) When angle of incidence is zero, then no lateral shift of emergent ray takes place.

Procedure

1. Take a sheet of white paper and fix it on the drawing board with the help of drawing pins at the four corners of the sheet.
2. Put a glass slab at the centre of paper and with a help of a pencil, draw its boundary *ABCD*.
3. Now, remove the glass slab and draw a line *OI* by making an angle of 30° with the normal at the point O.
4. After putting the glass slab back on its boundary line, fix the two pins P_a and P_b vertically on the line *OI* atleast 10 cm apart and one pin close to the slab.
5. Now, try to look for the images of these pins in the slab from the opposite side *CD*.
6. Again, fix two more pins P_c and P_d in such a way that they should be in line with the images of P_a and P_b as observed through the slab and atleast 10 cm apart.
7. After this, join the point of P_c to the point P_d in order to obtain the emergent ray.
8. Draw a normal to *CD* at point O′ and join OO′ in order to get refracted ray.
9. Take the measurement of angle of incidence, angle of refraction and angle of emergence.

10. Extend the ray OI forward and draw a perpendicular from O' on OI to meet it at G. So, the lateral displacement is given by $O'G$.
11. Repeat the same experiment with different angles of incidence (i.e., 45°, 60°).

bservations

Least count of scale = ... cm.

Least count of protractor = ... degree.

Observation table for measuring the angle of incidence (i), angle of emergence (e) and lateral displacement (d)

S. No.	Angle of incidence (i)	Angle of refraction (r)	Angle of emergence (e)	Lateral displacement ($O'G$)
1.				
2.				
3.				

Result

There are following conclusions that are drawn with in the experimental error limit, they are as follows

1. The incident rays and emergent rays are parallel to each other but laterally displaced.
2. Angle of incidence is equal to the angle of emergence.
3. Lateral displacement increases on increasing the thickness of glass slab for refracted ray and on increasing the angle of incidence.
4. If a ray of light passes from rarer to glass, the refracted ray bend towards the normal.

Precautions

1. The angles should be measured carefully.
2. The tips of the pins should be in a straight line.
3. In order to draw the rays, sharp pencils should be used.
4. The marking of arrow heads should be done gently in order to show the direction of light.

Viva-Voce Based Questions

Q 1. In what manner do the frequency of light gets affected when it passes

(i) from the rarer to denser medium?

(ii) from denser to the rarer medium?

Ans. In both cases, the frequency of light remains constant.

Q 2. What do you understand by the term "refraction"?

Ans. The phenomena of bending of ray of light when it passes from one optical medium to another is known as refraction of light.

Q 3. State law of refraction.

Ans. According to the law of refraction,

(i) the "incident ray, the refracted ray and the normal, all lie in the same plane at the point of incidence".

(ii) the ratio of sine of an angle of incidence to the sine of angle of refraction for a given pair of media is always constant.

This constant is known as refractive index (μ) of the medium in which the refraction takes place.

This law is also known as Snell's law of refraction

i.e., $${}^1\mu_2 = \frac{\sin i}{\sin r}$$

where, ${}^1\mu_2$ is the refractive index of medium 1 w.r.t 2.

Q 4. Mention the cause of refraction of light?

Ans. Due to different optical densities of the medium there is change in speed of light in the different medium, which causes the refraction of light.

Q 5. State whether a parallel sided glass slab produce any deviation in the incident light?

Ans. No, a parallel sided glass slab does not produce any deviation in the incident light. Emergent ray is always parallel to the incident ray but laterally displaced.

Q 6. Define the term "optical density"?

Ans. The ratio of velocity of light in vacuum to the velocity of light in medium is known as the optical density of a medium.

Q 7. State the factors on which the lateral displacement produced by a glass slab depends?

Ans. *The lateral displacement depends upon*

(i) angle of incidence
(ii) refractive index of the medium
(iii) thickness of the glass slab

Q 8. Is it possible for angle of incidence to be lesser than the angle of refraction?

Ans. Yes, it is possible in the condition when the ray of light suffers refraction from optically denser to optically rarer medium.

Q 9. Mention the factors on which the refractive index of a medium depends?

Ans. *The refractive index of a medium depends upon*

(i) nature of medium (ii) colour of incident ray

Q 10. What is the angle of refraction, if the angle of incidence is zero?

Ans. If the angle of incidence is zero, then the angle of refraction will be zero.

It is because when the incident ray falls normally on the surface no refraction takes place.

Q 11. State whether the refractive index of water with respect to glass is more than one or less than one?

Ans. Since, refractive index of water with respect to glass, ${}^{g}\mu_w = \frac{v_g}{v_w}$

As it is known that, $v_g < v_w \Rightarrow {}^{g}\mu_w < 1$

$\therefore$ Refractive index of water with respect to the glass in less than 1.

Q 12. If a ray falls on glass and water at some angle of incidence, then state whether the angle of refraction will be larger or smaller in glass?

Ans. As, we know that, bending of light increases on increasing refractive index, ${}^{a}\mu_w < {}^{a}\mu_g$. So, bending of a ray of light for same angle of incidence will be larger in glass. So, angle of refraction in glass will be smaller than in water for same angle of incidence.

Experiment 4-A

Aim

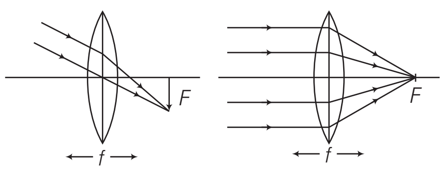
To determine the focal length of a convex lens by the distant object method.

Apparatus Required

Lens holder, a small screen fixed on a stand, thin convex lens and a meter scale.

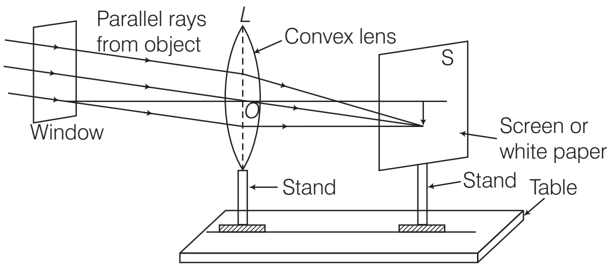
Theory/Principle Used

When the parallel rays of light coming from the distant object falls on a convex lens, then after refraction they form real, inverted and very small image on screen at the principal focus.



Procedure

1. First of all, take a convex lens and with the help of holder, put it on a table between a window of laboratory and screen on the table.



2. Now, try to focus the sharp image of the object on the sheet of paper or a wall as a screen.
3. With the help of a half meter scale, measure the distance between the lens and the screen as the image is formed at focus.
4. Repeat this experiment for atleast two more times by obtaining the images of two different distant objects and measure the distance between the convex lens and the screen. Then, record them in observation table.
5. At last, take the mean distance to obtain focal length.

Observations

Least count of meter scale = ... cm.

Obervation table to obtain the distance between lens and screen

S. No.	Position of lens x (cm)	Position of screen y (cm)	Distance between lens and screen f' (cm)
1.			f_a = ...
2.			f_b = ...
3.			f_c = ...
4.			f_d = ...

Calculations

Mean focal length, $f' = \dfrac{f_a + f_b + f_c + f_d}{4}$ = ... cm.

Result

Focal length of convex lens by distant object method,

f' = ... cm.

Precautions

1. The lens should be cleaned before using it.
2. The image of the object should be properly focused on the screen.
3. There should be no obstacle in the path of rays of light from the distant object incident on the convex lens.

Experiment 4-B

Aim

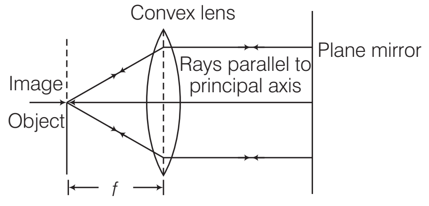
To determine the focal length of a convex lens by using a needle and plane mirror.

Apparatus Required

There is no use of optical bench in the experiment. A convex lens, an iron stand with a clamp, a plane mirror, plumb line, a half meter scale, an optical pin.

Theory/Principle Used

When incident rays of light from an object placed on focus of convex lens, passes through the lens, then they become parallel to the principal axis after refraction and falls perpendicularly on a plane mirror placed behind it.

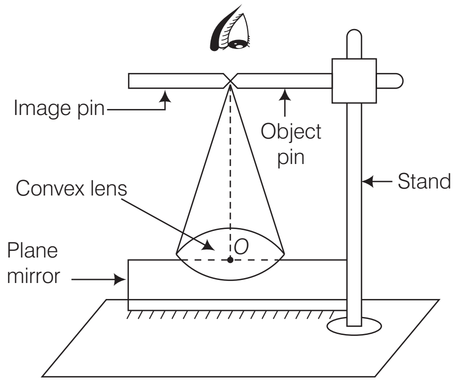


So, these rays covers the same path after reflecting back from the mirror and then after suffering the refraction again from convex lens form an inverted image at the focus itself.

Focal length of convex lens is the distance between the object and optical centre of the lens.

Procedure

1. Determine the rough focal length of convex lens, which forms the image of an object.
2. Then, put the convex lens over a plane mirror on the base of the stand.
3. With the help of clamp of stand, mount the object optical pin near the focal length of lens in such a way that the tip of pin comes over the centre of lens as shown in figure given below.



4. Try to look from the top and adjust the pin at height when the tip of the pin coincide with object pin.
5. After removing the parallax, tight the clamp of stand at this position.
6. Record the height between pin and lens and plane mirror.
7. The mean of above two heights gives the focal length of lens.
8. Repeat the experiment for at least three to four times.

Observations

Least count of meter scale = ... cm.

Observations table to obtain mean focal length of the convex lens

S. No.	Height between object pin and		Focal length of convex lens, $f' = \frac{a+b}{2}$ (cm)
	plane mirror a (cm)	convex lens b (cm)	
1.			f_a = ...
2.			f_b = ...
3.			f_c = ...
4.			f_d = ...

Calculation

Mean focal length, $f' = \frac{f_a + f_b + f_c + f_d}{4}$ = ... cm.

Result

The focal length of the convex lens, f' = ... cm.

Precautions

1. While taking observations, eye should be exactly focused over the tip of pin.
2. Carefully, measure the height of pin from mirror and lens.
3. The parallax should be removed between the tip of pin and its image.

Experiment 5

Aim

To find the focal length of a convex lens using u-v method and the formula, $f = \frac{uv}{u+v}$.

Apparatus Required

A thin convex lens, optical bench, white screen and an illuminated object (say candle or a needle).

Theory/Principle Used

If an object is placed between F and $2F$ in the case of convex lens, then a real, inverted and enlarged image of the object is formed beyond $2F$.

So, focal length f can be calculated by measuring the image distance v and object distance u.

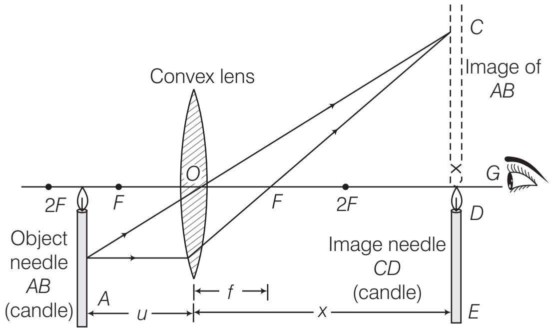
∴ By applying lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

⇒ According to sign convention u is taken as negative, so $\frac{1}{f} = \frac{1}{v} - \frac{1}{(-u)} \Rightarrow \frac{1}{f} = \frac{1}{v} + \frac{1}{u} \Rightarrow$ focal length, $f = \frac{uv}{u+v}$

Procedure

1. On the optical bench, arrange the lens, screen and object (say candle) in such a way that the lens gets positioned between the screen and the candle.
2. Now, try to adjust the height of the candle, lens and screen in such a way that the candle flame, centre of the lens and the screen are on the same level.
3. Make the illuminated object to get focused on the screen.
4. By to and fro movement of screen along the optical bench a clear image of the object should be formed on it.
5. Now, take the measurement of distance between the screen, i.e., image and the lens v.
6. Also, measure the distance between the object and lens u.
7. For obtaining the corresponding values of u and v, repeat the same experiment for the different positions of the object.



8. Determine the focal length f of the convex lens using the lens formula for each case. Also, position of screen will also change in each observation.

Observations

Least count of meter scale = ... cm.

Observations table to obtain the focal length of convex lens

S. No.	Distance of the object, u (cm)	Distance of the image, v(cm)	Focal length, $f = \frac{uv}{u+v}$ (cm)
1.			f_a = ...
2.			f_b = ...
3.			f_c = ...
4.			f_d = ...

Calculations

Mean focal length, $F = \frac{f_a + f_b + f_c + f_d}{4}$ = ... cm.

Result

The focal length of a convex lens, $F' =$ .... cm.

Precautions

1. Sign conventions must be applied properly.
2. In order to the get a bright image on the screen, the experiment should be performed in the dark room.
3. The candle should not be disturb by the air currents.
4. The centre of screen, the optical centre of lens and the candle flame should not be at the same height.

Viva-Voce Based Questions

Q 1. Define the term "magnification"?

Ans. The ratio of the size of an image to the size of an object is known as magnification.

$$\Rightarrow \text{Magnification, } m = \frac{\text{Size of the image}}{\text{Size of the object}}$$

Q 2. Is the virtual image ever inverted?

Ans. No, virtual image is always erected in lens and mirrors.

Q 3. In which manner, do the parallax can be removed?

Ans. When the apparent shift in the position of tips of object and image does not take place, when observer's eye is moved side ways, then it is said that parallax is removed.

Q 4. Is it possible to obtain a real image with a concave lens?

Ans. No, concave lens always forms virtual image of the real object.

Q 5. What is the position of the object when a convex lens is used as a magnifying glass?

Ans. When a convex lens is used as a magnifying glass, then the position of the object will be in between the focus and optical centre of the convex lens.

Q 6. What type of lens is the eye lens?

Ans. An eye lens is a double convex lens.

Q 7. Is it possible to determine the rough focal length of a concave lens?

Ans. No, it is not possible to calculate the rough focal length of a concave lens because concave lens always always forms a virtual image.

Q 8. Which formula is used to find the focal length of the convex lens?

Ans. The formula used to find the focal length of convex lens is given by

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

where, u = object distance,

v = image distance

and f = focal length.

Q 9. Between the convex and concave lens, which one has virtual focus?

Ans. Concave lens has virtual focus because parallel incident rays diverges after refraction, so forms virtual focus.

Q 10. State whether the focal length of a lens depends on the position of object in front of lens?

Ans. No, the focal length of a lens does not change on changing the position of an object. It is because on changing the position of object, position of image also changes accordingly, so that the focal length comes same by formula,

$$f = \frac{uv}{u - v}$$

Q 11. What does the negative power of lens indicates?

Ans. As, it is known that, $P = \frac{1}{f}$

So, if f will be negative, then P will also be negative. So, negative power, indicates that the lens will be a concave lens.

Q 12. Define the term "parallax"?

Ans. Parallax is defined as the apparent shift in position of two things, object and image, when the observer eye's move side ways.

Experiment 6

Aim

To trace the path of a ray of light through a prism and to show that $i_1 + i_2 = A + \delta$ and $A = r_1 + r_2$.

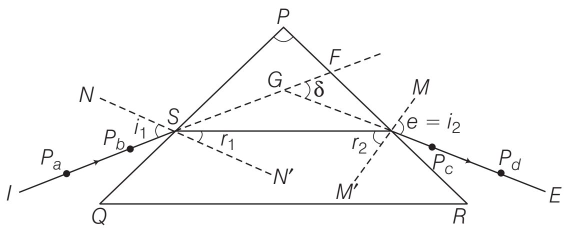
Apparatus Required

Pins, board pins, sheet of paper, drawing board, a triangular equilateral prism.

Theory/Principle Used

Whenever a ray of light suffers the refraction at the two faces of prism, then it gets deviated.

This is shown in the figure given below.



The angle between the incident and the emergent ray is called the angle of deviation.

There are following factors on which the value of angle of deviation depends, they are as follows

(i) The angle of incidence, i

(ii) The material of the prism

(iii) The colour or wavelength of the light

(iv) The angle of prism

The value of angle of deviation for a certain angle of incidence is minimum. This position is known as the position of minimum deviation of the prism with respect to the incident ray.

Therefore, angle of minimum deviation is given by the relation,

$$i_1 + i_2 = A + \delta$$

where, i_1 = angle of incidence,

i_2 = angle of emergence,

A = angle of prism

and δ = angle of deviation.

Procedure

1. Firstly, take a sheet of white paper and fix it on the drawing board with drawing pins.
2. Put the prism in the middle of paper and draw its outline as PQR.
3. Measure angles of ΔPQR, i.e., angle P, Q and R.
4. After taking the mean of all the angles of ΔPQR, the calculated value of the angle P, will be the angle of prism.
5. Now, take a point S on PQ and draw the normal SN.
6. With the help of a sharp pencil, draw a line SI making any angle preferably angle between 30° and 60°.
7. Put the prism again on its original position PQR.
8. Now, fix two pins P_a and P_b around 10 cm apart.
9. Try to observe from the side RS and erect two more pins P_c and P_d in such a way that all four pins (i.e., image of P_a, P_b and image of P_c and P_d) form a straight line.
10. Encircled the points clearly.
11. After removing the prism, join P_a and P_b and extend it to meet PQ at S.
12. In the similar manner, join P_c and P_d and extend it to meet PR at F.
13. Now, join S and F.
14. Extend P_a P_b and P_c P_d to meet at G. This angle δ is known as angle of deviation.
15. Take the measurement of angle e which is equal to i_2 and also measure r_1 and r_2.
16. For the different values of angle of incidence, repeat the same experiment and measure i_2 in each case.
17. Calculate the value of angle of prism for each case by formula,

$$i_1 + i_2 = \delta + A$$

Observations

Least count of protractor = ... degree.

Angle of prism, A = ... degree.

Observation table to verity the relation, $i_1 + i_2 = \delta + A$

S. No.	Angle of incidence (i_1)	Angle of refraction		Angle of emergence = i_2	Angle of deviation, δ	$i_1 + i_2$	$A + \delta$	$r_1 + r_2$
		r_1	r_2					
1.								
2.								
3.								

Result

From the observation table, it is verified that with in the limit of experimental error,

$$i_1 + i_2 = A + \delta \quad \text{and} \quad A = r_1 + r_2$$

Precautions

1. During the course of experiment, the prism should not be disturbed.
2. In order to show the direction of rays of light, arrow heads should be marked.
3. Encircle the marked position of pins.
4. The bases of pins must be in a straight line.

Experiment 7

Aim

To trace the course of a ray of light incident normally ($i = 0°$) on different types of prisms and also to measure the angle of deviation, δ.

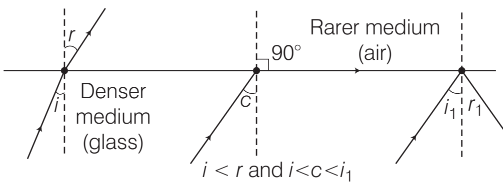
Apparatus Required

Drawing board, drawing sheet, alpins, scale, protractor, thumb pins, three types of prisms.

1. Right angled (45°, 90°, 45°) prism
2. Equilateral (60°, 60°, 60°) prism
3. Triangular (30°, 90°, 60°) prism

Theory/Principle Used

As, shown in the figure given below that whenever a ray of light passes from denser to rarer medium, i.e., from glass to air, then the refracted ray bends away from normal. So, $i < r$.



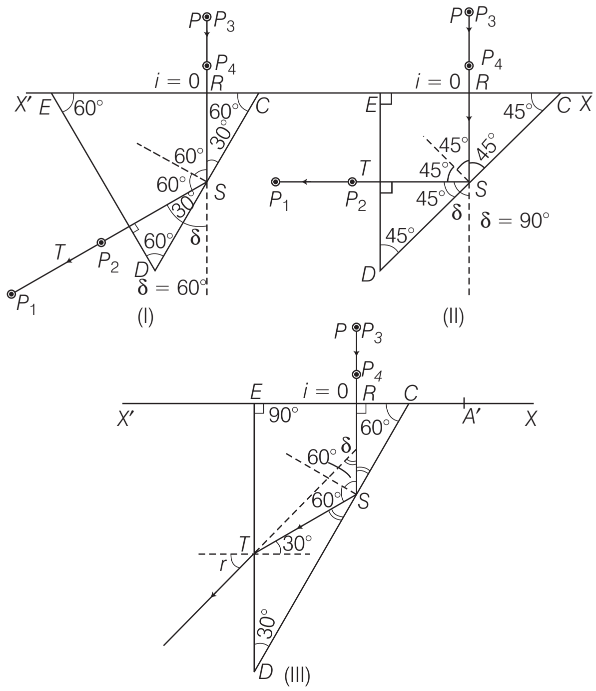
$i < r$ and $i < c < i_1$

So, in case, if angle of incidence is increased in such a manner that the refracted angle becomes 90°, then such angle of incidence is known as critical angle.

The phenomenon in which, if angle of incidence in denser medium is increased beyond the critical angle, then the refraction does not take place in rarer medium and get reflected back in same medium by obeying law of reflection without any valuable loss of intensity of light, is known as total internal reflection.

Procedure

1. Take a sheet of white paper and with the help of thumb pins, fix it on the drawing board.
2. With the help of a sharp pencil, draw a straight line $X'X$ near the middle of paper and parallel to its length.



3. Now, mark the point of incidence R at 3 places on $X'X$ line equidistant each other.
4. At the point of incidence R on line $X'X$, draw a normal PR.
5. Atleast 10 cm apart, fix two points P_3 P_4 vertically on PR.
6. Put a triangular face prism PQR on $X'X$ near R in such a manner that the desired angle is towards the right side and side DE on XX'.
7. Construct the boundaries of prism.
8. Try to observe the images of P_3P_4 pins through the face DE.
9. Prism can be shifted along XX' to observe the images P'_3 P'_4.
10. Now, try to fix up the pins P_1P_2 in the line of images P'_3 and P'_4.
11. After removing the pins, encircled the pins position.
12. Geometrically, measure the various angles with the help of protractor.
13. Repeat the same procedure for other two prisms.

Observations

Least count of protractor = ... degree.

Since, for equilateral prism, $\angle C = \angle D = \angle E = 60°$

For right angled isosceles prism, $\angle C = 45°$,

$\angle D = 45°$, $\angle E = 90°$

For right angle prism, $\angle C = 60°$,

$\angle D = 30°$, $\angle E = 90°$.

Observation table to obtain angle of deviation for different prisms

S. No.	Type of prism	Angle of prism	Angle of incidence on face		Angle of refractions on face		$\angle PST$	Angle of devia-tion, $\angle\delta$
			CE	*CD*	*CE*	*CD*		
1.								
2.								
3.								

Result

When a ray of light falls normally on face CE of prism, then angle of deviation suffered by

1. equilateral prism (60°, 60°, 60°) is .... degree.
2. right angled isosceles prism (45°, 90°, 45°) is .... degree.
3. right angled prism (30°, 90°, 60°) is .... degree.

Precautions

1. During the course of experiment, prism should not be displaced.
2. The sharp and vertical all pins must be used.
3. Each ray should be marked by an arrow head.
4. After removing the drawing board, position of all pins should be encircled.

Viva-Voce based Questions

Q 1. Define the term "prism"?

Ans. A transparent, homogeneous medium bounded by three rectangular triangular plane surfaces is known as a prism.

Q 2. In what manner do the angle of deviation changes with the angle of incidence?

Ans. The angle of deviation increases with increase in angle of incidence till it reaches a certain minimum angle (δ_m). So, on further increasing the angle of incidence, angle of deviation also increases.

Q 3. What do you understand by the term "angle of deviation"?

Ans. The angle made by the incident ray and the emergent ray is called angle of deviation.

Q 4. State the relation between refractive index and the angle of minimum deviation produced by a prism.

Ans. The relation between refractive index and the angle of minimum deviation produced by a prism is given by

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Q 5. Mention the factors on which the angle of deviation depends?

Ans. *The angle of deviation depends on*

(i) angle of incidence
(ii) angle of prism
(iii) material of the prism
(iv) wavelength of light ray

Q 6. How does a ray of light bends after refraction in prism?

Ans. After suffering refraction through prism, ray of light bends towards the base of the prism.

Q 7. When the prism is set in the position of minimum deviation, how does the refracted ray passes through prism?

Ans. When the prism is set in the position of minimum deviation, the refracted ray passes parallel to the base of the prism.

Q 8. Name the colour which deviates the most and deviates the least?

Ans. Violet colour deviates the most while red colour deviates the least.

Q 9. Define "critical angle"?

Ans. When a ray of light passes from denser to the rarer medium, the angle of incidence in denser medium for which angle of refraction in rarer medium becomes 90° is known as critical angle.

Q 10. Mention the difference that you detect between the direction of emergent ray in a glass slab and prism?

Ans. In the case of glass slab, the emergent ray is laterally displaced but it is parallel to the incident ray. In the case of prism, the emergent ray is deviated. It is because in a glass slab, the two refracting faces are parallel to each other, while in a prism, they are inclined at an angle A.

Q 11. What do you understand by refracting edge or angle of prism in prism?

Ans. The angle at which the two refracting surfaces of prism meet is called refracting edge or angle of prism.

Experiment 8

Aim

To calculate the specific heat of the material of given calorimeter, from the temperature readings and masses of cold water, warm water and its mixture taken in the calorimeter.

Apparatus Required

Weight box, physical balance, two half degree thermometers and a calorimeter with outer jacket.

Theory/Principle Used

By the method of mixtures, the specific heat of the material (or copper) can be determined. Consider that a mass m_a of hot water at temperature t_a is added to cold water of mass m_b at temperature t_b in a calorimeter of mass m.

Since, according to the principle of calorimetry,

heat lost by hot water = heat gained by cold water and calorimeter ...(i)

The final temperature becomes T.

$\because$ Heat lost by hot water $= m_a (t_a - T)$

Heat gained by cold water and calorimeter

$$= m_b(T - t_b) + mc(T - T_b)$$
$$= (T - t_b)(m_b + mc)$$

where, c is specific heat of material of calorimeter.

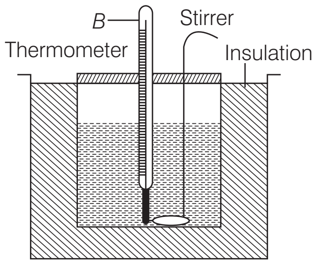
$\therefore$ From Eq. (i), we get

$$(T - t_b)(m_b + mc) = m_a (t_a - T)$$

$$\Rightarrow \quad c = \frac{m_a (t_a - T)}{m(T - t_b)} - \frac{m_b}{m}$$

Procedure

1. Firstly, measure the room temperature with the two thermometers B and D.
2. Determine the mass of empty and dry calorimeter along with the stirrer.



Copper calorimeter

3. Fill the calorimeter with some cold water and find its mass again.
4. Now, put this calorimeter in the outer jacket.
5. Record the temperature of this cold water.
6. Observe that thermometer does not touch the sides or bottom of this calorimeter.
7. After determining the temperature of some hot water, check that its temperature should be in between 70°C–80°C.
8. Fill this water into the cold water already taken in calorimeter.
9. Gently, stir it with the help of stirrer and record the final temperature.
10. Determine the mass of calorimeter along with the mixture of cold water, hot water and stirrer using a physical balance.

Observations and Calculations

Reading of thermometer, $B = t_1\,°C$

Reading of thermometer, $D = t_2\,°C$

Correction to be applied to $B = (t_1 - t_2)°C$

Mass of calorimeter + stirrer (m) = ... g.

Mass of calorimeter + stirrer + cold water

(W_a) = ... g.

Corrected initial temperature of cold water

(t_b) = ... °C.

Corrected initial temperature of hot water

(t_a) = ... °C.

Final temperature of mixture (T) = ... °C.

Mass of calorimeter + stirrer + cold water + hot water

= .... g.

Mass of cold water

$(m_b) = (W_a - m)$ = ... g.

Mass of hot water

$(m_a) = (W_b - W_a)$ = ... g.

Specific heat of material of copper $= c$

$$c = \frac{m_a (t_a - T)}{m(T - t_b)} - \frac{m_b}{m}$$

= .... cal $g^{-1}\,°C^{-1}$

or .... J $kg^{-1}K^{-1}$

Actual value of specific heat of copper from standard table = ... J $kg^{-1}K^{-1}$.

Result

The specific heat capacity of material of calorimeter is .... cal $g^{-1}\,°C^{-1}$ or .... J $kg^{-1}K^{-1}$.

Precautions

1. The quantity of water in the calorimeter must not be more than about three-fourth.
2. Gently, stir the contents of calorimeter so that water does not splash out from calorimeter.
3. The correction of temperature should be applied.
4. Physical balance should be in proper working condition.

Experiment 9

Aim

To determine the specific heat of a metal by the method of mixtures.

Apparatus Required

Two half degree thermometers, fractional weights, weight box, burner, physical balance, a calorimeter with non conducting jacket, the given metal in the form of powder and hypsometer apparatus.

Theory/Principle Used

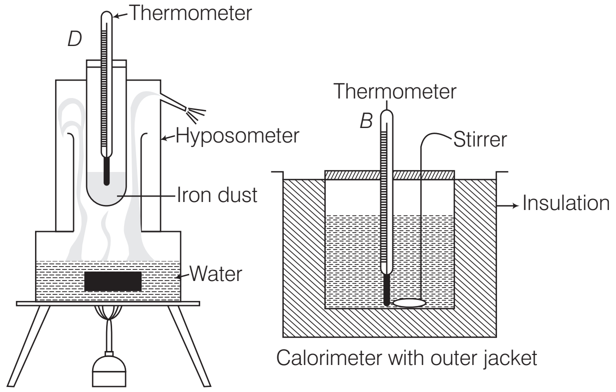
Specific heat of metal can be determined by the method of mixture. It is done when some hot metal is put into the water taken in the calorimeter, then the heat is lost by the metal and it is gained by water and calorimeter due to which its temperature rises.

So in case, if the heat is not allowed to radiate from the surface of calorimeter, then

heat lost by metal = heat gained by water and calorimeter

Procedure

1. Determine the room temperature with the help of thermometer B and D.



Calorimeter with outer jacket

2. Now, determine the mass of some metal powder by using the physical balance and fractional weights.
3. After putting the iron dust (metal powder) in the copper calorimeter, heat it till its temperature becomes constant as recorded by thermometer D. Record its temperature.
4. Now, find the mass of empty and dry calorimeter.
5. Fill the calorimeter with some cold water and again determine its mass.
6. Calculate the mass of water from the two readings calculated in step (4) and (5).
7. Record the initial temperature of water.
8. Now, place the calorimeter in the insulating jacket.
9. Immediately, transfer the hot iron dust into the calorimeter without any loss of time and stir it gently.
10. After this, note down the final maximum temperature of mixture of water and iron dust.
11. At last, note down the specific heat of copper from the standard table.

Observations and Calculations

Room temperature with thermometer, $B = T_a$

Room temperature with thermometer, $D = T_b$

Correction to be applied to thermometer,

$$B = T_a - T_b$$

Mass of iron dust (m) = ... g.

Corrected initial temperature of iron dust

(t') = ... °C.

Mass of empty calorimeter + stirrer

(W_a) = ... g.

Mass of calorimeter + water + stirrer

(W_b) = ... g.

Mass of water, $(m_a) = W_b - W_a$ = ... g.

Initial temperature of water

(t'') = ... °C.

Final temperature of mixture

(T) = ... °C.

Specific heat of copper (from standard table)

(c) = ... cal $g^{-1}\,{}^\circ C^{-1}$.

Water equivalent of calorimeter

$(W) = W_a \times c$ = ... g.

Fall in temperature of iron dust

$(t' - T)$ = ... °C.

Rise in temperature of water and calorimeter

$(T - t'')$ = ... °C.

Let specific heat of iron dust = c

Heat lost by iron dust = $ms(t' - T)$

Heat gained by water and calorimeter

$$= (m_a + W)(T - t'')$$

According to principle of calorimetry,

heat lost = heat gained

$$mc(t' - T) = (m_a + W)(T - t'')$$

$$c = \frac{(m_a + W)(T - t'')}{m(t' - T)} \text{ cal g}^{-1}\,^\circ\text{C}^{-1} = ..\text{J kg}^{-1}\text{K}^{-1}$$

Actual value from standard tables

= .... cal $g^{-1}\,^\circ C^{-1}$.

Percentage error

$$= \frac{\text{Difference between the calculated and actual value}}{\text{Actual value}} \times 100$$

= .... %

Result

The specific heat capacity of given metal piece by experiment is .... cal $g^{-1}\,^\circ C^{-1}$.

Precautions

1. Metal dust must be preferred on the place of metal piece.
2. The correction of temperature must be applied in both the readings of thermometer.
3. Calorimeter jacket must be in good condition.
4. During heating, stir the water, so that the temperature of water and metal must be same.

Experiment 10

Aim

To determine the specific latent heat of fusion of ice.

Apparatus Required

Fractional weights, weight box, a small piece of ice, calorimeter with non-conducting jacket, half degree thermometer, blotting papers and physical balance.

Theory/Principle Used

The amount of heat required to melt unit mass of ice at 0°C without any rise of temperature, is known as latent heat of fusion of ice. It is denoted by L.

Consider if mass m_a of ice is dipped into the water of mass m_b at temperature t_a, contained in a calorimeter of water equivalent W, the ice takes the heat from water for its melting. Assume T be the final temperature. So, if no heat is lost by the radiation, then according to the principle of calorimetry,

$$\text{heat gained} = \text{heat lost} \quad ...(i)$$

Heat gained by ice $= m_a L + m_a (T - 0)$

$$= m_a L + m_a T \quad ...(ii)$$

Heat lost by water and calorimeter

$$= (m_b + W)(t_a - T) \quad ...(iii)$$

From Eqs. (i), (ii) and (iii), we get

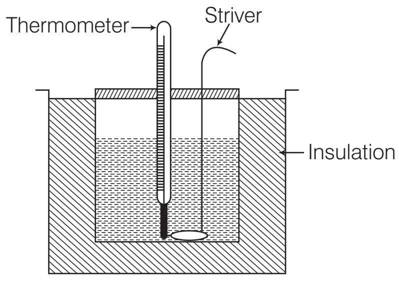
$$m_a L + m_a T = (m_b + W)(t_a - T)$$

$$\Rightarrow \quad L = \frac{(m_b + W)(t_a - T) - m_a T}{m_a}$$

By the above formula, the value of L can be calculated.

Procedure

1. Firstly, determine the mass of empty and dry calorimeter along with the stirrer.
2. Try to fill about half of calorimeter with water and determine its mass again with the help of a physical balance.



Calorimeter with outer jacket

3. Now, put this calorimeter in the insulating jacket.
4. By using a thermometer, determine the final temperature of water.
5. Dry the small piece of ice by placing it between the layers of blotting papers.
6. Immediately use the forceaps to put this ice into the calorimeter.
7. Gently, stir the water and keep on doing it till the whole of the ice melts.
8. Observe whether the temperature starts falling or not.
9. If it starts, then note down the final and minimum temperature of water when the whole of ice melts.

10. At last, determine the mass of calorimeter including the original water and melted ice using a physical balance.

Observations and Calculations

Mass of calorimeter (W) = ... g

Mass of calorimeter + Water (W_a) = ... g

Mass of water, $m_b = (W_a - W)$ = ... g

Initial temperature of water (t_a) = ... °C

Final temperature when whole ice melts

(T) = ... °C

Mass of calorimeter + Water + Ice (W_b) = ... g

Mass of ice $(m_a) = (W_b - W_a)$ = ... g

Specific heat of copper from standard table

(c) = ... cal $g^{-1}\,°C^{-1}$

Water equivalent $(W) = W \times c$ = ... g

Let latent heat of ice $= L$

$$\Rightarrow \qquad L = \frac{(m_b + W)(t_a - T) - m_a T}{m_a} \text{ cal g}^{-1}$$

= .... J kg^{-1}

Actual value from standard tables = ... J kg^{-1}

Percentage error

$$= \frac{\text{Difference between the actual and calculated values}}{\text{Actual value}} \times 100$$

= .... %

Result

The specific latent heat of fusion of ice = ... cal $g^{-1}K^{-1}$ or .... J $kg^{-1}K^{-1}$.

Precautions

1. It should be ensured that during transferring of water, no droplets of water in calorimeter should not get left.
2. During measurement of temperature, correction of thermometer must be applied.
3. In order to minimise the radiations of heat, calorimeter must be cleaned.
4. Final temperature must be recorded when it becomes steady.

Viva-Voce Based Questions

Q 1. Define calorimetry?

Ans. The branch of physics which deals with the measurement of heat energy, specific heat, latent heat, etc., of material, is known as calorimetry.

Q 2. State the relation between the units J $kg^{-1}K^{-1}$ and cal $g^{-1}\,°C^{-1}$.

Ans. $\because 1 \text{ cal g}^{-1}\,°\text{C}^{-1} = \dfrac{4.186 \text{ J}}{1 \text{ g}°\text{C}}$

$$= \frac{4.186 \text{ J}}{\frac{1}{1000} \text{ kg K}}$$

$\therefore 1 \text{ cal g}^{-1}\,°\text{C}^{-1} = 4186 \text{ kg}^{-1}\text{K}^{-1}$

Q3. Give reason of stirring water during the measurement of temperature?

Ans. Since, water is a bad conductor of heat. It is stirred by stirrer continuously, so that the temperature of whole water remains the same.

Q 4. Mention the latent heat of ice.

Ans. The latent heat of ice is 80 cal g^{-1}.

Q 5. State the principle of calorimetry.

Ans. According to the principle of calorimetry, "heat gained by one substance is always equal to the heat lost by the other substance," when they are mixed together provided that the heat is not lost to the surroundings by any other way.

Q 6. Give the SI unit of latent heat.

Ans. The SI unit of latent heat is J kg^{-1}.

Q 7. Define latent heat of fusion?

Ans. The amount of heat required to melt the unit mass of the substance at its melting point, is known as latent heat of fusion of that substance.

Q 8. Define the term "specific heat capacity".

Ans. The amount of heat required to raise the temperature of 1g of the body through 1°C, is known as specific heat capacity of the body.

Q 9. State whether the specific heat capacity is a constant quantity or not?

Ans. No, specific heat capacity is not a constant quantity because it varies from substance to substance and is constant for the given substance.

Q10. Define the term "water equivalent" of a body?

Ans. It is equal to the quantity of water which has the same thermal capacity as that of body. In practical, it is equal to the product of mass and specific heat.

Q11. Name the liquid which has highest specific heat capacity.

Ans. Water has the highest specific heat capacity.

Q 12. When heat is transferred between substance, a final temperature is attained by the substance. What is the name of this final temperature?

Ans. The name of this final temperature is equilibrium temperature.

Q 13. Ice cream at 0°C is colder than water at 0°C, Why?

Ans. It is because ice cream can extract 80 cal/g more heat from mouth as compared to that of water at 0°C.

Q 14. Which metal used to make a calorimeter?

Ans. Copper is used to make a calorimeter.

Q 15. Why is calorimeter made of copper?

Ans. Because copper is a very good conductor of heat.

Experiment 11

Aim

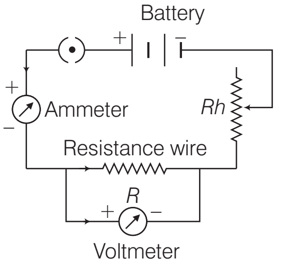
To verify Ohm's law and hence find the value of unknown resistance.

Apparatus Required

A resistance wire, dry cells, key, voltmeter of range 0-15 V, ammeter of range 0-1.5 A, rheostat, connecting wires and sand paper.

Theory/Principle Used

As, per the Ohm's law, if the physical conditions like length, breadth, temperature, etc., of a conductor are constant, then the current flowing through the conductor in a closed circuit is directly proportional to the potential difference across its two ends.



Circuit diagram

$$\therefore \quad I \propto V \Rightarrow \frac{V}{I} = \text{constant} = R \text{ (say)} \Rightarrow R = \frac{V}{I}$$

where, R is a constant for a conductor and is known as resistance of conductor.

The property of a conductor which opposes the flow of current (I) in the conductor or increases the potential difference (V) across its ends, is known as resistance of conductor. The SI unit of resistance is Ohm (Ω).

Since, $\frac{V}{I} = R$

where, R is a constant.

Therefore, the I *versus* V graph will be a straight line, also the components that conducts the current in accordance with Ohm's law are said to be Ohmic.

Procedure

1. Firstly, arrange the apparatus on the table and make the circuit connections as shown in the above circuit diagram.
2. With the help of connecting wires, connect the ammeter in series and voltmeter in parallel with the resistance.
3. Record the least count and zero errors of voltmeter and ammeter.
4. After inserting the plug key, adjust the rheostat in order to register a small current in the resistance wire.
5. Now, note down the corresponding ammeter and voltmeter readings.
6. In order to increase, the current in the regular steps, move the variable terminal of the rheostat and note down the ammeter and voltmeter readings.
7. To have the different sets of observations, take more readings.
8. Lastly, draw the graph between voltage (V) and current (I), find its slope.

Observations

1. Range of ammeter = ... A
2. Least count of ammeter = ... A
3. Zero error of ammeter = ... A
4. Range of voltmeter = ... V
5. Least count of voltmeter = ... V
6. Zero error of voltmeter = ... V
7. Correction applied to the ammeter = ... A
8. Correction applied to the voltmeter = ... V

Observation table for calculating the resistance

S. No.	Reading of Ammeter (I)		Reading of Voltmeter (V)		Resistance, $R = V/I$ (ohm)
	Observed	Corrected (A)	Observed	Corrected (A)	
(i)					R_a = ...
(ii)					R_b = ...
(iii)					R_c = ...
(iv)					R_d = ...

Calculations

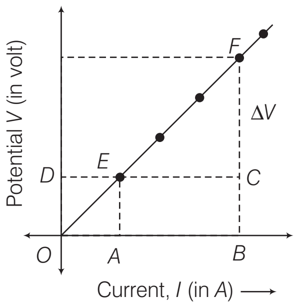
Mean value of resistance,

$$R = \frac{R_a + R_b + R_c + R_d}{4} = ...\Omega$$

Graph

Plot a graph between the voltage (V) and the current (I) by taking V along Y-axis and I along X-axis.

Here, we will find that



$$\text{Slope} = \frac{FC}{EC} \Rightarrow R = \frac{FC}{EC} = \frac{\Delta V}{\Delta I} \Rightarrow R = \frac{\Delta V}{\Delta I} = ...\Omega$$

Result

The graph of V *versus* I is a straight line. It shows that

$V \propto I$ which proves Ohm's law.

From observation table, resistance of a conductor

= .... Ω

From graph, resistance of a conductor

= .... Ω

Precautions

1. The end of the connecting wires should be rubbed with the sand paper.
2. The emf of the cell should be less than the range of the voltmeter.
3. In order to avoid heating of conductor, fan should be used.
4. The key should be removed for sometime and then reconnect while taking the reading so that the resistance wire becomes cold.
5. While making the connections, join the positive ends of ammeter and voltmeter with the positive terminal of the body.
6. A rheostat of low resistance should be used.

Viva-Voce Based Questions

Q 1. Define the term "current".

Ans. Current can be defined as rate of flow of charge.

Q 2. What is meant by the thick connecting wire are used?

Ans. Since, thin wires have higher resistance while the thick wires have low resistance which will not affect the result. Hence, they are used as connecting wires.

Q 3. What is meant by the term "resistance of a conductor"?

Ans. The property of conductor which opposes the flow of current through it, is known as the resistance of a conductor.

Q 4. State the function of rheostat.

Ans. Rheostat is a device which is used to provide variable resistance in a circuit.

Q 5. What is meant by one ohm?

Ans. If current passing through the resistance is one ampere and potential difference between the ends of a conductor is one volt, then the resistance of conductor is said to be one ohm.

Q 6. Is it possible to have a negative resistance?

Ans. Resistance can be negative if on increasing the potential, its current decreases. It may be in semiconductor devices like transistors, etc.

Q 7. State how resistance of a conductor can be increased?

Ans. *Resistance of a conductor increases on*

(i) increasing the length of conductor.
(ii) decreasing area of cross-section.
(iii) increasing the temperature of conductor.

Q 8. What is the meaning of cell or a battery?

Ans. Cell or a battery is a device in which potential difference between the two points or terminals is maintained by either chemical reaction or generator.

Q 9. State any one limitation of Ohm's law.

Ans. It is not applicable for diode, triode or where temperature resistance is high like bulbs.

Q 10. If a wire of resistance 2 Ω is stretched to double its length, what will be its new resistance?

Ans. If a wire of resistance 2 Ω is stretched to double its length, then its new resistance will be 8 Ω.

Q11. Do the resistance of a conductor vary with temperature?

Ans. Yes, resistance of a conductor varies with temperature. It increases with rise of temperature.

Experiment 12

Aim

To set up a model of household wiring circuit including main wiring circuit and to study the functions of switches and fuse.

Apparatus Required

Plugs, bulb, bulb holder switch (30 A, 20 A, 15 A, 5 A, 5 A), three core electric wire, brown colour, black colour, green colour wire with yellow strip, five fuses (25 A, 15 A, 10 A, 5 A, 5 A), plugs, wall socket, tester and tools, etc.

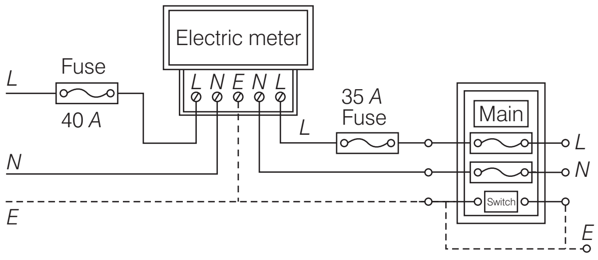
Theory/Principle Used

A ring system of wiring is followed in the household circuiting. In this system, the three wires, live, neutral and Earth as separate wires runs from the main switch to different rooms or parts of a house and ends again at main switch from where it starts.

A separate fuse wire (MCB) is connected to a room or a part of house for the power supply to all appliances of a room or part. Also, all connections of room are in parallel and all switches and fuses are in series.

The responsibility of electric power supply to the consumer is undertaken by the state electricity board. It provides the power supply upto the input and output of electric meter with two fuses in series one input other input of live wire or phase wire. The cable from pole to electric meter and wires in the house wiring has following codes of colour.

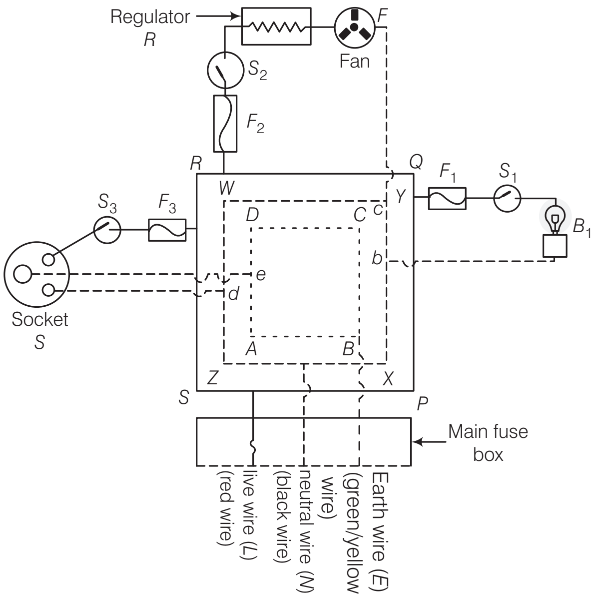
Type of Wire	Colour of Insulation	
	Old Convention	International Colour Coding
Live	Red	Brown
Neutral	Black	Light blue
Earth	Green	Green with yellow strip or *vice-versa*



Main switch wiring

Procedure

1. By taking a panel board, spread the red coloured wire in a from of a sing *PQRS*. Its terminal will be used as live wire.
2. Now, use black coloured wire and spread it in the form of another ring *XYWZ*. Then, connect a wire at any point on the ring and the other terminal to the main fuse as shown in the figure given below. This black wire will be used as neutral wire.
3. Next, take a yellow coloured wire and spread in the form of ring *ABCD*. connect a wire to the main fuse as shown in the figure. This yellow wire will be used as Earth wire.
4. Take some copper wire with proper insulation with the *PVC* as covers red, black and yellow.
5. Using red wires, make a connection with one terminal of fuse F_1 and its another terminal to one terminal of switch S_1 as shown in the figure.



6. Then, connect the second terminal by switch S_1 to one terminal of bulb B_1 and another terminal of this bulb to any point on the sing *XYWZ* using block wires.
7. Similarly make other connections of regulator, fan, socket and switches as given in the figure.
8. Connect the terminals *S*, *L*, *N* and *E* to the source of alternating current i.e., AC mains.

Observations

Function of Switches

S.No.	Switch	ON/OFF	Bulb, B_1	Fan, *F*	Appliance connected to the socket *S*
(i)	S_1	ON	ON	OFF	OFF
(ii)	S_2	ON	OFF	ON	OFF
(iii)	S_3	ON	OFF	OFF	ON
(iv)	S_1 and S_2	ON	ON	ON	OFF
(v)	S_2 and S_3	ON	OFF	ON	ON
(vi)	S_1 and S_3	ON	ON	OFF	ON
(vii)	S_1, S_2 and S_3	ON	ON	ON	ON

Function of Fuse

When switches S_1, S_2 and S_3 are ON.

S.No.	Fuse blown	Bulb, B_1	Fan, *F*	Appliance connected with socket, *S*
(i)	F_1	OFF	ON	ON
(ii)	F_2	ON	OFF	ON
(iii)	F_3	ON	ON	OFF
(iv)	F_1 and F_2	OFF	OFF	ON
(v)	F_2 and F_3	ON	OFF	OFF
(vi)	F_1 and F_3	OFF	ON	OFF
(vii)	F_1, F_2 and F_3	OFF	OFF	OF

Result

All the electrical appliances example fans, bulbs, etc when connected in parallel combination can operate at the same voltage. Also, they can be operated independently.

Precautions

1. All the connection should be made light.
2. Use sand paper to clean the ends of the wires for proper connections.
3. Use fuse of proper rating.
4. Always covers the connections with an electric insulation tape.

Viva-Voce based Questions

Q 1. What is the potential difference between live wire and neutral wire in domestic power supply?

Ans. In India, the potential difference between the live wire and the neutral wire is 220 V.

Q 2. How are lamps or bulbs or fans connected in a homes?

Ans. All the electrical appliances in a house are connected in parallel combination.

Q 3. Name the device which is used to protect the electric circuits from overloading and short circuits.

Ans. Electric fuse is used to protect overloading and short circuits.

Q 4. State the feature why tungsten filament is used on bulbs.

Ans. As, tungsten has high resistivity and very high melting point.

Q 5. Name the wire (live or neutral) through wire electric fuse is connected in circuits.

Ans. Live wire is used to connect fuse in circuits.

Q 6. What is the unit of electrical energy?

Ans. The unit of electrical energy is kwh (Kilowatt hour).

Q 7. What is an electric meter?

Ans. It is device used in houses to measure the electrical energy used.

SAMPLE QUESTION PAPERS (1-5)

&

LATEST ICSE SPECIMEN QUESTION PAPER

SAMPLE QUESTION PAPER 1

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS X

PHYSICS (FULLY SOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

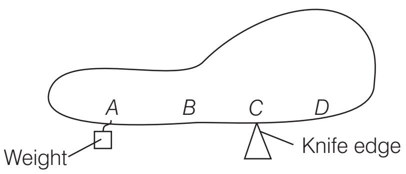
Time : 2 Hrs **Max. Marks : 80**

Section-A [40 *Marks*]

1. (a) Seema tried to push a heavy rock of 100 kg for 200 s but could not move it. Find the work done by Seema at the end of 200 s. ***[2]***

(b) A ray of light travelling in air is incident on a rectangular glass slab. What will happen? ***[2]***

(c) (i) A pivot balances a non-uniform object on a knife-edge. To do this, a weight is suspended from the left-hand end of the object.



Where is centre of gravity of the object?

(ii) What is the direction of moment generated due to the weight? ***[2]***

(d) What do you understand by the clockwise and anti-clockwise moment of force? When is it taken positive? ***[2]***

(e) Compute the speed of 2 kg ball having kinetic energy of 4 J. ***[2]***

2. (a) What should be the angle between force and displacement to get the work? ***[2]***

(i) Maximum (ii) Minimum

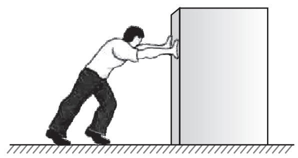
(b) What kind of energy is possessed by a body in following cases.

(i) A moving bullet (ii) A spinning top? ***[2]***

(c) At the bottom of the waterfall, water is warmer than at the top. Give reason. ***[2]***

(d) During the motion of a planet around the Sun, what is the nature of centripetal force? ***[2]***

(e) A man pushes a heavy box across a floor. He exerts a force of 80 N and the box moves 4.0 m in 5.0 s.



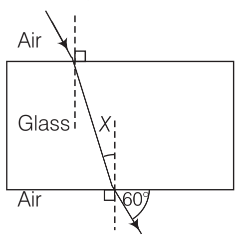
What useful power does the man develop? ***[2]***

3. (a) (i) Explain, why the mechanical advantage is less than one in class III types of lever.

(ii) Define the term "driving gear" in reference to gear system. ***[2]***

(b) For a certain parallel-sided glass block, the value of $\frac{\sin i}{\sin r}$ is 1.50.

A ray of light passes through the block and emerges at an angle 60° to the surface of the block.



What is the value of the angle marked X? ***[2]***

(c) (i) What do you mean by resonance?

(ii) How does the medium affect the amplitude of free vibrations? ***[2]***

(d) An electrician puts a fuse of rating 5A in that part of domestic electrical circuit in which an electric heater of rating 1.5 KW, 220 V is operating. What is likely to happen in this case and why? **[2]**

(e) (i) What is the range of the wavelength of the γ-radiations?

(ii) Name the radiation which can be detected by a thermopile. **[2]**

4. (a) Define the terms (i) Heat capacity and (ii) Specific heat capacity. **[2]**

(b) State what would happen to the direction of rotation of a motor, if

(i) the current were reversed?

(ii) both current and magnetic field were reversed simultaneously? **[2]**

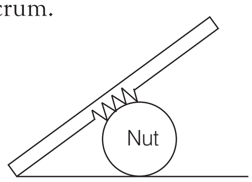
(c) An electric lamp uses energy at the rate of 48 W on a 12 V supply. How much charge passes through the lamp in 2.0 s? **[2]**

(d) What is the principle of electric motor? **[2]**

(e) A magnetic compass shows a deflection when placed near a current carrying wire. How will the deflection of the compass get affected, if the current in the wire is increased? Support your answer with a reason. **[2]**

Section-B [40 *Marks*]

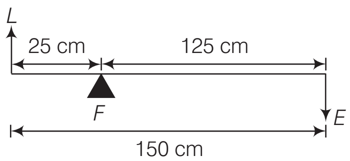
5. (a) The diagram shows a type of nut cracker. In diagram, show with the letter *F*, the position of the fulcrum.



[3]

(b) (i) Define power and state its SI units.

(ii) A crowbar of total length 150 cm is at a distance of 25 cm from the load. What is the mechanical advantage of this crowbar?



[3]

(c) A body of mass 50 kg has a momentum of 3000 kgms^{-1}. Calculate

(i) the kinetic energy of the body

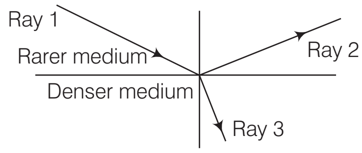
(ii) the velocity of the body. **[4]**

6. (a) (i) State two advantages of using a right-angled prism over plane mirror in periscope.

(ii) What is meant by the statement "the critical angle of diamond is 24°"? **[3]**

(b) (i) The velocity of light in air is 3×10^8 m/s. Find the velocity of light in a medium of refractive index 1.5.

(ii) A ray of light moves from a rarer medium to a denser medium as shown in the diagram below. Write down the name of the ray which represents the partially reflected ray. **[3]**



(c) A ray of monochromatic light is incident from air on a glass slab.

(i) Draw a labelled ray diagram showing the change in the path of the ray till it emerges from the glass slab.

(ii) Name the two rays that are parallel to each other.

(iii) Mark the lateral displacement in your diagram. **[4]**

7. (a) (i) Draw a diagram to show the propagation of sound and denote compression and rarefaction.

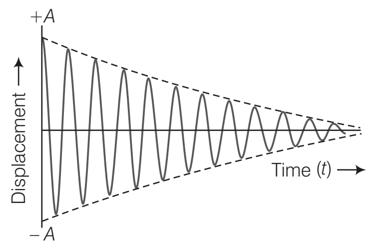
(ii) State the conditions required to hear an echo. **[3]**

(b) On sending an ultrasonic wave from a ship towards the bottom of a sea, the time interval between sending the wave and receiving it back is found to be 1.5 s. If the velocity of wave in sea water is 1400 ms^{-1}.

(i) Write the formula for distance.

(ii) Find the depth of the sea. **[3]**

(c) The diagram below shows the displacement-time graph for a vibrating body.



The amplitude displacement decreases exponentially with time

(i) Name the type of vibrations produced by the vibrating body.

(ii) Give one example of a body producing such vibrations.

(iii) Why is the amplitude of the wave gradually decreasing?

(iv) What will happen to the vibrations of the body after sometime? **[4]**

8. (a) (i) What is the purpose of a fuse in an electrical circuit?

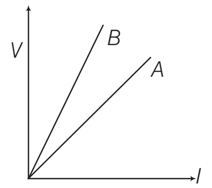
(ii) Why is it more economical to transmit electrical energy at high voltage and low current?

(iii) State one ways by which the emf in an AC generator can be increased. *[3]*

(b) The *V-I* graph for a series combination and for a parallel combination of two resistors is as shown in the figure below.

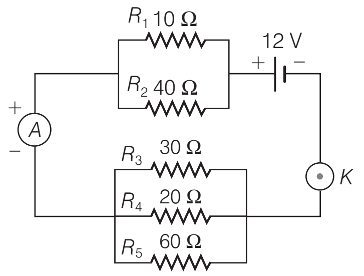
(i) Which of the two *A* or *B*, represents the parallel combination?

(ii) Give a reason for your answer.



(iii) What is the SI unit of electrical power? Name the unit in which electric energy consumed for domestic or commercial purposes is measured. *[3]*

(c) Five resistors of different resistance are connected together as shown in the figure. A 12 V battery is connected to the arrangement. Calculate



(i) the total resistance in the circuit.

(ii) the total current flowing in the circuit. *[4]*

9. (a) Name the radiations for which the green house gases are

(i) transparent and

(ii) opaque. *[3]*

(b) State in brief, the meaning of each of the following

(i) The specific latent heat of fusion of ice is 336000 J kg^{-1}.

(ii) The specific heat capacity of copper is 0.4 J g^{-1}°C^{-1}.

(iii) What is the principle of method of mixtures?

(iv) Name the law on which this principle is based. *[3]*

(c) A piece of ice of mass 15 g is added to water of mass 100 g in a Cu calorimeter of mass 50 g. The temperature of water is 15° C but falls to 3° C, after the addition of ice. Calculate the latent heat of fusion of ice. (Take, specific heat of Cu = 0.42 J/g°C and specific heat of water = 4.2 J/g°C) *[4]*

10. (a) (i) Name the principle on which a transformer works.

(ii) What is the function of a step-up transformer?

(iii) Can transformer work when it is connected to a DC source? Give reason. *[3]*

(b) (i) What do you mean by radioactivity ? What type of radiations are emitted in it? Explain briefly the nature of these radiations.

(ii) An atomic nucleus denoted by $^{A}_{Z}X$ emits an alpha particle.

Write an equation to show the formation of the daughter product. *[3]*

(c) (i) A fusion reaction is represented as follows

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{4}_{2}He + X$$

Identify X.

(ii) When do α and β-emissions take place?

(iii) Explain, how β-emission changes the nucleus of an unstable element? *[4]*

ANSWERS

1. (a) Work done by Seema in pushing a rock for 200 s is zero. Because there is no displacement in this case, i.e.,

$$W = F \times s = 0 \qquad (\because s = 0)$$ *[2]*

(b) A ray of light passing through a rectangular glass slab undergoes two refractions and it emerges from opposite side of the slab in a direction parallel to the direction of incident light. The emergent ray is displaced laterally. *[2]*

(c) (i) For the system to balance, the sum of moment of anti-clockwise direction has to be equal to the sum of moment of clockwise direction. The weight in this case is generating moment in anti-clockwise direction. *[1]*

Therefore, centre of gravity must be situated at right side (*D*), so that it produces clockwise moment.

(ii) The weight in this case is generating anti-clockwise moment. *[1]*

FULLY SOLVED

(d) **Clockwise Moment of Force** When the moment of force produces rotation in the clockwise direction.

Anti-clockwise Moment of Force When the moment of force produces rotation in anti-clockwise direction.

It is taken positive for anti-clockwise moment. ***[2]***

(e) Given, mass of ball, $m = 2$ kg

Kinetic energy of ball, KE = 4 J

As, $\text{KE} = \frac{1}{2} mv^2$

$\Rightarrow \quad v^2 = \frac{2\,\text{KE}}{m} = \frac{2 \times 4}{2} = 4 \Rightarrow v = 2\ \text{ms}^{-1}$ ***[2]***

2. (a) (i) If $\theta = 0°$, i.e., the angle between the force F and the displacement s is in the same direction.

$\therefore$ Work done, $W = Fs \cos 0°$

$\Rightarrow W = Fs = \text{maximum} \quad (\because \cos 0° = 1)$ ***[1]***

(ii) If $\theta = 90°$, i.e., the force under consideration is normal to the direction of motion.

$\therefore$ Work done, $W = Fs \cos 90°$

$\Rightarrow \quad W = 0 = \text{minimum} \quad (\because \cos 90° = 0)$ ***[1]***

(b) (i) Translational KE (ii) Rotational KE ***[2]***

(c) When water falls on the ground, its mechanical energy (KE + PE) is converted into heat energy, due to which the temperature of water at the bottom of the waterfall increases. ***[2]***

(d) During the motion of the planet, centripetal force is provided by gravitational force of attraction which is directed towards the centre of the circular path. ***[2]***

(e) Power is defined as the rate of work done.
It may be calculated by

$$p = \frac{W}{t}$$

Given, $t = 5.0$s, $W = F \times d = (80)(4.0) = 320$J ***[1]***

Note Students need to know that work done = force × distance moved in the direction of the force.

$\therefore$ Power developed by the man, $P = \frac{320}{5} = 64$ W ***[1]***

3. (a) (i) Mechanical advantage,

$$\text{MA} = \frac{\text{Effort arm length}}{\text{Load arm length}}$$

In class III order of lever,
effort arm length < load arm length

$\therefore \quad \text{MA} < 1$ ***[1]***

(ii) The gear wheel closer to the source of power is called driving gear. ***[1]***

(b) Using the reversibility of light and considering the air-glass boundary,

$$i = (90° - 60°) = 30°$$ ***[1]***

Since, $X = r$

$$\sin X = \frac{\sin 30°}{1.5} = 0.333$$

$\therefore \quad X = 19.5°$ ***[1]***

(c) (i) It is a special case of forced vibrations. When the natural frequency of body and frequency of the externally applied periodic force are equal, then the body vibrates with an increased amplitude. ***[1]***

(ii) Amplitude of free vibration decreases due to the force of friction between vibrating body and medium particles. ***[1]***

(d) Given, $P = 1.5\ \text{kW} = 1.5 \times 10^3$ W

$V = 220$ V

$\therefore$ The current drawn by heater, $I = \frac{P}{V}$

$$= \frac{1.5 \times 10^3}{220\ \text{V}} = 6.8\ \text{A}$$ ***[1]***

The above amount of current is greater than the rated value of fuse current. Hence, the fuse will melt and break the circuit. ***[1]***

(e) (i) Range of wavelength for γ-radiations is 10^{-3} Å to 0.1 Å. ***[1]***

(ii) Radiation detected by thermopile is infracted radiation. ***[1]***

4. (a) (i) **Heat Capacity** It is the amount of heat required to raise the temperature of a body by 1°C. Its unit is J°C^{-1}. ***[1]***

(ii) **Specific Heat Capacity** It is the amount of heat required to raise the temperature of unit mass of a substance through 1°C. Its unit is J kg^{-1}°C^{-1}. ***[1]***

(b) (i) Direction of rotation would be reversed. ***[1]***

(ii) Direction of rotation would remain unchanged. ***[1]***

(c) Current through the lamp,

$$I = \frac{P}{V} = \frac{48}{12} = 4.0\ \text{A}$$ ***[1]***

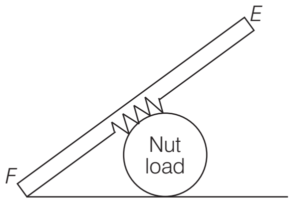
$\therefore$ Charge passing through the lamp,

$$Q = It = (4.0)\ (2.0)$$
$$= 8.0\ \text{C}$$ ***[1]***

(d) An electric motor is based on the principle that, when a rectangular coil is placed in a magnetic field and current is passed through it, two equal and opposite forces (on opposite side) act on coil which rotates it continuously. ***[2]***

(e) If the current in the wire is increased, then the deflection increases. The strength of magnetic field is directly proportional to the magnitude of current passing through the straight conductor. ***[2]***

5. (a) *The diagram showing fulcrum (F) and effort (E) is given below*



[3]

(b) (i) The rate of doing work is called power.

It is given as, Power $= \dfrac{\text{Work done}}{\text{Time taken}}$

Its SI unit is watt (W). **[1½]**

$$1\text{ W} = 1\text{ Js}^{-1}$$

(ii) We have, $L \times 25 = E \times 125$

Mechanical Advantage,

$$\text{MA} = \frac{\text{Effort arm length } (d_E)}{\text{Load arm length } (d_L)} = \frac{125}{25} = 5$$

$\text{MA} = 5$ **[1½]**

(c) (i) $\text{KE} = \dfrac{p^2}{2m} = \dfrac{3000 \times 3000}{2 \times 50} = 90000\text{ J}$

(ii) $p = mv$

where, p = momentum

and m = mass of the body.

Here, $m = 50$ kg and $p = 3000$ kg ms^{-1}

$\therefore \quad 3000 = 50 \times v \Rightarrow \dfrac{3000}{50} = v$

$\Rightarrow \quad v = 60$ m/s **[2×2]**

6. (a) (i) • The image is brighter and sharper as there is 100% reflection.

• Presence of moisture and dust on the glass does not affect the clearity of image.

(ii) When light travels from diamond to air, at an angle of incidence of 24°, the corresponding angle of reflection is 90°. **[1½ × 2]**

(b) (i) Given, velocity of light in air $(c) = 3 \times 10^8$ m/s

As we know,

Refractive index (μ)

$$= \frac{\text{Velocity of light in air}}{\text{Velocity of light in a medium}}$$

$\Rightarrow$ Velocity of light in a medium

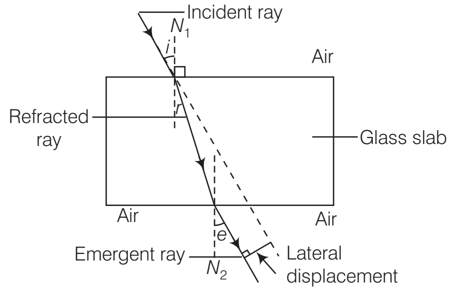
$$= \frac{\text{Velocity of light in air}}{\text{Refractive index}}$$

$$= \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ m/s}$$

[2]

(ii) Ray 2 represents partially reflected ray. **[1]**

(c)



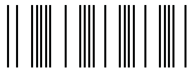
[3]

Incident ray and emergent ray are parallel to each other. **[1]**

7. (a) (i) *Propagation of sound waves are as follows*

Compression $\rightarrow B, D, F$

Rarefaction $\rightarrow A, C, E, G$



[1]

(ii) *The condition required to hear echo is as follows*

- The time interval between source sound and reflected sound must be atleast 0.15s.
- The minimum distance between the obstacle and source of sound should be atleast 17.2 m. **[2]**

(b) Let, depth of sea $= d$ metre

$\therefore$ Total distance travelled by ultrasonic wave before it is received back at the ship $= 2d$ m

Time taken = 1.5s **[1]**

Velocity of ultrasonic wave in sea-water

$= 1400$ ms^{-1} **[1]**

As, we know, distance = velocity × time

$\therefore \quad 2d = 1400 \times 1.5$ or $d = \dfrac{1400 \times 1.5}{2}$ m $= 1050$ m **[1]**

(c) (i) Damped vibrations are produced by the vibrating body. **[1]**

(ii) A simple pendulum oscillating in air, tuning fork vibrating in air are examples of a body producing such vibrations. **[1]**

(iii) The amplitude of the wave gradually decreasing due to friction as energy is continuously losing. **[1]**

(iv) Its amplitude decreases and finally stops. **[1]**

8. (a) (i) The electric fuse is a device, to limit the current in an electric circuit so that the appliances connected in the circuit may be safeguarded from over loading or short circuiting.

(ii) The loss of energy along the transmission liens is proportional to the square of current, hence the transmission of energy is economical at high voltage and low current.

(iii) In an AC generator, emf can be increased by increasing the strength of the magnetic field. **[1×3]**

(b) (i) Graph A represents parallel combination of resistance.

(ii) Since, the slope of A is less steeper than B, so the graph A represents less resistance. In parallel combination the resistance decreases, so A represents the parallel combination of two resistors.

(iii) SI unit of electrical power is watt. Electrical energy is measured in kilo-watt hour. **[1×3]**

(c) (i) $\frac{1}{R_{12}} = \frac{1}{10} + \frac{1}{40} = \frac{4+1}{40} = \frac{5}{40} = \frac{1}{8}$

$$\Rightarrow \quad R_{12} = 8\,\Omega$$

$$\frac{1}{R_{345}} = \frac{1}{30} + \frac{1}{20} + \frac{1}{60} = \frac{2+3+1}{60}$$

$$\Rightarrow \quad \frac{1}{R_{345}} = \frac{6}{60} = \frac{1}{10} \Rightarrow R_{345} = 10\,\Omega$$

Total resistance, $R = R_{12} + R_{345}$

$$= 8 + 10 = 18\,\Omega$$ **[2]**

(ii) Total current, $I = \frac{V}{R} = \frac{12}{18} = \frac{2}{3} = 0.67$ A **[2]**

9. (a) (i) Green house gases are transparent to short wavelength infrared radiations from the Sun. **[1½]**

(ii) Green house gases are opaque to long wavelength infrared radiation emitted by the hot surface of the Earth. **[1½]**

(b) (i) 336000 J kg^{-1} means that every 1 kg of ice will require 336000 J of heat energy to melt and form water without change in its temperature.

(ii) 0.4 Jg^{-1}°C^{-1} means that 1 g of copper will require 0.4 J of heat energy to raise its temperature by 1°C.

(iii) When a hot body is mixed or kept in contact with a cold body, there is a transfer of heat from the body at higher temperature to a body at lower temperature till both the bodies attain the same temperature, i.e., heat lost by the hot body is equal to the heat gained by the cold body provided there is no heat loss to the surroundings.

(iv) Law of conservation of energy. **[3]**

(c) Let the latent heat of fusion of ice be L J/g.

Heat lost by water $= 100 \times 4.2 \times (15 - 3)$ J

Heat lost by calorimeter $= 50 \times 0.42 \times (15 - 3)$

Total heat lost by water and calorimeter

$$= (100 \times 4.2 \times 12) + (15 \times 0.42 \times 12)$$

Heat gained by ice at 0 degrees $= 15\,L$

Heat gained by water formed from ice

$$= 15 \times 4.2 \times (3 - 0)\text{ J}$$

Total heat gained $= (15\,L) + (15 \times 4.2 \times 3)$

Since, heat gained = heat lost **[2]**

We have, $(100 \times 4.2 \times 12) + (15 \times 0.42 \times 12)$

$$= (15L) + (15 \times 4.2 \times 3)$$

$$189 + 15L = 252 + 5040$$

$$15L = 5292 - 189 = 5103 \quad \Rightarrow L = \frac{5103}{15} = 340.2$$

J/g **[2]**

10. (a) (i) A transformer works on the principle of electromagnetic induction. **[1]**

(ii) A step-up transformer convert a low AC voltage to a high AC voltage. **[1]**

(iii) No, as DC source provides a steady voltage, due to which there will be zero change in magnetic flux across the secondary coil. Hence, transformer cannot work when it is connceted to a DC source. **[1]**

(b) (i) Radioactivity is the process of spontaneous disintegration of the atomic nuclei with the emission of particles from within the nuclei of atoms. Experimental investigations reveal that the radiations emitted by radioactive elements are of three types: First type of radiations with least penetrating power was named as α-rays.

Second type of radiations with comparatively larger penetrating power was called β-rays.

Third type of radiations with maximum penetrating power was called γ-rays. **[2]**

(ii) When α-particle is emitted from a parent atom $^{A}_{Z}X$, it gives rise to daughter nucleus $^{(A-4)}_{(Z-2)}Y$, α-particle and some energy.

$$^{A}_{Z}X \rightarrow {}^{(A-4)}_{(Z-2)}Y + {}^{4}_{2}\text{He} + \text{energy}$$ **[1]**

(c) (i) $^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + 24$ MeV

X represents the energy produced by fusion of two $^{2}_{1}$**H** atoms, which is 24 MeV.

(ii) If an unstable nucleus contains excess of neutrons or protons is emits α-emissions.

If an unstable nucleus contains more neutrons than protons, it emits β-emissions.

(iii) In emitting a β-particle, the mass number of the nucleus remains same but the number of neutrons decrease by one and number of protons, i.e., atomic number increase by one. Thus, the element moves forward one place in the periodic table. **[4]**

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SAMPLE QUESTION PAPER 2

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS X

PHYSICS (FULLY SOLVED)

GENERAL INSTRUCTIONS

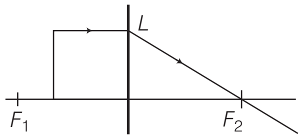
1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

Section-A [40 *Marks*]

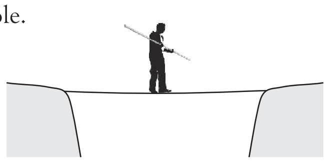
1. (a) A girl of mass 20 kg is sitting at a distance of 3 m from the middle of a see-saw. Where should a girl of mass 30 kg sit so as to balance the see-saw? ***[2]***

(b) (i) Study the given diagram and answer the given questions: Name the lens L and also name the points F_1 and F_2.



(ii) Name a common device that uses electromagnet. ***[1 + 1]***

(c) (i) A man walks along a tight rope, carrying a long pole.



Why does he carry the pole?

(ii) State the principle of moments. Give one device as an application of it. ***[2]***

(d) (i) State one way to reduce the moment of given force about a given axis to rotation.

(ii) Is it possible to have an accelerated motion with speed? Name such type of motion. ***[2]***

(e) (i) Write one condition to make a body more stable.

(ii) In which type of equilibrium is a cone resting on its base? ***[2]***

2. (a) Write the work done by a force, when

(i) there is no displacement and

(ii) displacement is normal to force. ***[2]***

(b) What kind of energy is associated with

(i) a compressed spring and

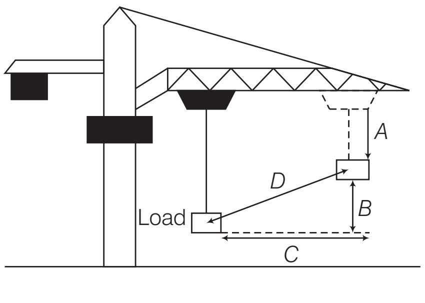
(ii) a body who is running. ***[2]***

(c) (i) Foot treadle is an example for which kind of lever?

(ii) What is the CGS unit of energy? ***[2]***

(d) Differentiate between centripetal and centrifugal force. ***[2]***

(e) A crane moves its load diagonally, as shown. By which distance must the weight of the load be multiplied in order to find the increase in gravitational potential energy of the load? ***[2]***



3. (a) (i) Which type of lever has a mechanical advantage always more than one?

(ii) What is the principle of an ideal machine? ***[2]***

(b) A ray of light travels from air into glass. The refractive index of the glass is 1.5.

FULLY SOLVED

Which of the following pairs could be values of the angle of incidence and the angle of refraction?

	Angle of incidence	Angle of refraction
A	21.5°	20.0°
B	10.0°	.60.0°
C	60.0°	35.3°
D	80.0°	53.3°

[2]

(c) (i) State the way to increase the frequency of vibration in air column.

(ii) Write one condition for a body to execute free vibration. ***[2]***

(d) (i) What is the commercial unit of electric energy?

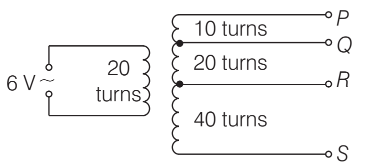
(ii) Which part of an electrical appliance is earthed? ***[2]***

(e) (i) Give one use of γ -rays.

(ii) Name the region beyond the violet end of electromagnetic spectrum. ***[2]***

4. (a) Explain, how does the volume of ice change when it is heated from 0°C to 10°C? ***[2]***

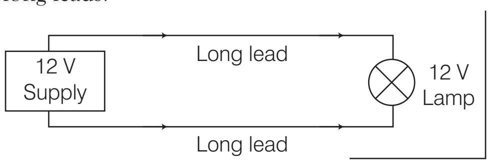
(b) (i) The number of turns between each pair of output terminals of a transformer is shown in the diagram.



Between which two terminals will the output be 12 V ?

(ii) State the polarity of the terminal obtained in (i). ***[2]***

(c) A 12 V lamp is connected to a 12 V supply using very long leads.



Why does the lamp glow dim? ***[2]***

(d) Represent AC and DC graphically. ***[2]***

(e) (i) Which radiation produces maximum biological damage?

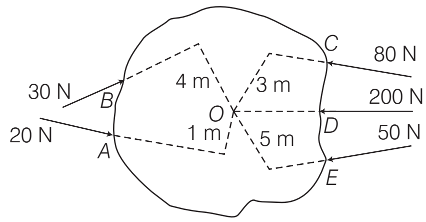
(ii) What happens to the atomic number of an element, when the radiation named by you in part (i) is emitted? ***[2]***

Section-B [40 *Marks*]

5. (a) Draw a diagram to illustrate the position of fulcrum, load and effort in working of scissors. ***[3]***

(b) (i) Give the energy conversion taking place in a microphone.

(ii) Calculate the resultant torque from the following diagram. ***[3]***



(c) A block and tackle system has 5 pulleys, if an effort of 1000 N is in the downward direction to raise a load of 4500 N.

Calculate

(i) the mechanical advantage and the velocity ratio.

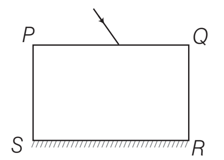
(ii) the efficiency of the system. ***[4]***

6. (a) (i) What is meant by "dispersion of light"?

(ii) In the atmosphere which colour of light gets scattered the least? ***[3]***

(b) (i) The diagram below shows a ray of white light which is incident on a rectangular glass block, silvered at one surface. The ray is partly reflected and partly refracted.

Draw a ray diagram to show these rays.



Silvered surface

(ii) On what factors does the critical angle for a given pair of media depend? ***[3]***

(c) The diagram below shows an object *OA* and its image *IB* formed by a lens.

(i) Complete the ray diagram.

(ii) Locate the focus of the lens by labelling correctly.

(iii) State the type of the lens used.

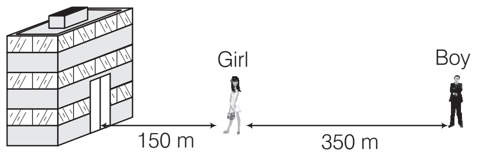
[4]

7. (a) (i) Which quantity determines the loudness of a sound wave?

(ii) How is loudness related to the quantity mentioned above in part (i) ?

(iii) Name the characteristic of sound is responsible to distinguish between a grave note of same loudness. ***[3]***

(b) A girl, standing 150 m in front of a tall building, fires a shot using a starting pistol. A boy, standing 350 m behind her, hears two bangs 1 s apart.



From this information. Find

(i) the speed of sound in air and

(ii) distance between two sounds heard. ***[3]***

(c) The stem of a vibrating tunning fork is pressed against a table top.

(i) Will it produce an audible sound?

(ii) Does it cause the table top to set in vibrations. If yes, what type of vibration are they?

(iii) Under what condition does it leads to resonance? ***[4]***

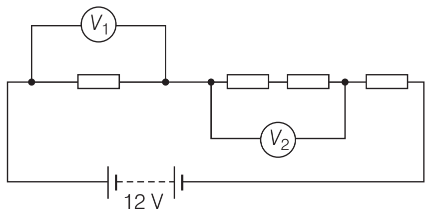
8. (a) What are ohmic and non-ohmic resistors? Give at least one example of each. Also, show their current voltage relationship. ***[3]***

(b) (i) A cell is sending current in an external circuit. How does the terminal voltage compare with the emf of the cell?

(ii) What is the purpose of using a fuse in an electrical circuit?

(iii) What are the characteristic properties of fuse wire? ***[3]***

(c) The circuit diagram shows four identical resistors connected in series with a 12 V battery.



What would be the readings of

(i) voltmeter V_1 and (ii) voltmeter V_2? ***[4]***

9. (a) (i) Why does land cools at a faster rate than water?

(ii) Why do we feel cool under a fan? ***[3]***

(b) (i) What is heat? (ii) Define temperature.

(iii) Explain calorimetry.

(iv) What is the SI unit of specific heat capacity? ***[3]***

(c) 250 g of water at 30°C is present in a copper vessel of mass 50 g. Calculate the mass of ice required to bring down the temperature of the vessel and its contents to 5°C.

(Take, specific latent heat of fusion of ice $= 336 \times 10^3$ J kg^{-1}, specific heat capacity of copper vessel = 400 J $kg^{-1}\,°C^{-1}$ and specific heat capacity of water = 4200 J $kg^{-1}\,°C^{-1}$) ***[4]***

10. (a) (i) When does the nucleus of an atom become radioactive?

(ii) How many α and β-particles are emitted when uranium nucleus $_{92}U^{238}$ decays to lead $_{82}Pb^{206}$? ***[3]***

(b) Compare

(i) the ionising powers.

(ii) the penetrating powers of α, β and γ-radiations. ***[3]***

(c) (i) Why do stable nuclei never have more protons than neutrons?

(ii) A certain radioactive nucleus emits a particle that leaves its mass unchanged, but increases its atomic number by one.

Identify the particle and write its symbol.

(iii) State the medical use of radioactivity. ***[4]***

ANSWERS

1. (a) Let the distance of the girl of mass 30 kg from the mean position be x metre.

Using principle of moments,

$$20 \times 3 = 30 \times x \Rightarrow x = 2$$

So, the girl of mass 30 kg should sit at a distance 2 m from the middle of see saw to balance it. ***[2]***

(b) (i) The lens is a convex lens. F_1 and F_2 are called the focal points of the lens. ***[1]***

(ii) Electric bell uses electromagnet. ***[1]***

(c) (i) The pole lowers his centre of gravity. This increases the stability of the man.

Note Centre of gravity is a single point through which its entire weight acts. ***[1]***

(ii) According to principle of moments, "in equilibrium the sum of anti-clockwise moments is equal to the sum of the clockwise moments. A physical balance works on the principle of moments. ***[1]***

(d) (i) One way of reduce the moment of a force is by reducing the magnitude of force applied. ***[1]***

(ii) Yes, uniform circular motion. ***[1]***

(e) (i) The centre of gravity should be as low as possible.

(ii) A cone resting on its base is in stable equilibrium. ***[1×2=2]***

2. (a) (i) Work done (W) = Force $(F) \times$ Displacement (d)

For no displacement, $d = 0$

$$\Rightarrow \quad W = F \times (0) = 0$$ ***[1]***

(ii) Work done (W) = Force (F). Displacement (d)

$$= F.s\cos\theta$$

Here, $\theta = 90°$

$$\Rightarrow \quad W = F \times d \times 0 = 0$$ ***[1]***

(b) (i) Potential energy (ii) Kinetic energy ***[2]***

(c) (i) Foot treadle is a third order lever. ***[1]***

(ii) The CGS unit of energy is erg. ***[1]***

(d)

Centripetal	Centrifugal
Force directed towards the centre of the circle at each part.	A force acting away from the centre of circular path.
e.g., Revolving of electrons around the nucleus.	e.g., A person throwing a hammer.

[2]

(e) The increase in gravitational potential energy is only dependent on the increase in vertical height. Increase in gravitational potential energy

$$= \text{Force} \times \text{Distance}$$

$$= \text{Weight} \times \text{Change in vertical height}$$ ***[2]***

3. (a) (i) The Mechanical Advantage (MA) of a lever is given by $\text{MA} = \dfrac{\text{Effort arm}}{\text{Load arm}}$

In levers of class II, i.e., the lever in which the load (L) lies in between the effort (E) and the fulcrum (F), the effort arm is always longer than the load arm. Therefore, the mechanical advantage of these levers is always more than one. ***[1]***

(ii) An ideal machine is that in which there is no dissipation of energy in any manner. The work output is equal to the work input. ***[1]***

(b) Refractive index $= \dfrac{\sin i}{\sin r} = \dfrac{\sin 60.0°}{\sin 35.3°} = 1.5$ ***[2]***

(c) (i) Frequency in air column can be increased by decreasing length of air column. ***[1]***

(ii) No, resistive force even by medium should act on vibrating body. ***[1]***

(d) (i) Kilowatt-hour (kWh). ***[1]***

(ii) Metallic body of an electrical appliance is earthed. ***[1]***

(e) (i) They are used in medical science to kill cancer cells. ***[1]***

(ii) Ultraviolet region. ***[1]***

4. (a) As, the ice melts at 0°C on heating, its volume decreases and converts into water at 0°C. When water at 0°C is heated further it starts contracting till it has minimum volume at 4°C. Thereafter on heating, the volume of water begins to increase. ***[2]***

(b) (i) *Use the equation below*

$$\frac{\text{Secondary voltage}}{\text{Primary voltage}} = \frac{\text{Number of secondary turns}}{\text{Number of primary turns}}$$

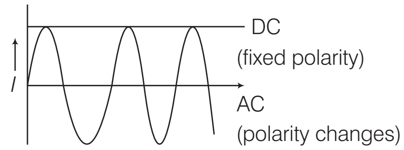
To obtain a secondary voltage of 12V, number of secondary turns required is $\dfrac{12}{6} \times 20 = 40$.

Thus, required terminal is R and S. ***[1]***

(ii) Polarity of the terminal between R and S will be same as that of input. ***[1]***

(c) The long lead would have a high resistance. A large proportion of the electrical energy would be lost as heat in the long leads. Therefore, a small current will pass through the circuit and will light up the lamp dimly. ***[2]***

(d) *AC and DC are graphically shown below*

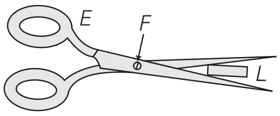


[2]

(e) (i) γ-radiation produces maximum biological damage. **[1]**

(ii) There is no change in atomic and mass number of element formed after γ-radiation are emission. **[1]**

5. (a) *The diagram of working scissors is given below as,*



where, E is effort, F is fulcrum and L is load. **[3]**

(b) (i) Electrical energy ⇔ Sound energy **[1]**

(ii) Resultant torque = Clockwise moments + Anti-clockwise moments

$= -[(30\text{ N}\times 4\text{ m}) + (50\text{ N}\times 5\text{ m})] + (20\text{ N}\times 1\text{ m}) + (80\text{ N}\times 3\text{ m}) + (200\text{ N}\times 0)$

(since, perpendicular distance between the rotation axis and the point of application of force is zero, hence torque is zero)

$= -(120\text{ N-m} + 250\text{ N-m}) + 260\text{ N-m}$

$= -110\text{ N-m}$ **[2]**

(c) (i) Mechanical advantage,

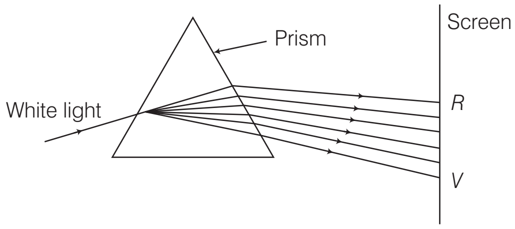
$$\text{MA} = \frac{\text{Load}}{\text{Effort}} = \frac{4500\text{ N}}{1000\text{ N}} = 4.5$$ **[1]**

Velocity ratio, VR = number of pulleys, $n = 5$ **[1]**

(ii) Efficiency,

$$\eta = \frac{\text{MA}}{\text{VR}} \times 100\% = \frac{4.5}{5} \times 100\% = 90\%$$ **[2]**

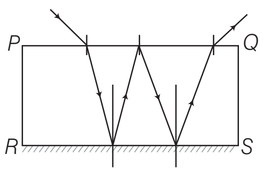
6. (a) (i) The phenomenon of splitting of white light into its constituent colours after passing through a prism is called dispersion.



Dispersion of white light **[2]**

(ii) Red **[1]**

(b) (i) **Ray diagram**

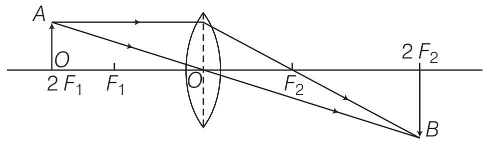


[2]

(ii) • The colour (or wavelength) of light.

• The temperature. **[1]**

(c)



Lens used in convex. Image is real and inverted. **[4]**

7. (a) (i) The loudness of sound is determined by amplitude. **[1]**

(ii) The loudness of sound is directly proportional to the square of the amplitude of the vibrating body. **[1]**

(iii) Pitch. **[1]**

(b) (i) The time difference between the given sound is 1 second.

i.e., $t_2 - t_1 = 1$

$$\frac{d_2}{v} - \frac{d_1}{v} = 1$$

$$\Rightarrow \quad \frac{1}{v}(d_2 - d_1) = 1$$

$$\Rightarrow \quad (d_2 - d_1) = v$$

$$(650 - 350) = v$$

$$\therefore \quad v = 300\text{ m/s}$$ **[2]**

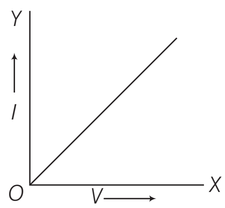
(ii) The distance between the two sounds is always $= 2d = 150 \times 2 = 300$ m apart. **[1]**

(c) (i) Yes, it will produce audible sound. **[1]**

(ii) Yes, it will set the table top into forced vibrations. **[1]**

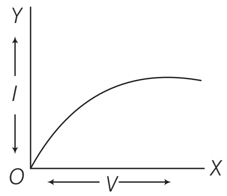
(iii) It will leads to resonance, when the natural frequency of vibrations of the table top becomes equal to the natural frequency of the vibrating tunning fork. **[2]**

8. (a) The conductors which obey Ohm's law are called ohmic resistors, e.g., All metallic conductors like Ag, Al, Cu, Fe, etc., for such conductors current voltage relationship is a straight line.



For ohmic resistors **[1½]**

The conductors which do not obey Ohm's law are called non-ohmic resistors or non-linear resistances, e.g., Diode valve, triode valve, electrolytes, etc., for these conductors graph plotted *V versus I* is not a straight line.



For non-ohmic resistors

[1½]

(b) (i) Terminal voltage (V) is less than emf (E) of the cell, i.e., $V = E - IR$. **[1]**

(ii) The purpose of fuse wire is an electrical circuit is to limit the current and thus delicate instruments are saved. **[1]**

(iii) Fuse wire must have low melting point and high resistance. **[1]**

(c) Since, the resistors are identical, the pd of 12 V is shared equally among each resistor, i.e., pd across each resistor is $\frac{12}{4} = 3\text{ V}\,(V_1)$. **[2]**

For two resistors, the potential difference across them is equal to the sum of the potential difference across the individual resistor i.e., pd $= 3 + 3 = 6\text{ V}\,(V_2)$. **[2]**

9. (a) (i) Water has high specific heat capacity (4200 J/kg°C). Therefore, it can take a large amount of heat without actually much change in its temperature. Therefore, a certain mass of water will impart nearly five times more heat energy than that given by the same mass of land for same fall in temperature. **[1½]**

(ii) We feel cool and comfortable under a fan because the sweat from our body evaporates rapidly due to the movement of air. Since, evaporation causes cooling, therefore, we get a cooling sensation. **[1½]**

(b) (i) Heat is a form of energy that flows from a body having higher temperature to the body having lower temperature.

(ii) The temperature is the degree of hotness or coldness of a body or heat is the total kinetic energy possessed by the molecules of the body and the temperature is the average kinetic energy of the molecules of the body.

(iii) The measurement of the quantity of heat is called calorimetry.

(iv) The SI unit of specific heat capacity is $\text{Jkg}^{-1}\text{ k}^{-1}$. **[3]**

(c) Given, mass of water = 250 g = 0.25 kg

Mass of copper vessel = 50 g = 0.05 kg

Initial temperature of water and vessel = 30° C

Final temperature of mixture = 5° C

Let, mass of ice added = m kg

Heat given by water

$$= 0.25 \times 4200 \times (30 - 5) = 26250\text{ J}$$

Heat given by copper vessel

$$= 0.05 \times 400 \times (30 - 5) = 500\text{ J}$$

Heat taken by ice

$$= m \times (336 \times 10^3) + m \times 4200 \times (5 - 0)$$

$$= 357000\ m\text{ J}$$

Assuming no loss of heat,

heat given by water and vessel = heat taken by ice

or $26250 + 500 = 357000\,m$

$\therefore$ Mass of ice added, $m = \frac{26750}{357000}$

$= 0.0749$ kg (or 74.9 k) **[4]**

10. (a) (i) The nucleus of an atom becomes radioactive when the number of neutrons exceed the number of protons, present inside the nucleus which thereby increases it unstability. **[1]**

(ii) 8 α-particles and 6 β-particles are emitted as the change in atomic number is 10 and the change in mass number is 32. **[2]**

(b) (i) Ionising power of α-particles is the most and of γ-radiations the least, i.e., ionising power $\alpha > \beta > \gamma$; (α-10000 times γ and 100 times β, β-100 times γ). **[1½]**

(ii) The penetrating power of α-particle is 1/100th times that of a β-particle and 1/10000 times that of γ-radiation. **[1½]**

(c) (i) Because the protons are positively charged and repel each other. This repulsion force is more causing instability, so an excess of neutrons are required to reduce this repulsion. **[1]**

(ii) Beta particle. Its symbol is ${}_{-1}^{\circ}e$ or ${}_{-1}^{\circ}\beta$. **[1]**

(iii)
- Many diseases such as leukemia, cancer, etc., are cured by radiation therapy.
- Radioactive tracers salts such as radio-sodium chloride, radio-iron, radio-iodine are used for diagnosis. They detect the suspected brain tumours and blood clots before they become dangerous. **[2]**

FULLY SOLVED

SAMPLE QUESTION PAPER 3

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS X

PHYSICS (FULLY SOLVED)

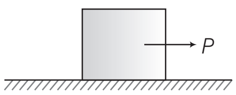
GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

Section-A [40 *Marks*

1. (a) An object of weight w is pulled along a rough, horizontal surface by a force P, as shown in the diagram.



(i) Name the force (F) acting parallel to the surface except P.

(ii) Draw a diagram which correctly shows the direction of forces P, w and F. *[2]*

(b) (i) The refractive index of glass with respect to air is 1.5.What is the value of the refractive index of air with respect to glass?

(ii) A ray of light is incident as a normal ray on the surface of separation of two different mediums. What is the value of the angle of incidence in this case? *[2]*

(c) (i) Can the centre of gravity be situated outside the material of a body? Give an example.

(ii) Why is it easier to open a door by applying the force at the free end of it? *[2]*

(d) (i) Write one way to obtain a greater moment of force about a given axis of rotation.

(ii) A planet moving around the sun is in a state of_____ equilibrium. *[2]*

(e) Differentiate between heat and temperature. *[2]*

2. (a) State the units of work in

(i) SI unit

(ii) CGS unit *[2]*

(b) What kind of energy is possessed by a body in following cases?

(i) A stone at rest at a certain height above the Earth's surface.

(ii) Water at the top of the reservoir of a dam. *[2]*

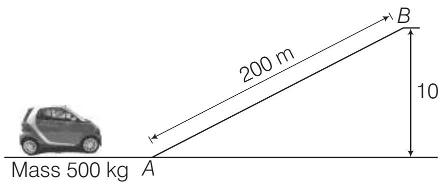
(c) Where does the position of centre of gravity lie for

(i) a circular lamina and

(ii) a triangular lamina? *[2]*

(d) What is centrifugal force? *[2]*

(e) The diagram shows a small car of mass 500 kg approaching a hill. It moves up the hill with uniform speed.



Ignore friction and take the value of g to be 10 N/kg.

How much work is done in moving the car up the hill? *[2]*

3. (a) (i) Write an expression for the mechanical advantage of an inclined plane in terms of its length l and vertical height h.

(ii) What is the value of VR for a class II lever? *[2]*

(b) The table shows measurements taken during an experiment in which a ray of light is incident at one of the sides of a rectangular block of glass.

Angle of incidence, i	26.0°	39.0°
Angle of refraction, r	15.5°	22.5°
sin i	0.438	0.629
sin r	0.267	0.383

What is the refractive index of the glass? *[2]*

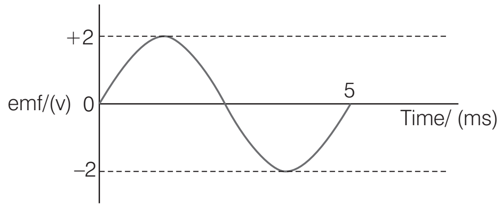
(c) (i) Why loud sound is heard at resonance?
(ii) What do you mean by level of sound zero dB? *[2]*

(d) (i) How does the resistance of a metallic wire depend on its temperature?
(ii) Material used for making filament of an electric bulb is .... *[2]*

(e) (i) Write name of a source of ultraviolet light.
(ii) Which colour of white light travels fastest in glass? *[2]*

4. (a) Distinguish between evaporation and boiling. *[2]*

(b) (i) Why is the core of a transformer made of iron?
(ii) The diagram shows how the emf of a simple generator varies with time.



What is the frequency and the maximum value of the emf? *[2]*

(c) The terminals of a battery are joined by a length of resistance wire.
Which change, on its own, will increase the current through the battery? *[2]*

(d) What is the role of split rings in electric motor? *[2]*

(e) Complete the following nuclear changes.
(i) ${}_{11}Na^{24} \longrightarrow \ldots Mg^{\cdots} + {}_{-1}\beta^{0}$
(ii) ${}_{92}U^{238} \longrightarrow {}_{90}Th^{234} + \ldots + \text{Energy}$ *[2]*

Section-B [40 *Marks*]

5. (a) In a single movable pulley, if the effort moves by a distance x upwards, by what height is the load raised? *[3]*

(b) (i) With reference to the terms mechanical advantage, velocity ratio and efficiency of a machine, name the term that will not change for a machine of a given design.
(ii) Which of the following remains constant in uniform circular motion, speed or velocity or both?
(iii) Name the force required for uniform circular motion. State its direction. *[3]*

(c) A scooter mechanic can open a nut by applying. 120 N force while using a lever of 50 cm in length.
(i) What is the moment of the force in first case?
(ii) How long handle is required if he wishes to open it by applying a force of only 40 N? *[4]*

6. (a) An object is placed in front of a lens between its optical centre and the focus and forms a virtual, erect and diminished image.
(i) Name the lens which formed this image.
(ii) Draw a ray diagram to show the formation of the image with the above stated characteristics. *[3]*

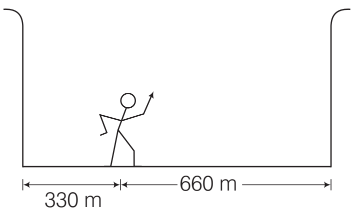
(b) (i) Which colour of white light is deviated
- least?
- most?

(ii) Draw a diagram to illustrate the use of a total reflecting prism to turn the ray of light through 180°. Name an instrument in which the device is used. *[3]*

(c) (i) Can the absolute refractive index of a medium be less than one? *[2]*
(ii) A coin placed at the bottom of a beaker appears to be raised by 4.0 cm. If the refractive index of water is 4/3, find the depth of the water in the beaker.
(iii) Draw the ray diagram also. *[2]*

7. (a) (i) Three musical instrument give out notes at the frequencies listed below. Flute: 400 Hz Guitar: 20 Hz, Trumpet: 500 Hz. Which one of these has the highest pitch?
(ii) With which of the following frequencies does a tuning fork of 256 Hz resonate?
288 Hz, 341 Hz, 333 Hz, 512 Hz. *[3]*

(b) A student stands 330 m from a tall cliff which is 990 m from another tall cliff.



The student fires a starting pistol and hears some echoes.

If the speed of sound between the cliffs is 330 m/s.

(i) What is the time taken by first echo to reach the student ?

(ii) Find the interval between the first echo and the second echo. **[3]**

(c) (i) How does a stretched string on being set into vibrations, produce the audible sound?

(ii) Will the sound be audible, if the string is set into vibration on the surface of the moon? Give reason for your answer. **[4]**

8. (a) (i) Name two systems of wiring used in a household electricity.

(ii) What is an AC generator or dynamo used for?

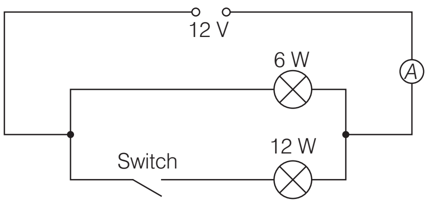
(iii) Name the principle on which it works. **[3]**

(b) (i) Explain, why are thick wires used in the leads of an electric radiator?

(ii) What is the effect of temperature on semiconductors?

(iii) At what voltage is the alternating current supplied to our houses? **[3]**

(c) The diagram shows two lamps in parallel in a circuit.



When the switch is open, the ammeter reads 0.5 A.

(i) What is the reading when the switch is closed?

(ii) Find potential difference across 12 W lamp. **[4]**

9. (a) Give reasons for the following :

(i) In cold countries, the steam pipes warm a building more effectively than the hot water pipes, both being at 100°C.

(ii) The heat supplied to a substance during its change of state, does not cause any rise in its temperature. **[3]**

(b) (i) Explain, why the weather becomes very cold after a hailstorm?

(ii) Write an expression for the heat liberated by a hot body.

(iii) Same amount of heat is supplied to two liquids *A* and *B*. The liquid *A* shows a greater rise in temperature. What can you say about the heat capacity of *A* as compared to that of *B* ?

(iv) Define specific latent heat of vaporisation of a substance. **[3]**

(c) A hot solid of mass 60 g at 100°C is placed in 150 g of water at 20°C. The final steady temperature recorded is 25°C. Calculate the specific heat capacity of the solid. (Take, specific heat capacity of water = 4200 J kg^{-1} °C^{-1}) **[4]**

10. (a) Mention two possible sources of background radiations. **[3]**

(b) A certain nucleus *X* has a mass number 14 and atomic number 6. The nucleus *X* changes to ${}_7Y^{14}$ after the loss of a particle.

(i) Name the particle emitted.

(ii) Represent this change in the form of an equation.

(iii) A radioactive substance is oxidised. What change would you expect to take place in the nature of its radioactivity? Give reason for your answer. **[3]**

(c) (i) Why do doctors wear lead aprons and spectacles while working near X-ray machine?

(ii) A radioactive nucleus undergoes a series of decays according to the sequence

$$X \xrightarrow{\beta} X_1 \xrightarrow{\alpha} X_2 \xrightarrow{\alpha} X_3$$

If the mass number and atomic number of X_3 are 172 and 69 respectively, what is the mass number and atomic number of *X* ?

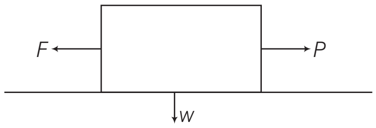
(iii) Which radiation produces maximum biological damage? **[4]**

FULLY SOLVED

ANSWERS

1. (a) (i) The force (F) is frictional force which always opposes the direction of pulling force P. ***[1]***

(ii) The direction of friction F always opposes the direction of the pulling force, P.



The weight of object, w is always acting vertically downwards from the centre of gravity of the object. ***[1]***

(b) (i) Given, refractive index of glass w.r.t air, ${}_a\mu_g = 1.5$. Refractive index of air w.r.t glass, ${}_g\mu_a = ?$

$${}_g\mu_a = \frac{1}{{}_a\mu_g} = \frac{1}{1.5} = \frac{10}{15} = \frac{2}{3} = 0.667$$ ***[1]***

(ii) The value of the angle of incidence in this case is zero. ***[1]***

(c) (i) Yes, e.g., of a ring. ***[1]***

(ii) At the free end of the door, torque is more due to longer arm and it becomes easier to open the door. ***[1]***

(d) (i) The force is applied at a point on the body for which the perpendicular distance of line of action of the force from the axis of rotation is maximum so that the given force may provide the maximum torque to turn the body.

(ii) The planet is in state of unstable equilibrium. ***[1 × 2]***

(e) *Differences between heat and temperature are given below*

Heat	Temperature
It is the internal energy of a body.	It is the degree of hotness or coldness of a body.
Its SI unit is joule.	Its SI unit is kelvin.
Other unit of heat is cal, kcal.	Its other unit is °C, °F.

[2]

2. (a) (i) SI unit of work is joule. Work is said to be one joule, if a force of one newton displaces, its point of application through one metre in its own direction. Thus, 1 joule (J) = 1 newton (N) × 1 metre (m). ***[1]***

(ii) CGS unit of work is erg. Work is said to be one erg, if a force of 1 dyne displaces its point of application through one centimetre in its own direction.

Thus, 1 erg = 1 dyne × 1 cm ***[1]***

(b) (i) PE ***[1]***

(ii) PE ***[1]***

(c) (i) The position of centre of gravity for a circular lamina lie at the centre of the circle.

(ii) The position of centre of gravity for a triangular lamina is at the centroid or the point of intersection of the medians. ***[1 × 2]***

(d) It is a pseudo force assumed to be exist in a rotating frame. It acts away from the centre and along the radius of the circular path. ***[2]***

(e) The work done by the car is equal to the gain in gravitational potential energy of the car up the hill.

$\therefore$ Work done = mgh = (500) (10) (10) = 50000 J

Note The distance along the slope is not required in this calculation. ***[2]***

3. (a) (i) Mechanical Advantage, $MA = \frac{l}{h}$

(ii) For class II lever,

effort arm > load arm

$\therefore$ MA and VR are always greater than one. ***[1 × 2]***

(b) Refractive index of glass $= \frac{\sin i}{\sin r}$

$$= \frac{\frac{0.438}{0.267} + \frac{0.629}{0.383}}{2} = 1.64$$ ***[2]***

(c) (i) At resonance amplitude increases, so a loud sound is heard.

(ii) Zero dB sound represents the lower limit of the sound level which can be heard by listener. ***[1 × 2]***

(d) (i) Resistance of a wire increases with increase in temperature.

(ii) Material used for making filament of an electric bulb is tungsten. ***[1 × 2]***

(e) (i) Carbon arc-lamp.

(ii) Red colour of white light travels fastest in glass. ***[1 × 2]***

4. (a)

Evaporation	Boiling
It takes place at the surface of liquid.	It takes place throughout the mass of liquid.
It takes place at all temperatures.	It takes place at a definite and constant temperature.

[2]

FULLY SOLVED

(b) (i) Iron can concentrate and increase the magnetic field without being magnetised.

(ii) Maximum emf = Peak to peak voltage

$= 2 - (-2) = 4$ V

Frequency $= \dfrac{1}{T}$

$= \dfrac{1}{5 \times 10^{-3}} = 200$ Hz **[1 × 2]**

(c) Resistance of wire is directly proportional to length but inversely proportional to cross-sectional area. To increase current, we must reduce resistance of the connecting wire. Hence, we either reduce length or increase thickness of wire. **[2]**

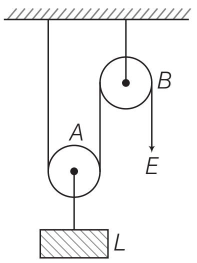
(d) The split rings reverse the direction of current passing through the coil. This helps to change the direction of force acting on coil. **[2]**

(e) (i) ${}_{11}\text{Na}^{24} \longrightarrow {}_{12}\text{Mg}^{24} + {}_{-1}\beta^{0}$ **[1]**

(ii) ${}_{92}\text{U}^{238} \longrightarrow {}_{90}\text{Th}^{234} + {}_{2}\text{He}^{4}$

(α-particle) + Energy **[1]**

5. (a) The height raised by load $= \dfrac{1}{2} \times$ Distance moved by effort upward, i.e., $\dfrac{x}{2}$



[3]

(b) (i) Velocity ratio will not change for a machine of a given design, because the distance moved by load in the same time is equal to the distance moved by the effort. **[1]**

(ii) Speed remains constant in uniform circular motion. **[1]**

(iii) Centripetal force. It is directed radially inwards. **[1]**

(c) (i) In first case, the moment of force

$= 120 \text{ N} \times 0.5 \text{ m} = 60$ N-m

(ii) In second case,

if he uses handle of length l m, then

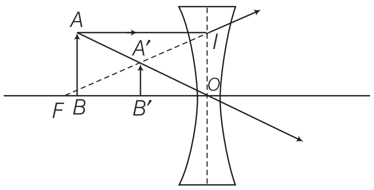
the moment of force $= 40 \text{ N} \times l$ m

$60 \text{ N-m} = 40 \text{ N} \times l$ m

$\Rightarrow \quad l = \dfrac{60 \text{ N-m}}{40 \text{ N}} = 1.5$ m **[2 × 2]**

6. (a) (i) Concave/diverging lens. **[1½]**

(ii) *Ray diagram is given below*

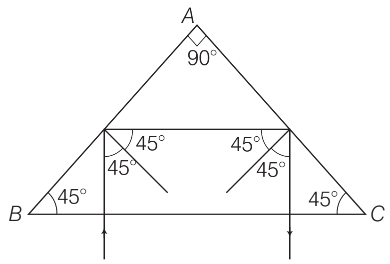


[1½]

(b) (i)
- The red colour light is deviated least.
- The violet colour light is deviated most.

[1]

(ii)



This device is used in binoculars. **[2]**

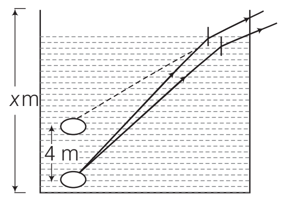
(c) (i) Absolute refractive index cannot be less than 1. **[1]**

(ii) Let the depth of water in the beaker be x m.

$\therefore$ Real depth of water $= x$ cm

Apparent depth $= (x - 4)$ cm

We know, $\quad \mu = \dfrac{\text{Real depth}}{\text{Apparent depth}}$



$\Rightarrow \quad \dfrac{4}{3} = \dfrac{x}{x - 4}$

$\Rightarrow \quad 4x - 16 = 3x \Rightarrow 4x - 3x = 16$

$\Rightarrow \quad x = 16$

$\therefore$ Depth of water in the beaker = 16 cm. **[3]**

7. (a) (i) Trumpet having highest frequency of 500 Hz have highest pitch, because pitch is directly proportional to the frequency. **[1½]**

(ii) The frequency 512 Hz will resonate a tuning fork of 256 Hz as 512Hz is an integral multiple of the natural frequency of the tuning fork. **[1½]**

(b) (i) Time taken by first echo to reach student,

$$t_1 = \frac{\text{Distance}}{\text{Speed}} = \frac{2 \times 330}{330} = 2 \text{ s}$$ **[1½]**

(ii) Time for second echo to reach student,

$$t_2 = \frac{\text{Distance}}{\text{Speed}} = \frac{2 \times 660}{330} = 4 \text{ s}$$

$\therefore$ Time interval $= (t_2 - t_1)$ s $= 2$ s **[1½]**

(c) (i) On striking, a vibrating string produces a very weak sound which cannot be heard at distance. Thus, all the stringed instruments are provided with a sound box. The vibrating string produces forced vibrations of large amplitude as now a larger volume of air is set into vibrations. Hence, this sound becomes audible. **[2]**

(ii) The sound produced on the surface of the moon by a vibrating string cannot be heard, because there is absence of any medium and we know that sound travels only in a medium. **[2]**

8. (a) (i) *The two systems are*

- tree system
- ring system

(ii) An AC generator or dynamo is used to obtain electrical energy from the mechanical energy.

(iii) It works on the principle of electromagnetic induction. **[1×3]**

(b) (i) Thick wires are used in high power instruments like electric iron, electric heater, heating rod, electric radiator, etc., because for the given voltage V,

$$P \propto I$$

Thus, the higher is the power of the electric appliance, larger is the current drawn by it and for given voltage V,

$$P \propto \frac{1}{R}$$ **[1½]**

i.e., if resistance is low, power will be more and for low resistance, area of cross-section will be more.

(ii) In case of metals resistance increases with the rise in temperature while in case of semiconductors, it decreases with the rise in temperature. **[1]**

(iii) 220 V **[1/2]**

(c) (i) As, P and V are given, current (I) can be calculated by using

power, $P =$ voltage $(V) \times$ current (I)

Once the switch is closed, pd across 12 W is 12 V,

$$\therefore \quad I = \frac{P}{V} = \frac{12 \text{ W}}{12 \text{ V}} = 1.0 \text{ A}$$

The ammeter will read $(0.5 + 1.0) = 1.5$ A. **[2]**

(ii) As, the lamps are connected in parallel combination.

Hence, the potential across each lamp would be same which is equal to the potential difference across the terminal of the source. Therefore, pd across 12W lamp is 12V. **[2]**

9. (a) (i) Because 1g of steam at 100°C imparts an additional 2268 J of heat energy, than that imparted by 1 g of hot water at 100°C.

(ii) Because this heat is used in increasing the potential energy of the molecules (in case of melting) and increasing potential energy of the molecules and for doing work for expansion (in case of boiling). **[1½×2]**

(b) (i) After the hailstorm the ice balls begin to melt and require 336 J of heat energy per gram to melt which is taken from the atmosphere thereby decreasing the temperature of atmosphere.

(ii) Expression for the heat energy liberated by hot body $= mc\,\Delta T$

where, $m =$ mass of body,

$c =$ specific heat of body

and $\Delta T =$ change in temperature of body.

(iii) Heat capacity of A is less than liquid B.

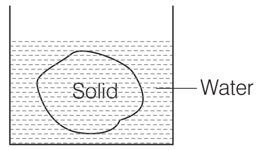
(iv) Specific latent heat of vaporisation (or heat of vaporisation) of a substance is the amount of heat required to convert unit mass of the liquid into vapour at its boiling point without any change in its temperature. **[3]**

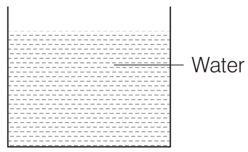
(c) Given, $m_1 = 60 \text{ g} = \frac{60}{1000}$ kg, $t_1 = 100°\text{C}$

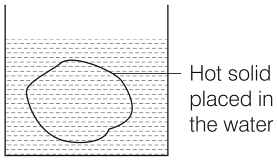
$c_1 = ?$

$m_2 = 150 \text{ g} = \frac{150}{1000} \text{ kg} \Rightarrow t_2 = 20°\text{C}$

$c_2 = 4200 \text{ J kg}^{-1}\,°\text{C}^{-1}$







Final temperature, $t_3 = 25°$ C

According to principle of calorimetry,

heat lost by solid = head gained by water

$\therefore\ m_1 \times c_1 \times (t_1 - t_3) = m_2 \times c_2 \times (t_3 - t_2)$

$$\Rightarrow \frac{60}{1000} \times c_1 \times (100 - 25) = \frac{150}{1000} \times 4200 \times (25 - 20)$$

$$\Rightarrow 6 \times c_1 \times 75 = 15 \times 4200 \times 5$$

$$\Rightarrow c_1 = \frac{15 \times 4200 \times 5}{6 \times 75}$$

$$\therefore c_1 = 700 \text{ J kg}^{-1}\,°\text{C}^{-1}$$ ***[4]***

10. (a) *The two possible sources of background radiations are as follows*

- earth and
- cosmic radiations. ***[3]***

(b) (i) Since during the $_{-1}\beta^0$-emission, there is gain in atomic number. ***[1]***

(ii) $_6X^{14} \xrightarrow{_{-1}\beta^0} {}_7\gamma^{14} + {}_{-1}e^0$ ***[1]***

(iii) There is no change in the nature of radioactivity during oxidation. Because oxidation is a phenomena in which involvement of electrons takes place, whereas in radioactivity nucleons takes part in reaction. ***[1]***

(c) (i) X-rays do not penetrate through lead and thus doctor's body is not exposed to X-rays. ***[2]***

(ii) According to the question,

$$_{T_2}X^{180} \xrightarrow{_{-1}\beta^0} {}_{T_3}X_1^{180} \xrightarrow{\alpha(_2\text{He}^4)} {}_{T_1}X_2^{176} \xrightarrow{\alpha(_2\text{He}^4)} {}_{69}X_3^{172}$$

Mass number of $X = 180$

Atomic number of $X = 72$ ***[1]***

(iii) γ-radiations are responsible for biological damages. ***[1]***

SAMPLE QUESTION PAPER 4

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS X

PHYSICS (UNSOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

UNSOLVED

Section-A [40 *Marks*

1. (a) (i) Derive the relation between CGS and SI unit of force.

(ii) A satellite revolves around the Earth in a circular orbit. What is the work done by the satellite? Give reason. ***[2]***

(b) A ray of light incident at an angle of incidence (i) passes through an equilateral glass prism such that the refracted ray inside the prism is parallel to its base and emerges from the prism at an angle of emergence (e).

(i) How is the angle of emergence (e) related to the angle of incidence (i)?

(ii) What can you say about the value of an angle of deviation in such a situation? ***[2]***

(c) (i) What type of lever is formed by the human body while raising a load on the palm and raising the weight of body on toes?

(ii) A spanner has a long handle, why? ***[2]***

(d) State two conditions for a body acted upon by several forces to be in equilibrium. ***[2]***

(e) A man can open a nut by applying a force of 150 N by using a lever handle of length 0.4 m. What should be the length of the handle, if he is able to open it by applying a force of 60 N? ***Ans.*** 1 m ***[2]***

2. (a) State the condition when the work done by a force is (i) positive and (ii) negative.

Explain each of them with the help of examples. ***[2]***

(b) What kind of energy is associated with

(i) a wound up watch spring?

(ii) a bent bow ? ***[2]***

(c) (i) What is meant by the term moment of force?

(ii) If the moment of force is assigned a negative sign, then will the turning tendency of the force be clockwise or anti-clockwise. ***[2]***

(d) A uniform circular motion is an accelerated motion. Explain it. ***[2]***

(e) A boy who weighs 50 N, runs up a flight of stairs 6.5 m high in 7s.

How much power does he develop? ***Ans.*** $\frac{50 \times 6.5}{7}$ W ***[2]***

3 (a) (i) The force needed to push a load up an inclined plane is less than the force need to lift it directly. Give a reason.

(ii) Define the term gain in speed in reference to a gear system. ***[2]***

(b) The speed of light in a medium is 1.5×10^5 km/s.

What is the refractive index of the medium? ***Ans.*** 2 ***[2]***

(c) (i) What are damped vibration?

(ii) Why are the string instruments provided with a sound box? ***[2]***

(d) (i) Sketch a graph to show the change in potential difference across the ends of an ohmic resistor and the current flowing in it. Label the axes of your graph.

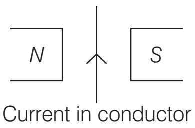
(ii) What does the slope of the graph represent? ***[2]***

(e) (i) Write one use of X-rays.

(ii) State one harmful effect of infrared radiation. ***[2]***

4. (a) Why are hot water bottles very efficient for fomentation? ***[2]***

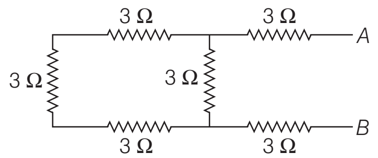
(b) (i) The diagram shows a current in a conductor in a magnetic field.



State the rule to find the force on the conductor.

(ii) In which direction the wire moves? ***[2]***

(c) For the combination of resistor shown in the figure below, calculate the equivalent resistances between A and B.



Ans. $\frac{33}{4}\,\Omega$ ***[2]***

(d) Draw a neat and labelled diagram of a DC motor. ***[2]***

(e) (i) 'Radioactivity is a nuclear phenomenon'. Comment on this statement.

(ii) What is meant by nuclear waste? State one way for the safe disposal of nuclear waste. ***[2]***

Section-B [40 *Marks*]

5. (a) Define the term inclined plane. How does the inclined plane act as a machine? ***[3]***

(b) (i) What is the velocity ratio of a single movable pulley? How does the friction in the pulley bearing affect it?

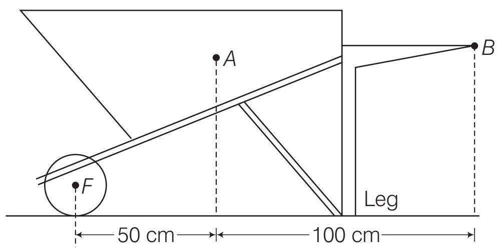
(ii) The weight of the wheelbarrow is 15 kgf and it holds sand of weight 60 kgf. Calculate the minimum force required to keep the leg just off the ground. ***Ans.*** 750 N

(iii) Give two examples of bodies possessing potential energy. ***[3]***

(c) In the diagram of a stationary wheelbarrow, the centre of gravity is at A.

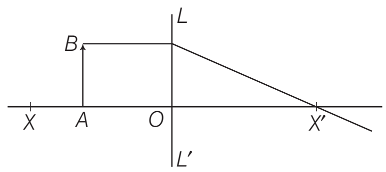
The wheel and the leg are in contact with the ground. The horizontal distance between A and F is 50 cm and that between B and F is 150 cm.

(i) What is the direction of the force acting at A? Name the force.



(ii) What is the direction of the minimum force at B to keep the leg off the ground? What is this force called? ***[4]***

6. (a)



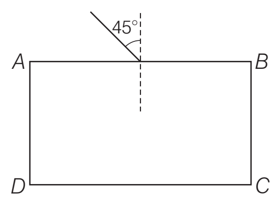
(i) Copy and complete the ray diagram to show the formation of the image of the object AB.

(ii) Name the lens LL'. ***[3]***

(b) (i) What do you mean by an optical fibre?

(ii) What is mirage? ***[3]***

(c) (i) A monochromatic light strikes the side AB of glass block of refractive index 1.5. Calculate the angle of refraction at surface AB. ***Ans.*** 28°



(ii) Complete the path of ray through the above glass slab by using the value of angle r.

(iii) Calculate the critical angle of glass for this monochromatic light. ***Ans.*** 41.8° ***[4]***

7. (a) (i) Sate three factors which affects the loudness of a sound heard by a listener.

(ii) How do bats avoid obstacles in their way, while they fly? ***[3]***

(b) A man standing 25 m away from a wall produces a sound and receives the reflected sound.

(i) Calculate the time after which he receives the reflected sound, if the speed of sound in air is 350 ms^{-1}.

(ii) Will the man be able to hear a distinct echo? Explain the answer. ***Ans.*** (i) 0.1438s, (ii) Yes ***[3]***

(c) (i) Differentiate between resonance and forced vibrations.

(ii) The ratio of amplitudes of two waves is 3 : 4. Find the ratio of their loudness and pitch.
Ans. For loudness-9 : 16, For pitch-1 : 1 ***[4]***

8. (a) (i) An electrical gadget can give an electric shock to its user under certain circumstances. Mention any two of these circumstances.

(ii) Can a transformer work when it is connected to a DC source?

(iii) Why are filaments coiled? ***[3]***

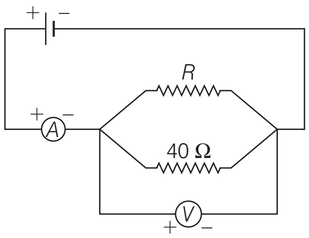
UNSOLVED

(b) (i) Define current. Give its SI unit.

(ii) Define electrical power. Give its SI unit.

(iii) Draw a circuit diagram of the ring system of house wiring. What advantages does it have over the tree system? ***[3]***

(c) In the circuit diagram, the voltmeter reading and ammeter reading are 4.0 V and 0.4 A respectively. Obtain



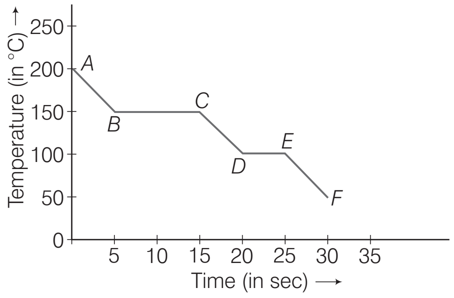
(i) the value of the combined resistance of 40 Ω and R Ω.

(ii) the value of R. ***Ans.*** (i) 10 Ω, (ii) 13.33 Ω ***[4]***

9. (a) (i) Why water is used as an effective coolant?

(ii) How is the melting point of ice affected by the increase of pressure? ***[3]***

(b) The given graph is a representation of the cooling curve of a given substance. Interpret it.



(i) Find the value of the bioling point of the substance. ***Ans.*** 150°C

(ii) Find the nature of change, if any in the region DE.

(iii) Give the reason for the region DE being shorter than BC.

(iv) State the effect of an increase of impurities on the melting point of ice. ***[3]***

(c) Water at 15°C is falling from the height of 50 m from a waterfall. If all the energy of falling water is absorbed by it on striking the base of waterfall, calculate the change in temperature of water.
(Take, $g = 10 \text{ ms}^{-2}$) ***Ans.*** $\Delta T = 0.1190°\text{C}$ ***[4]***

10. (a) (i) Which of the following radiations, α, β and γ similar to a beam of electrons?

(ii) How is the radioactivity of an element affected, when it undergoes a chemical change to form a chemical compound?

(iii) Mention one use and one harmful effect of radioactivity. ***[3]***

(b) The isotope of $_{92}U^{238}$ decays by α-emission to an isotope of thorium (Th). The thorium isotopes decays by β-emission to an isotope of protactinium (Pa). Write down the equations to represents these two nuclear charges. ***[3]***

(c) A radioactive source emits three types of radiations.

(i) Name the three radiations.

(ii) Name the radiations which are deflected by the electric field.

(iii) Name the radiation which is most penetrating. ***[4]***

UNSOLVED

SAMPLE QUESTION PAPER 5

A HIGHLY SIMULATED SAMPLE QUESTION PAPER FOR ICSE CLASS X

PHYSICS (UNSOLVED)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Time : 2 Hrs **Max. Marks : 80**

Section-A [40 *Marks*]

1. (a) (i) Give one application of moment of force.

(ii) Where is the centre of gravity of a rhombus is situated ? *[2]*

(b) (i) What is the cause of refraction of light?

(ii) What is the direction of magnetic field at the centre of a coil, if the direction of current at the end is facing the observer ? *[2]*

(c) (i) Why does a body rotate?

(ii) The stone of hand floar grinder is provided with a handle near its rim. Give a reason. *[2]*

(d) Explain, why one leans forward while climbing up a hill? *[2]*

(e) (i) State one method to increase the stability of a body.

(ii) A ball on ground is an example for which type of equilibrium. *[2]*

2. (a) How is the work done by a force measured, when

(i) force is in direction of displacement.

(ii) force is at an angle to the direction of displacement. *[2]*

(b) What kind of energy is possessed by a

(i) moving hammer and

(ii) stretched rubber membrane? *[2]*

(c) Give one example for a first order and second order lever. *[2]*

(d) Is it possible to have an accelerated motion with a constant speed? Give an example of such type of motion. *[2]*

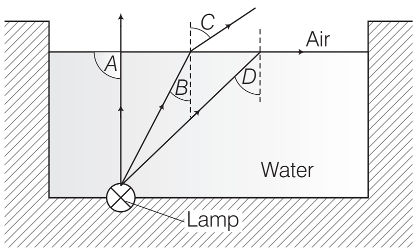
(e) What is the relationship between the mechanical advantage and the velocity ratio for

(i) ideal machine and (ii) practical machine? *[2]*

3. (a) (i) Which order lever is used as a multiplier?

(ii) State the use fullness of a machine whose mechanical advantage is less than one. *[2]*

(b) A swimming pool is lit by a lamp in the bottom of the pool. The directions of three rays from the lamp are shown in figure bottom.



Which of the marked angles is the critical angle for the light? *[2]*

(c) (i) How do you tune your radio set to a particular station?

(ii) Define intensity of sound wave. *[2]*

(d) (i) What is the necessary condition for a conductor to obey Ohm's law?

(ii) At which temperature mercury behaves as superconductor ? *[2]*

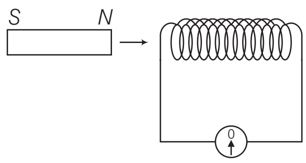
(e) (i) A shirt is seen in white light. It appears yellow. How would you expect it to appear, when seen in yellow light?

(ii) Name the instrument used to obtain a pure spectrum. *[2]*

UNSOLVED

4. (a) The specific latent heat of fusion of ice is 336 Jg^{-1}. Comment on this statement. *[2]*

(b) (i) A small coil is connected to a meter as shown.

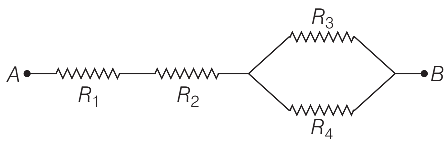


When a magnet is pushed into the coil, the pointer of the meter kicks to the right of zero.

What happens to the pointer of the meter, when the magnet is pulled back from the coil?

(ii) How reading of the meter changes? *[2]*

(c) Calculate the equivalent resistance of the following combination of resistors R_1, R_2, R_3 and R_4 between A and B.



[2]

(d) Which material is generally used as a core in AC generator and why? *[2]*

(e) (i) Give one use of radio isotopes.

(ii) What is meant by background radiation? *[2]*

Section-B

[40 *Marks*]

5. (a) Name a machine is used to

(i) multiply force and

(ii) change the direction of force applied. *[3]*

(b) (i) Define 'Joule'.

(ii) A machine raises a load of 750 N through a height of 16 m in 5 s. Calculate the power at which the machine works. ***Ans.*** 2400 W

(iii) State the principle of conservation of energy. *[3]*

(c) (i) The mechanical advantage of a machine is 5 and its efficiency is 80%. It is used to lift a load of 200 kgf to a height of 20 m. Calculate: (i) the effort required and (ii) the work done on the machine

(Take, $g = 10\ ms^{-2}$). ***Ans.*** (i) 40 kgf, (ii) 50 kJ *[4]*

6. (a) (i) What is meant by the term 'critical angle'?

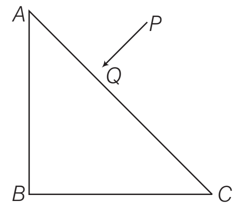
(ii) How is it related to the refractive index of the medium? *[3]*

(b) Write the range of wavelength of

(i) visible spectrum and

(ii) ultraviolet spectrum. *[3]*

(c) A ray of light PQ is incident normally on the hypotenuse of a right-angled prism ABC as shown in the diagram given below



(i) Copy the diagram and complete the path of the ray PQ till it emerges from the prism.

(ii) What is the value of the angle of deviation of the ray?

(iii) Name an instrument where this action of the prism is used. *[4]*

7. (a) (i) State three characteristics of a musical sound.

(ii) How does the musical sound differ from noise?

(iii) State one way of increasing frequency of vibration of stretched string. *[3]*

(b) The wavelength of waves produced on the surface of water is 20 cm. If the wave velocity is 48 ms^{-1}. Calculate

(i) the number of waves produced is one second and

(ii) the time in which one wave is produced.

Ans. (i) 240, (ii) 4.16 ms *[3]*

(c) (i) What is meant by resonance? Describe a simple experiment to illustrate the phenomenon of resonance and explain it.

(ii) A tuning fork is set into vibrations in air. Name the kind of vibrations it executes. *[4]*

8. (a) (i) Explain the terms Ohmic resistor and emf.

(ii) Why are transformers so important for the transmission of electric energy?

(iii) Draw a neat diagram for an AC transformer suitable for lighting 12 V lamp from 240 V mains. *[3]*

(b) An electrical appliance is rated 1500 W, 250 V. This appliance is connected to 250 V mains.

Calculate

(i) the current drawn. ***Ans.*** 6 A

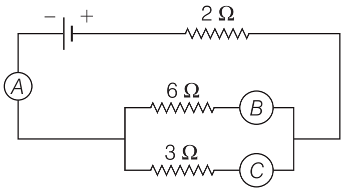
(ii) the electrical energy consumed in 60 hours.

Ans. 90 kWh

(iii) the cost of electrical energy at ₹ 2.50 per kWh.

Ans. 225 ₹ *[3]*

(c) In the figure, A, B and C are three ammeters. The ammeter B reads as 0.5 A. Calculate



(i) the readings in ammeter A and C.

(ii) the total resistance of the circuit.

Ans. (i) 1.5 A and 1A, (ii) 4Ω ***[4]***

9. (a) (i) Why is copper preferred over other metals for making calorimeter?

(ii) Why does ice seem colder to teeth than ice-cold water ?

(iii) Wet clothes usually dry more quickly on a warm day than on a cold day. Explain. ***[3]***

(b) (i) Name the liquid which has the highest specific heat capacity.

(ii) Why do the farmers fill their fields with water on a cold winter night?

(iii) What happens to the average kinetic energy of the molecules as ice melts at 0°C? ***[3]***

(c) 20 g of ice at −25° C is heated by a burner supplying heat energy at a rate of 100 Js^{-1}. The specific heat capacity of ice is 2.1 $Jg^{-1}\,{}^\circ C^{-1}$, specific latent heat of ice is 336 Jg^{-1}. Calculate the time in which the water formed from ice attains a temperature of 90°C.

Ans. 55.02 s ***[4]***

10. (a) (i) Differentiate between nuclear fission and nuclear fusion.

(ii) Mention one use and one harmful effect of radioactivity. ***[3]***

(b) A mixture of radioactive substance gives off three types of radiations.

(i) Name these three types of radiations.

(ii) Name the type consisting of the same kind of particles as the beam of electrons. ***[3]***

(c) A nucleus $^{24}_{11}Na$ is β -radioactive.

(i) What are the numbers 24 and 11 called?

(ii) Write the equation representing β-decay.

(iii) What general name is given to the product nucleus with respect to $^{24}_{11}Na$? ***[4]***

UNSOLVED

ICSE

LATEST SPECIMEN QUESTION PAPER

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

SPECIMEN QUESTION PAPER

Section A [40 Marks]

1. (a) Name a metal commonly used to make a calorimeter. Give a reason to support your answer. *[2]*

(b) Draw a well labelled circuit diagram for the verification of Ohm's law. *[2]*

(c) Why is radioactivity considered to be a nuclear phenomenon? *[2]*

(d) Draw a ray diagram to show how a convex lens can be used as a magnifying glass. *[2]*

(e) A metal ball of mass 60 g falls on a concrete floor from a vertical height of 2.8m and rebounds to a height of 1.3m. Find the change in KE in SI units. *[2]*

2. (a) What is the work done by a force when the force is

(i) normal to the displacement produced.

(ii) in the same direction as the displacement produced? *[2]*

(b) State the SI unit of specific heat capacity and heat capacity. *[2]*

(c) Draw a labelled diagram to show the path of a monochromatic light ray of light in a prism kept at its angle of minimum deviation. *[2]*

(d) Explain, why a single fixed pulley is used despite no gain in mechanical advantage? *[2]*

(e) A metal wire has a resistance of 60 Ω. It is cut into three equal lengths. Find the equivalent resistance when two parts are connected in parallel and the third part is in series with them. *[2]*

3. (a) Establish a relation between an electron volt and the SI unit of the physical quantity which it measures. *[2]*

(b) Why is the earth pin of a three-pin plug made longer and thicker? *[2]*

(c) Write the energy conversions in the following

(i) microphone (ii) lighted candle. *[2]*

(d) Mention two ways to increase the strength of an electromagnet. *[2]*

(e) What characteristics of sound would change if there is a change in its

(i) amplitude (ii) waveform? *[2]*

4. (a) Which cools faster, land or water? Give a reason for your answer. *[2]*

(b) State any two properties of α-radiation. *[2]*

(c) Scissors for cutting cloth have blades much longer than handles. Why? *[2]*

(d) Two lamps, one rated 40 W, 220 V and the other having resistance 605 Ω 60 W, 220 V are connected in parallel combination across to a 220 V supply. Calculate the current drawn from the supply line. *[2]*

(e) State two precautions that should be taken while handling radioactive substances. *[2]*

Section B [40 Marks]

5. (a) Show how the energy of a freely falling object remains conserved. *[3]*

(b) A uniform metre rod is balanced at the 70 cm mark by suspending a weight of 50 gf at the 40 cm mark and 200 gf at the 95 cm mark. Draw a diagram of the arrangement and calculate the weight of the metre rod. **[3]**

(c) Draw a diagram of a pulley system of velocity ratio 4. Calculate its mechanical advantage if its efficiency is 90%. **[4]**

6. (a) What is understood by lateral displacement? State two factors on which it depends. **[3]**

(b) An objet is kept at a distance of 15 cm from a convex lens of focal length 10 cm. Calculate the image distance and state the characteristics of the image formed. **[3]**

(c) (i) Write two properties common to all the electromagnetic radiations.

(ii) Give one use each of infrared and ultraviolet radiations. **[4]**

7. (a) A vibrating tuning fork is placed over the mouth of a burette filled with water. The tap of the burette is opened and the water level gradually starts falling. It is found that the sound from the tuning fork becomes very loud for a particular length of the water column.

(i) Name the phenomenon taking place when this happens.

(ii) Why does the sound become very loud for this length of the water column? **[3]**

(b) (i) Define power of a lens.

(ii) A child is using a spectacle with power of −2.5 D. What is meant by the negative sign?

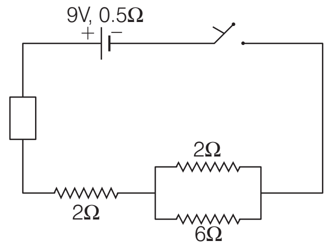
(iii) Find the focal length of the lens used. **[3]**

(c) A man standing in front of a wall produces a sound and hears an echo after 3s. He walks '*x*' m away from the wall and produces the same sound. Now he hears an echo after 5.25s. Calculate the distance he walked away from the wall. (Speed of sound in air is 340 m/s) **[4]**

8. (a) What is an electrical fuse? State two characteristics of an electrical fuse. **[3]**

(b) What is internal resistance of a cell? Write two factors on which is depends. **[3]**

(c) In the circuit diagram given below, a cell of 9V and internal resistance 0.5 Ω is connected across a resistor A of 2 Ω in series and two resistors 2 Ω and 6 Ω which are in parallel.



Find

(i) the total resistance

(ii) the total current

(iii) the current in the 6 Ω resistor

(iv) the potential difference across the terminals of the cell. **[4]**

9. (a) (i) Define specific latent heat of fusion of ice.

(ii) What happens to the heat supplied to the substance when the heat supplied causes no change in the temperature of the substance? **[3]**

(b) Two liquids *A* and *B* have specific heat capacities $2.5\ Jg^{-1}C^{-1}$ and $3.2\ Jg^{-1}\ {}^{0}C$ respectively.

(i) Which liquid is a good conductor of heat? Why?

(ii) Which liquid is more suitable as a liquid in radiators for cooling? **[3]**

(c) A calorimeter of mass 60 g contains 180 g of water at 29°C. Find the final temperature of the mixture, when 37.2 g of ice at − 10°C is added to it (specific heat capacity of water = 4200 J/kg K, latent heat of ice $= 336 \times 10^3$ J/kg, specific heat capacity of ice = 2100 J/kg K, specific heat capacity of the calorimeter is $0.42\ Jg^{-1}\ °C^{-1}$). **[4]**

10. (a) (i) What are background radiations?

(ii) Write an equation of an α-emission from U^{238}_{92}.

(iii) What will be the change in the rate of radioactivity if the temperature of the radioactive substance is raised to four times the initial temperature? **[3]**

(b) What is nuclear fusion? Write an equation for it. **[3]**

(c) (i) Draw a simple labelled diagram of the device you would use to transform 230 V AC to 15 V AC.

(ii) What is the name of this device?

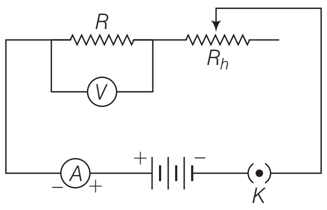
(iii) On what principle does the device work? **[4]**

ANSWERS

1. (a) Copper is the metal which is commonly used to make a calorimeter. ***[1]***

Reason behind it is that copper has low specific heat capacity so that the heat capacity of the calorimeter is low and the amount of the heat energy taken in by it from its content is to acquire the temperature is negligible. ***[1]***

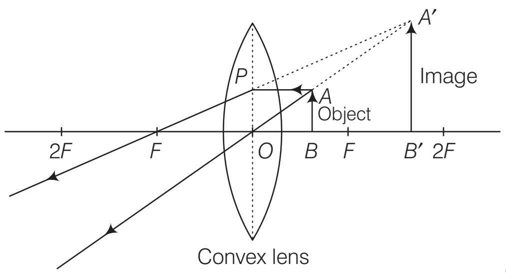
(b) Circuit diagram to show experimental set up for the verification of Ohm's law is shown below.



[2]

(c) Any physical or a chemical change does not alter the rate of decay of a radioactive substance. So, it is clear that the phenomena of radioactivity cannot be due to orbital electrons. Thus, radioactivity is said to be a nuclear phenomena as it is the process of spontaneous emission of alpha, beta or gamma radiations from the nuclei of an atom. ***[2]***

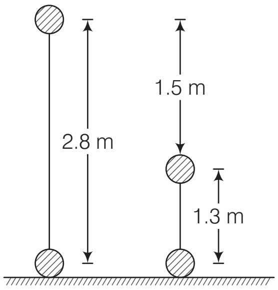
(d) A convex lens can be used as magnifying glass, as shown in the diagram given below



[2]

(e) When a body moves in vertical direction under the gravity, then change in kinetic energy + change in potential energy = 0

i.e. Δ KE + Δ PE = 0



[1]

Here, a ball falls from a height 2.8 m, after striking ball rebounds 1.3 m above the ground.

$\therefore$ Separation between final position to initial position of particle, $= 1.3 - 2.8 = -1.5$ m

(Here, negative sign shows the body appears below the reference level)

$\therefore$ Change in potential energy, Δ PE = mgh

$$= -0.06 \times 10 \times 1.5$$
$$= -0.9\text{ J} \qquad (\because g = 10\text{ ms}^{-2})$$

But Δ KE + Δ PE = 0

or $\quad \Delta$ KE − 0.9 J = 0

$\therefore$ Change in KE, Δ KE = 0.9 J ***[1]***

2. (a) We know that work done, $W = Fs\cos\theta$

(i) when the force is normal to the displacement produced i.e. $\theta = 90°$, then work done is given as

$$W = Fs\cos 90° = 0 \qquad (\because \cos 90° = 0)$$ ***[1]***

(ii) when the force is in the same direction as the displacement produced i.e., $\theta = 0°$,

then work done is given as,

$$W = Fs\cos 0° \qquad (\because \cos 0° = 1)$$
$$= Fs \qquad \text{(i.e. positive work done)}$$ ***[1]***

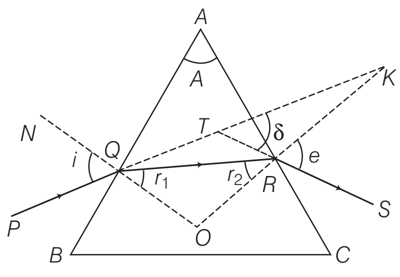
(b) Specific heat capacity, $S = \dfrac{1}{m}\left(\dfrac{\Delta Q}{\Delta T}\right) = \dfrac{\text{J}}{\text{kg - K}}$

Specific heat capacity is equal to 1 J/kg-K, when 1 J of heat required to raise the temperature of 1 kg mass of the body by 1 kelvin.

Heat capacity, $S = \dfrac{\Delta Q}{\Delta T} = \dfrac{1\text{ J}}{1\text{ K}} = 1\text{ JK}^{-1}$

$\therefore$ Heat capacity is said to be 1 JK^{-1}, when 1 of heat required to raise the temperature of the body by 1 kelvin. ***[2]***

(c) The labelled diagram of refraction for a ray of monochromatic light passing through a glass prism is shown as below.



[2]

(d) A single fixed pulley is used to left load by changing the direction of the lifting force. Even through a single fixed has no mechanical gain. The effort applied is greater than the load, it is preferred in use since we do not have to pull or push the pulley up and down. ***[2]***

(e) We know that, resistance of wire, $R = \rho\dfrac{l}{A}$

i.e. $R \propto l$ (l is length of wire)

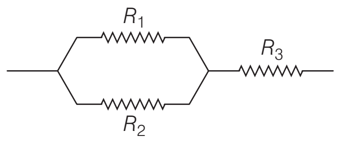
$\therefore$ If we cut the wire of resistance 60 Ω into 3 equal parts, then resistance of each wire will be,

$$= \frac{60}{3}\,\Omega = 20\Omega$$

$\therefore R_1 = R_2 = R_3 = 20\Omega$ *[1]*

Now, according to question

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{20} + \frac{1}{20}$$



$$= \frac{2}{20} = \frac{1}{10}$$

$\therefore \quad R_P = 10\Omega$

$\Rightarrow$ Further, $R_S = R_P + R_3 = 10 + 20 = 30\Omega$

$\therefore$ The equivalent resistance will be 30Ω. *[1]*

3. (a) We know that, work done, $W = qV$

when, q = charge on electron,

$$1\text{ eV} = 1.6 \times 10^{-19}\text{ C}, V = 1\text{ V}$$

$\therefore \quad W = 1.6 \times 10^{-19}$ eV

1 electron volt is the energy gained by an electron when it is accelerated by a potential difference of 1 V.

As the SI unit of energy is joules

$\therefore \quad 1\text{ eV} = 1.6 \times 10^{-19}$ J *[2]*

(b) The earth wire starts from the metal body of the appliance and ends in the earth. So it should never come into contact with live wire. In case the earth pin is connected wrongly with the live socket, the user touching the appliances might receive and electrical shock. The earthing being thicker in the diameter as compared to the other pins, can never enter the live or neutral socket. Thus, the appliance can get connected only in proper electrical position. *[1]*

Secondly, the earthling pin is made longer than the other pins, so that it gets connected the earth terminal first before the other pins (live and neutral) make the contact in their respective sockets. This ensure safety of the user. *[1]*

(c) *The energy conservation takes place as,*

(i) In microphone, sound energy $\longrightarrow$ electrical energy

(ii) In lighted candle, light energy $\longrightarrow$ heat energy *[2]*

(d) *The strength of electromagnet can be increased by*

(i) using a soft iron core.

(ii) increasing the number of turns making the coil. *[2]*

(e) (i) By changing the amplitude of sound, loudness of the sound will change.

(ii) By changing the waveform of the sound, quality or timbre will change. *[2]*

4. (a) Land cools faster than the water. This is because, specific heat of water is higher than the sand, hence water needs to impart a lot of heat before cooling. Which require a long duration. That's why land cools faster than the water. *[2]*

(b) *Properties of* α*-radiation are given as,*

(i) α-radiations are deflected in electric and magnetic fields.

(ii) These radiations have minimum penetration power and highest ionisation power. *[2]*

(c) In case of scissors, blades may be much longer than the handles, because in this case we do not needs much mechanical advantage, as

$$\text{MA} = \frac{\text{Effort arm}}{\text{Load arm}}$$ *[1]*

But in case of scissors for cutting metals, much higher value of mechanical advantage is needed, to cut metal easily. So, the handles need to be long and blades short. *[1]*

(d) Power of first lamp, $P_1 = 40$ W

Voltage of first lamp, $V_1 = 220$ V

$\therefore$ Resistance of first lamp, $R_1 = \frac{V^2}{P}$

$$= \frac{48400}{40} = 1210\ \Omega$$

Power of second lamp, $P_2 = 60$ W

Voltage of second lamp, $V_2 = 220$ V

Given, resistance of second lamp, $R_2 = 605\ \Omega$ *[1]*

As both are connected in parallel,

$\therefore$ Equivalent resistance, $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$

$$= \frac{1}{1210} + \frac{1}{605} = \frac{1+2}{1210} = \frac{3}{1210}$$

$\therefore \quad R_{eq} = 403.3\ \Omega$

Now, current drawn from the supply line, $I = \frac{V}{R}$

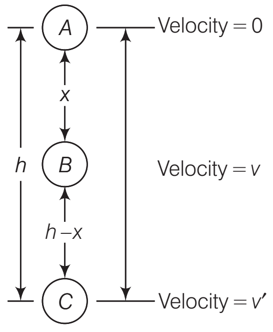
$\therefore \quad I = \frac{220\text{ V}}{403.3\text{ W}} = 0.5$ A *[1]*

(e) (i) While handling radioactive materials, always wear the appropriate protective clothing.

(ii) Always wear gloves when handling radioactive substance and do check the radiation level regularly of these gloves. *[2]*

5. (a) Consider a body of mass m lying at position A at a height h above the ground.

As the body falls, its kinetic energy increases at the expense of potential energy as shown in figure.



Conservation of energy in a freely falling body

At point *A* The body is at rest

KE of the body, $K_A = 0$

PE of the body, $U_A = mgh$

Total mechanical energy

$$E_A = K_A + U_A = 0 + mgh$$

Mechanical energy at position A, $E_A = mgh$ **[1]**

At point *B* Suppose the body falls freely through a distance x and reaches the point B with velocity v.

Then, $v^2 - 0^2 = 2ax$ (using $v^2 - u^2 = 2as$)

or $v^2 = 2gx$

$$\therefore \quad K_B = \frac{1}{2} mv^2 = \frac{1}{2} \times m \times 2gx = mg\,x$$

$$U_B = mg\,(h - x)$$

$$E_B = K_B + U_B = mgx + mg\,(h - x) = mgh$$

Mechanical energy at position B, $E_B = mgh$ **[1]**

At point *C* Suppose the body finally at point C on the ground with velocity v'. Then, considering motion from A to C,

$$v'^2 - 0^2 = 2gh \text{ or } v'^2 = 2gh$$

$$K_C = \frac{1}{2} mv^2 = \frac{1}{2} \times m \times 2gh = mgh$$

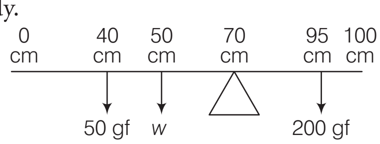
$$U_C = mg \times 0 = 0$$

$$\therefore E_C = U_C + K_C = 0 + mgh = mgh$$

Mechanical energy at position C, $E_C = mgh$

Clearly, as the body falls, its PE decreases and KE increases by an equal amount. Thus, total mechanical energy is conserved during free fall of the body. **[1]**

(b)



[1]

Let w be weight of rod.

(For a uniform metre rod, its weight acts at 50 cm)

Anti-clockwise moment

$$= [F \times S(\text{from pivot})] + (w \times 20)$$
$$= (50 \times 30) + (w \times 20)$$
$$= (1500 + 20\,w) \text{ N - m}$$

Clockwise moment $= F \times S$

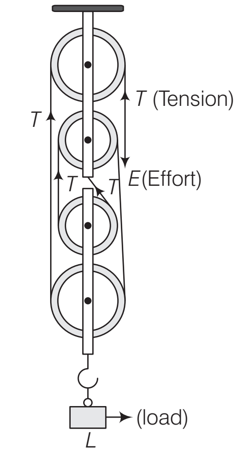
$$= 200 \times 25 = 5000 \text{ N-m}$$ **[1]**

According to principle of moments, when a rod is in equilibrium,

Anti-clockwise moment = Clockwise moment

$$1500 + 20w = 5000$$
$$20w = 3500$$
$$w = 175 \text{ N}$$ **[1]**

(c) A labelled diagram of a pulley system of velocity ratio 4 is given below,



Labelled diagram of system of pulleys

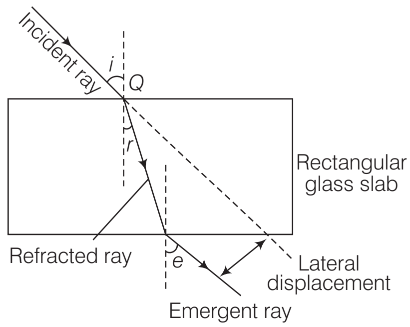
[2]

Here, given, VR = 4, $\eta = 90\%$

$\therefore$ MA = VR × $\eta\%$

$$= 4 \times \frac{90}{100} = \frac{360}{100} = 3.6 \text{ N}$$ **[2]**

6. (a) **Lateral Displacement** The perpendicular separation between the incident ray produced and the emergent ray is called lateral displacement.



[2]

The lateral displacement depends on

(i) the thickness of the glass block.

(ii) the angle of incidence. **[1]**

(b) Given, $u = -15$ cm

$f = 10$ cm

$v = ?$

We know that,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

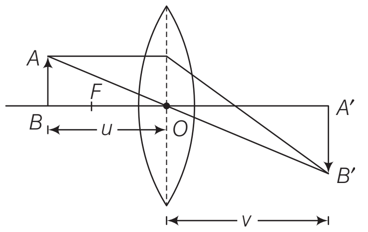
$$\Rightarrow \quad \frac{1}{v} - \frac{1}{(-15)} = \frac{1}{10}$$

$$\frac{1}{v} + \frac{1}{15} = \frac{1}{10} \Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{15}$$

$$\frac{1}{v} = \frac{15-10}{150} \Rightarrow \frac{1}{v} = \frac{5}{150}$$

$\therefore \quad v = 30$ cm ***[1]***

To find characteristics of image, we need to find 'm'.



$$m = \frac{v}{u} \Rightarrow m = \frac{30}{-15} \Rightarrow m = -2$$ ***[1]***

As magnification is – 2, so the image is enlarged, real and inverted. ***[1]***

(c) (i) *Properties of electromagnetic radiations*

1. The electromagnetic radiations do not require any material medium for propagation.

2. These radiations in free space travel with the speed of light i.e. $3 \times 10^8 \text{ ms}^{-1}$. ***[2]***

(ii) *Uses of infrared and ultraviolet radiations*

1. Infrared radiations are used in solar water heater, solar cells and cooker.

2. Ultraviolet radiations are used in burglar alarm. ***[2]***

7. (a) (i) In the above process, the phenomenon taking place is resonance.

(ii) The sound becomes very loud for this length of the water column, because the frequency of the air column becomes equal to the frequency of the tuning fork i.e., $f_a = f_t$. ***[3]***

(b) (i) The power of lens is the degree of convergence or divergence of rays falling on it. It can be defined as reciprocal of focal length.

$$P = \frac{1}{f} \text{ (in m)}$$ ***[1]***

(ii) A child is using −2.5 D, here negative sign indicates it is concave lens and child is suffering from myopia disease. In myopia, one can see near things clearly but finds difficulty in seeing far off things. ***[1]***

(iii) $P = -2.5$ D

$$-2.5 \text{ D} = \frac{1}{f}$$

$$f = -\frac{1}{2.5} = -\frac{10}{25} = -\frac{2}{5}$$

$$= -0.4 \text{ m} = -0.4 \times 100$$

$$= -40 \text{ cm}$$

$\therefore$ Focal length of given concave lens is – 40 cm. ***[1]***

(c) Given, speed of sound = 340 m/s

Case I $t = 3$ s

Distance = $s \times t$

$\Rightarrow 2 \times$ actual distance $= 340 \times 3$

$$\text{Distance between wall and man} = \frac{340 \times 3}{2}$$

$= 510$ m ***[2]***

Now, **Case II** $t = 5.25$ s

$\Rightarrow 2 \times$ distance $= 340 \times 5.25$

Distance $= 170 \times 5.25 = 890.50$ m

So, distance he walked away from the wall

$= 890.5 - 510 = 380.5$ m ***[2]***

8. (a) **Electrical Fuse** It is a safety device having short length of thin wire made of tin (25%) and lead (75%) alloy having low melting point around 200°C. The fuse wire is of chosen thickness, so as to fix its resistance and hence amount of heating on passage of a particular amount of current. Whenever current through the fuse exceeds the set limit, the fuse wire melts and breaks the circuit. This saves the main electrical appliances. components from damage. ***[2]***

Characteristics of fuse wire

(i) It should have low melting point.

(ii) It should have high resistivity. ***[1]***

(b) **Internal Resistance of Cell** The opposition offered by the electrolyte of the cell to the flow of electric current through it is called the internal resistance of cell. ***[2]***

It depends on the following factors

(i) Concentration of electrolyte.

(ii) Distance between the two electrode. ***[1]***

(c) (i) Let effective resistance between 2 Ω and 6 Ω is R_P

$$R_P = \frac{R_1 R_2}{R_1 + R_2} = \frac{2 \times 6}{2+6} = \frac{12}{8} = 1.5\ \Omega$$

$\therefore$ Total resistance of the circuit

$= 1.5 + 2 + 0.5 = 4.0\,\Omega$ **[1]**

(ii) $i = \dfrac{V}{(R+r)} = \dfrac{9\text{ V}}{4\Omega} = 2.25$ A **[1]**

(iii) Voltage across $2\Omega = i \times R$

$= 2 \times 2.25 = 4.5$ V

Now, voltage across parallel network

$= (9 - 4.5) = 4.5$ V

$\therefore$ Current through 6Ω is $= \dfrac{4.4}{6} = 0.75$ A **[1]**

(iv) Potential difference across terminal $= i \times r$

$= 2.25 \times 0.5 = 1.125$ V **[1]**

9. (a) (i) **Specific Latent Heat of Fusion** It is defined as the heat required to change 1 kg of a solid substance into liquid state at the melting point of the substance. **[1½]**

(ii) When the heat supplied causes no change in the temperature of the substance, then we can say that heat is stored as, latent heat which is used in the change of the state of substance. **[1½]**

(b) (i) As the specific heat capacity is the energy required to raise the temperature of 1g of substance through 1°C and liquid '*A*' has low specific heat capacity. It is a good conductor of heat. **[1½]**

(ii) Liquid '*B*' has more specific heat. It is prefer as a car radiator, as it act as coolant. **[1½]**

(c) Let assume water lose the energy in such a way that temperature will be 0° C.

Then, $Q_1 = mS\Delta T$, here S is specific heat capacity of water

$S = 4200$ cal/g/°C, $m = (60 + 180)$ g $= 240$ g

So, $Q_1 = 240 \times 4200 \times (29 - 0)$

$= 2.9232 \times 10^7$ cal

Let assume ice increases the temperature at 0° C and melt.

$Q_2 = m_2 S_2 \Delta T + m_2 Lv$

where, S_2 is specific heat of ice = 2100 cal/g/°C

Lv is the latent heat of fusion = 80 cal/g

Now, $Q_2 = 37.2 \times 2100 \times (0 - (-10)) + 37.2 \times 80$

$= 7.812 \times 10^5 + 2976$

$= 7.84176 \times 10^5$ cal

Here, you can see $Q_1 > Q_2$. **[2]**

It means water doesn't decrease the temperature to 0°C.

Let the final temperature is T.

Then, $m_1 S_1 \Delta T = (m_2 S_2 \Delta T + m_2 Lv) + m_2 S_1 \Delta T$

$240 \times 4200 \times (29 - T)$

$= 7.84176 \times 10^5 + 37.2 \times 4200 \times T$

$2.9232 \times 10^7 - 1008000T$

$= 7.84176 \times 10^5 + 156240T$

$2.8447824 \times 10^7 = 1.164240 \times 10^6 T$

$T = 24.43°$C

Hence, final temperature of mixture is 24.43° C **[2]**

10. (a) (i) **Background Radiations** Those radiations which are come from environmental sources including the earth's crust, the atmosphere, cosmic rays and radio isotopes. **[1]**

(ii) Equation of α-emission of U^{238}_{92} is given as,

$$^{238}_{92}\text{U} \longrightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}\ (\alpha\text{-particle})$$ **[1]**

(iii) Rate of radioactivity substance is independent on external factors like temperature, pressure etc. Hence by raising temperature four times to the initial temperature of radioactive substance, the rate of radioactivity still remains same. 1991 **[1]**

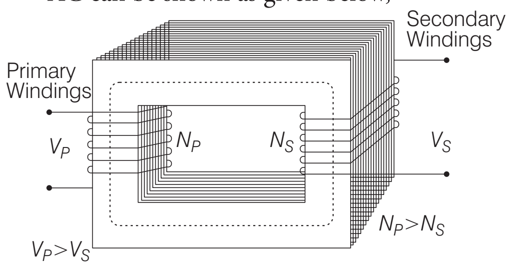
(b) **Nuclear Fusion** Nuclear fusion is an atomic reaction in which two or more atoms combine to form a single, more massive atom.

The resulting atom has a slightly small mass than the sum of masses of the original atoms. The difference is mass is released in the form of energy during the reaction. **[2]**

A typical example is the fusion of two deuterium nuclei to form a tritium nucleus and a proton i.e.,

$${}_1H^2 + {}_1H^2 \longrightarrow {}_1H^3 + {}_1H^1 + \text{Energy}$$ **[1]**

(c) (i) A device used to convert 230 V AC into 15 AC can be shown as given below,



A step-down transformer **[2]**

(ii) Step-down transformer. **[1]**

(iii) A step-down transformer works on the principle of mutual induction. **[1]**

SPECIMEN QUESTION PAPER

ICSE EXAMINATION PAPER 2019

ICSE

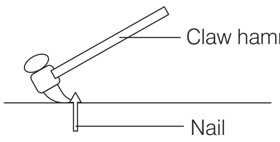
EXAMINATION PAPER 2019

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt all questions from **Section A** and any 4 questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Section A [40 Marks]

1. (a) The diagram below shows a claw hammer used to remove a nail.



(i) To which class of lever does it belong?

(ii) Give one more example of the same class of lever mentioned by you in (i) for which the mechanical advantage is greater than one. *[2]*

(b) Two bodies A and B have masses in the ratio 5:1 and their kinetic energies are in the ratio 125:9. Find the ratio of their velocities. *[2]*

(c) (i) Name the physical quantity which is measured in calories.

(ii) How is calorie related to the SI unit of that quantity? *[2]*

(d) (i) Define couple.

(ii) State the SI unit of moment of couple. *[2]*

(e) (i) Define critical angle.

(ii) State one important factor which affects the critical angle of a given medium. *[2]*

2. (a) An electromagnetic radiation is used for photography in fog.

(i) Identify the radiation.

(ii) Why is this radiation mentioned by you, ideal for this purpose? *[2]*

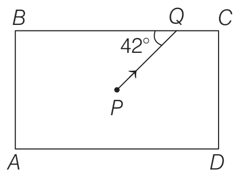
(b) (i) What is the relation between the refractive index of water with respect to air ($_a\mu_w$) and the refractive index of air with respect to water ($_w\mu_a$)?

(ii) If the refractive index of water with respect to air ($_a\mu_w$) is $\frac{5}{3}$. Calculate the refractive index of air with respect to water ($_w\mu_a$). *[2]*

(c) The specific heat capacity of a substance A is $3800\ \text{J kg}^{-1}\text{K}^{-1}$ and that of a substance B is $400\ \text{J kg}^{-1}\text{K}^{-1}$. Which of the two substances is a good conductor of heat? Give a reason for your answer. *[2]*

(d) A man playing a flute is able to produce notes of different frequencies. If he closes the holes near his mouth, will the pitch of the note produced, increase or decrease? Give a reason for your answer. *[2]*

(e) The diagram alongside shows a light source P embedded in a rectangular glass block $ABCD$ of critical angle 42°. Complete the path of the ray PQ till it emerges out of the block. [Write necessary angles]. *[2]*



3. (a) (i) If the lens is placed in water instead of air, how does its focal length change?

(ii) Which lens, thick or thin has greater focal length? *[2]*

(b) Two waves of the same pitch have amplitudes in the ratio 1: 3. What will be the ratio of their

(i) intensities?

(ii) frequencies ? *[2]*

(c) How does an increase in the temperature affect the specific resistance of a

(i) metal?

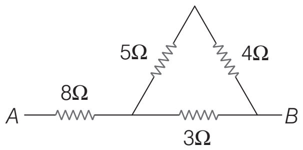
(ii) semiconductor?

(d) (i) Define resonant vibrations.

(ii) Which characteristic of sound, makes it possible to recognise a person by his voice without seeing him? ***[2]***

(e) Is it possible for a hydrogen ($^1_1$H) nucleus to emit an alpha particle? Give a reason for your answer . ***[2]***

4. (a) Calculate the effective resistance across *AB*.

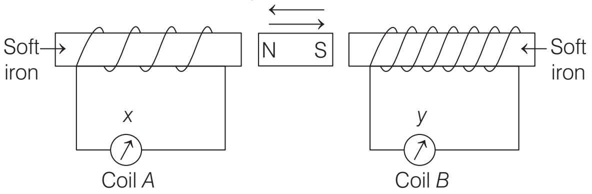


[2]

(b) (i) State whether the specific heat capacity of a substance remains same, when its state changes from solid to liquid.

(ii) Give one example to support your answer. ***[2]***

(c) A magnet kept at the centre of two coils *A* and *B* is moved to and fro as shown in the figure given below. The two galvanometers show deflection.



State with a reason whether $x > y$ or $x < y$, where x and y are magnitudes of deflection. ***[2]***

(d) (i) Why is a nuclear fusion reaction called a thermonuclear reaction ?

(ii) Complete the reaction

$^3He_2 + ^2H_1 \longrightarrow ^4He_2 + \ldots\ldots\ldots + \text{Energy}$ ***[2]***

(e) State two ways to increase the speed of rotation of a DC motor. ***[2]***

Section B [40 Marks]

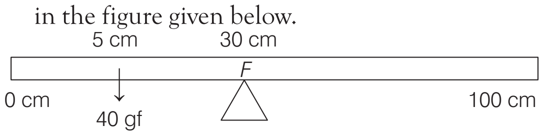
5. (a) A body of mass 10 kg is kept at a height of 5 m. It is allowed to fall and reach the ground.

(i) What is the total mechanical energy possessed by the body at the height of 2 m assuming it is a frictionless medium?

(ii) What is the kinetic energy possessed by the body just before hitting the ground? ***[3]***

(Take, $g = 10 \text{ m/s}^2$).

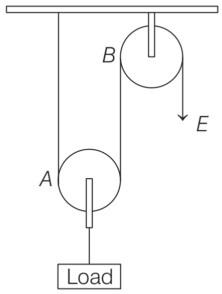
(b) A uniform meter scale is in equilibrium as shown in the figure given below.



(i) Calculate the weight of the meter scale.

(ii) Which of the following option is correct to keep the ruler in equilibrium, when 40 gf-wt is shifted to 0 cm mark? *F* is shifted towards 0 cm. *Or* *F* is shifted towards 100 cm. ***[3]***

(c) The figure below shows a pulley arrangement.



(i) Copy the figure and mark the direction of tension on each strand of the string.

(ii) What is the velocity ratio of the arrangement?

(iii) If the tension acting on the string is *T*, then what is the relationship between *T* and effort *E*?

(iv) If the free end of the string moves through a distance *x*, then find the distance by which the load is raised. ***[4]***

6. (a) How does the angle of deviation formed by a prism change with the increase in the angle of incidence?

Draw a graph showing the variation in the angle of deviation with the angle of incidence at a prism surface. ***[3]***

(b) A virtual, diminished image is formed when an object is placed between the optical centre and the principal focus of a lens.

(i) Name the type of lens which forms the above image.

(ii) Draw a ray diagram to show the formation of the image with the above stated characteristics. ***[3]***

(c) An object is placed at a distance 24 cm in front of a convex lens of focal length 8 cm.

(i) What is the nature of the image so formed?

(ii) Calculate the distance of the image from the lens.

(iii) Calculate the magnification of the image. ***[4]***

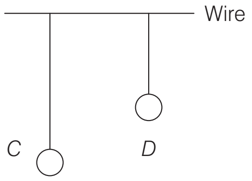
7. (a) It is observed that during march past we hear a base drums distinctly from a distance compared to the side drums.

(i) Name the characteristic of sound associated with the above observation.

(ii) Give a reason for the above observation. ***[3]***

(b) A pendulum has a frequency of 4 vibrations per second. An observer starts the pendulum and fires a gun simultaneously. He hears the echo from the cliff after 6 vibrations of the pendulum. If the velocity of sound in air is 340 m/s, find the distance between the cliff and the observer. *[3]*

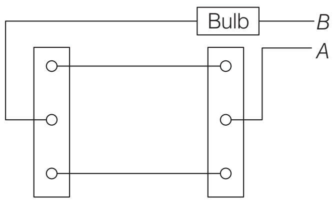
(c) Two pendulums C and D are suspended from a wire as shown in the figure given below. Pendulum C is made to oscillate by displacing it from its mean position. It is seen that D also starts oscillating.



(i) Name the type of oscillation, C will execute.
(ii) Name the type of oscillation, D will execute.
(iii) If the length of D is made equal to C, then what difference will you notice in the oscillations of D?
(iv) What is the name of the phenomenon when the length of D is made equal to C? *[4]*

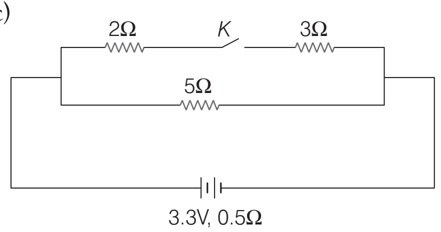
8. (a) (i) Write one advantage of connecting electrical appliances in parallel combination.
(ii) What characteristics should a fuse wire have?
(iii) Which wire in a power circuit is connected to the metallic body of the appliance? *[3]*

(b) The figure below shows a dual control switch circuit connected to a bulb.



(i) Copy the figure and complete it so that the bulb is switched ON.
(ii) Out of A and B which one is the live wire and which one is the neutral wire? *[3]*

(c)



The above figure shows a circuit with the key K open. Calculate

(i) the resistance of the circuit when the key K is open.
(ii) the current drawn from the cell when the key K is open.
(iii) the resistance of the circuit when the key K is closed.
(iv) the current drawn from the cell when the key K is closed. *[4]*

9. (a) (i) Define calorimetry.
(ii) Name the material used for making a calorimeter.
(iii) Why is a calorimeter made up of thin sheets of the above material answered in (ii)? *[3]*

(b) The melting point of naphthalene is 80 °C and the room temperature is 30 °C. A sample of liquid naphthalene at 100 °C is cooled down to the room temperature. Draw a temperature-time graph to represent this cooling. In this graph, mark the region which corresponds to the freezing process. *[3]*

(c) 104 g of water at 30°C is taken in a calorimeter made of copper of mass 42 g. When a certain mass of ice at 0°C is added to it, the final steady temperature of the mixture after the ice has melted, was found to be 10°C. Find the mass of ice added.
[Take, specific heat capacity of water $= 4.2\ Jg^{-1}\ {}^\circ C^{-1}$; Specific latent heat of fusion of ice $= 336\ Jg^{-1}$; Specific heat capacity of copper $= 0.4 Jg^{-1}\ {}^\circ C^{-1}$.] *[4]*

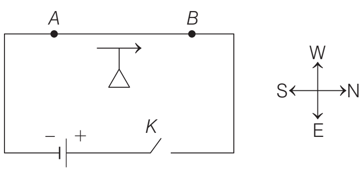
10. (a) Draw a neat labelled diagram of an AC generator. *[3]*

(b) (i) Define nuclear fission.
(ii) Rewrite and complete the following nuclear reaction by filling in the atomic number ` of Ba and mass number of Kr.

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{144}_{\dots\dots}Ba + ^{\dots\dots}_{36}Kr + 3^{1}_{0}n + \text{Energy}$$

[3]

(c) The figure below shows a magnetic needle kept just below the conductor AB which is kept in North-South direction.



(i) In which direction will the needle deflect when the key is closed?
(ii) Why is the deflection produced?
(iii) What will be the change in the deflection, if the magnetic needle is taken just above the conductor AB?
(iv) Name one device which works on this principle. *[4]*

ANSWERS

1. (a) (i) A claw hammer used to remove a nail is a class 1 lever.

(ii) A seesaw is an example of class 1 lever.
For class 2 lever, mechanical advantage is always greater than 1. It is also called force multiplier lever.

(b) Let mass of body A is m_A and mass of body B is m_B.

Given, $$\frac{m_A}{m_B} = \frac{5}{1} \quad \ldots\text{(i)}$$

and $$\frac{(\text{KE})_A}{(\text{KE})_B} = \frac{125}{9} \quad \ldots\text{(ii)}$$

We know that, kinetic energy,

$$\text{KE} = \frac{1}{2} mv^2$$

$$\therefore \quad \frac{(\text{KE})_A}{(\text{KE})_B} = \frac{\frac{1}{2} m_A v_A^2}{\frac{1}{2} m_B v_B^2}$$

From Eqs. (i) and (ii), we get

$$\Rightarrow \quad \frac{125}{9} = \frac{5}{1}\left(\frac{v_A}{v_B}\right)^2$$

$$\Rightarrow \quad \frac{25}{9} = \left(\frac{v_A}{v_B}\right)^2$$

$$\Rightarrow \quad \frac{v_A}{v_B} = \frac{5}{3}$$

Hence, ratio of their velocities is 5 : 3.

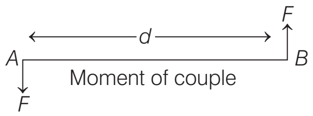
(c) (i) Heat

(ii) The SI unit of heat is joule and it is represented by J.

1 calorie = 4.186 Joule

(d) (i) A couple is a pair of forces equal in magnitude, oppositely directed and displaced by perpendicular distance or moment. The simplest kind of couple consists of two equal and opposite forces whose lines of action do not coincide. This is called a simple couple.

(ii) The moment of couple is defined as the product of either force and the perpendicular distance between the line of action of forces.



The SI unit of moment of couple = N-m ^{2}

(e) (i) Critical angle is the angle of incidence beyond which rays of light passing through a denser medium to the surface of a less dense medium are no longer refracted but totally reflected.

Or The angle of incidence in denser medium for which angle of refraction in rarer medium is 90° is called critical angle.

(ii) **Temperature** On increasing the temperature of the medium, its refractive index decreases so the critical angle for that pair of media increases. Thus, the critical angle increases with increase in temperature.

2. (a) (i) Infrared radiation are used in photography in fog and mist and also at night.

(ii) Because infrared radiation have long wavelength. As they are having low frequency the energy associated with them is also low. So, they do not scatter much and can penetrate appreciably through it.

(b) (i) Refractive index of water with respect to air

$${}_a\mu_w = \frac{\mu_w}{\mu_a} \quad \ldots\text{(i)}$$

and refractive index of air with respect to water

$${}_w\mu_a = \frac{\mu_a}{\mu_w} \quad \ldots\text{(ii)}$$

From Eqs. (i) and (ii), we get

$${}_a\mu_w = \frac{1}{{}_w\mu_a}$$

(ii) Refractive index of water with respect to air

$$({}_a\mu_w) = \frac{1}{\text{Refractive index of air with respect to water } ({}_w\mu_a)}$$

Given, $${}_a\mu_w = \frac{5}{3}$$

$$\therefore \quad {}_a\mu_w = \frac{1}{{}_w\mu_a}$$

$$\therefore \quad {}_w\mu_a = \frac{3}{5}$$

(c) The substance B is a good conductor of electricity comparative the substance A, because it needs less amount of heat to be get heated quickly.

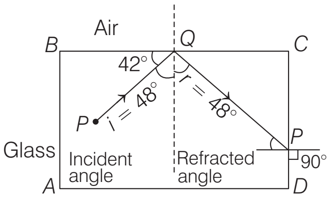
(d) If we close the near hole, the wavelength of the sound wave will decrease. Since, frequency of the sound wave is inversely proportional to wavelength, so frequency will increase. Greater the frequency of a sound, the higher will be its pitch. Hence, pitch will increase.

(e) Given, critical angle, $C = 42°$

At a point Q, $i = 48°$ and $i_C = 42°$

i.e. $i > i_C$

$r = 48°$



At a point P, $i = 42°$ and $i_C = 42°$

$\Rightarrow$ $i = i_C$

Therefore, $r = 90°$

3. (a) (i) The refractive index of water is more than air.

The formula of focal length,

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where, f = focal length,

n_2 = refractive index of lens

and n_1 = refractive index of water.

Here, n_1 is greater than of air.

So, n_1 increases then ratio of refractive index is $\frac{n_2}{n_1}$ decreases, which gives us decrease in $\frac{n_2}{n_1} - 1$.

So, $\frac{1}{f}$ decreases, then focal length f increases.

(ii) A thin lens has greater focal length.

(b) (i) Given, amplitude of two waves,

$$\frac{a_1}{a_2} = \frac{1}{3} \qquad \dots\text{(i)}$$

$\because$ We know that, intensity is proportional to amplitude square, i.e. $I \propto a^2$

$\therefore$ Ratio of intensity, $\frac{I_1}{I_2} = \left(\frac{1}{3}\right)^2 = \frac{1}{9}$

(ii) Frequency of the sound wave has no effect on amplitude, so ratio of frequency remains same, i.e. 1 : 3.

(c) (i) If the temperature of the metal is raised, the atom vibrate more strongly and the electrons make more violent collisions with them, so the resistance of the metal increase. Hence, resistivity will increase.

Hence, specific resistance of the metal increase.

(ii) In case of semiconductor as the temperature increase, the electrons in the valence band get excited and jump into the conduction band and hence the conductance increase resulting in the decreasing of resistance. As resistance is directly proportional to resistivity.

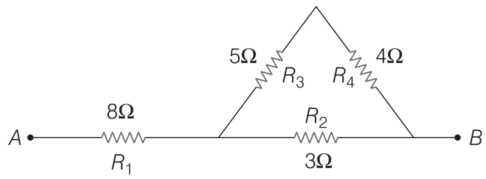
Hence, resistivity of semiconductor decreases rapidly with rise in temperature.

(d) (i) The increase in amplitude of oscillation of an electric or mechanical system exposed to a periodic force whose frequency is equal or very close to the natural undamped frequency of the system, called resonant vibrations.

(ii) The quality (timbre) of sound.

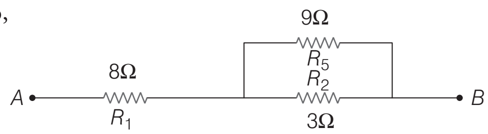
(e) No, it is not possible because it is alpha particle consists of two protons and two neutrons. However none of the isotopes of hydrogen has the same number or more of protons and neutrons in its nuclei. Thus, they cannot emit an alpha particle.

4. (a)



Here, R_3 and R_4 are in series combination, so total resistance $R_5 = R_3 + R_4 = 5 + 4 = 9\Omega$

So,

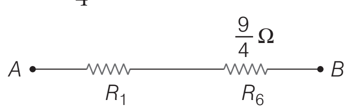


Here, R_5 and R_2 are in parallel combination, so total resistance

$$\frac{1}{R_6} = \frac{1}{R_2} + \frac{1}{R_5} = \frac{1}{3} + \frac{1}{9}$$

$$\frac{1}{R_6} = \frac{4}{9}$$

$$\therefore \quad R_6 = \frac{9}{4}\,\Omega$$



Here, R_1 and R_6 are series combination, so resultant resistance across AB.

Now, equivalent resistance,

$$R_{eq} = R_1 + R_6 = 8 + \frac{9}{4} = \frac{41}{4}\,\Omega$$

(b) (i) The specific heat (S) of a substance is the quantity of heat in calorie required to rise the temperature of 1 g of that substance by 1°C. Specific heat does not apply when a substance is undergoing phase change. Because specific heat causes temperature change.

So when substance's state changes from solid to liquid, then no temperature changes. So specific heat capacity will be same.

(ii) Specific heat of ice and specific heat of water.

(c) In the figure, the number of turns in coil B is greater than coil A. Hence, deflection in B will be greater than deflection in coil A. i.e. $y > x$.

(d) (i) Nuclear fusion is also called thermonuclear reaction because it takes place at extremely high temperature and hence create enormous amount of energy, e.g. reactions in the sun.

(ii) ${}^3He_2 + {}^2H_1 \rightarrow {}^4He_2 + {}^1H_1 + \text{Energy}$

(e) (i) To install a high power commercial horseshoe magnet.

(ii) To increase the current, so that the coil rotates rapidly.

5. (a) (i) Given, mass of body, $m = 10$ kg
height, $h = 5$ m

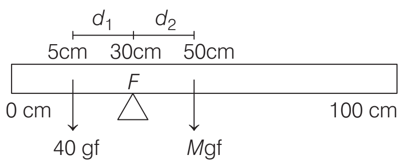
So, potential energy at height of 5m

$$= mgh = 10 \times 10 \times 5 = 500 \text{ J}$$

If it falls to a height of 2m, the increase in kinetic energy will be equal to the decrease in potential energy, so the total mechanical energy will equal to potential energy. So, total mechanical energy = 500 J.

(ii) From principle of energy transformation when body is about to reach the ground, potential energy will be converted to kinetic energy. So, kinetic energy (KE) = 500 J.

(b)



(i) At 50 cm,
Mass of meter scale = Mgf

Now, $$F_1 d_1 = F_2 d_2$$

$$(40\text{gf})(30 - 5) = F_2 (50 - 30)$$

$$F_2 = 50 \text{ gf}$$

$$F_2 = 0.49 \text{ N}$$

$$\therefore \quad F_2 = mg$$

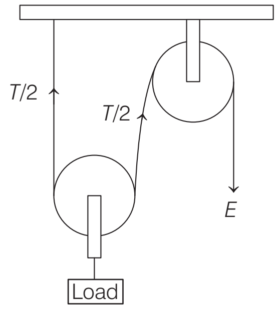
$$0.49 = m \times 9.8$$

$$m = \frac{0.49}{9.8}$$

$$\therefore \quad m = 0.05 \text{ kg}$$

(ii) F is shifted towards 0 cm.

(c) (i)



(ii) Velocity ratio of the system, which one fixed pulley and one movable pulley, then

velocity ratio = $2^1 = 2$

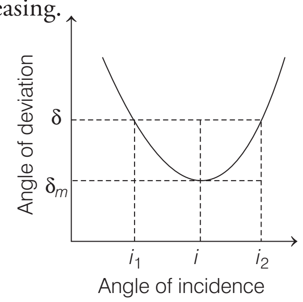
(iii) The relation between T and effort E is given by

$$\frac{T}{2} = E$$

$$T = 2E$$

(iv) If the free end of the the string moves through a distance x, then the load is raised by $\frac{x}{2}$ distance.

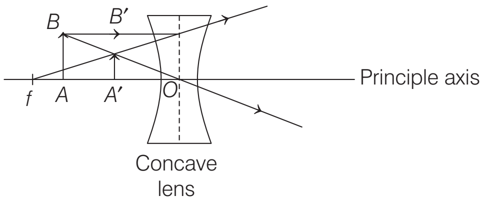
6. (a) If the angle of incidence is increased gradually, then angle of deviation first decreases, attains a minimum value (δ_m) and then again starts increasing.



When angle of deviation is minimum, the prism is said to be placed in the minimum deviation position.

(b) (i) When a object is placed between the optical centre and the principle focus of a concave lens, then virtual and diminished image of object is formed.

(ii) **Ray diagram**



where, f = principle focus

and O = optical centre of lens.

(c) Given,

Object distance, $u = -24$ cm (for convex lens)

Focal length of lens, $f = 8$ cm

(i) As for convex lens, if $|u| > |f|$ then real and inverted image is formed and as $|u| > 2|f|$ then it diminished.

(ii) As we know that,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

where, v is the image distance from lens.

$$\frac{1}{v} = \frac{1}{f} + \frac{1}{u}$$

$$v = \frac{uf}{f+u} = \frac{(-24)(8)}{(8)+(-24)}$$

$$v = \frac{(-24)\times 8}{-16} = 12 \text{ cm}$$

(iii) As we know that,

Magnification, $m = \frac{v}{u} = \frac{12}{-24} = -0.5$

Here, negative sign indicates that the image is inverted.

7. (a) (i) Pitch and timbre.

(ii) Side drums and base drums are made up of different material, so they have different frequency, hence the pitch. The quality (timbre) of sound enables us to distinguish between two sounds. Base drums and side drums have different quality due to different material.

(b) Given,

Frequency of pendulum, $\nu = 4$ Hz

Velocity of sound in air, $v_s = 340$ m/s

As we know that,

Time period, $T = \frac{1}{\text{Frequency}} = \frac{1}{4}$ s

Time's in which echo is heard,

$$t = 6 \times \frac{1}{4} = 1.5 \text{ s}$$

According to the question,

$$2d = v_s \times t \Rightarrow d = \frac{v_s \times t}{2} = \frac{340 \times 1.5}{2} = 255 \text{ m}$$

(c) (i) C will execute damped oscillation.

(ii) D will execute forced oscillation.

(iii) D will start executing with very large amplitude.

(iv) Resonance.

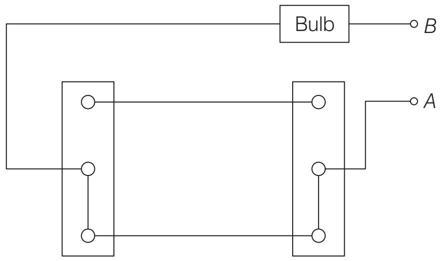
8. (a) (i) If any appliances gets faulty, rest of the circuit gets unaffected by it and no discontinued supply.

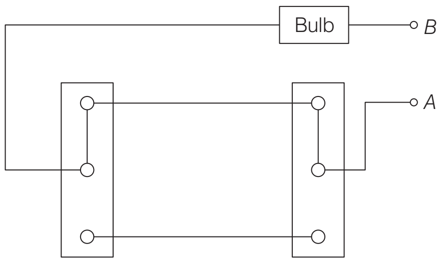
(ii) (a) It should have a low melting point.

(b) It should have a high resistance.

(iii) Earth wire.

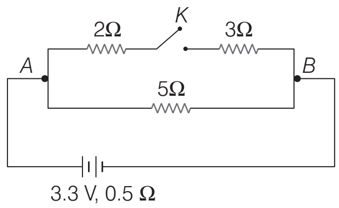
(b) (i)





(ii) A is live wire and B is the neutral wire.

(c)



(i) When key K is open then 2Ω and 3Ω resistance are not in the circuit, i.e. this branch is not accounted in the circuit.

Now, equivalent resistance,

$$R_{eq} = 5 + 0.5 = 5.5\ \Omega$$

(ii) According to the Ohm's law,

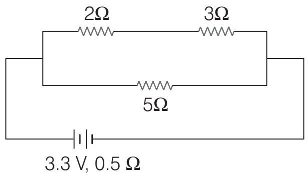
$$V = I\,R_{eq}$$

$$I = \frac{V}{R_{eq}}$$

Here, $V = 3.3$ V and $R_{eq} = 5.5\ \Omega$.

So, current, $I = \frac{3.3}{5.5} = 0.6$ A

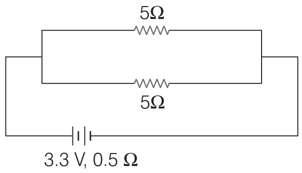
(iii) When the key K is closed, then circuit becomes as shown in the figure.



In the circuit 2Ω and 3Ω resistance are connected in series combination. Hence, equivalent resistance,

$$R' = 2 + 3 = 5\,\Omega$$

Now, circuit becomes



In the circuit two 5 Ω resistances are connected in the parallel combination.

Hence, equivalent resistance,

$$R_{eq} = 0.5 + \frac{5 \times 5}{5 + 5} = 0.5 + 2.5 = 3.0\,\Omega$$

(iv) According to the Ohm's law,

$$V = IR$$

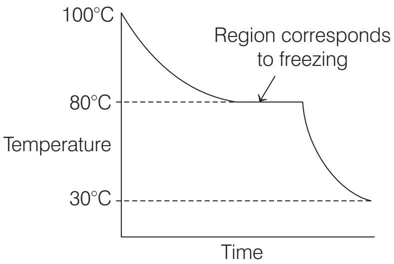
Current, $$I = \frac{V}{R_{eq}} = \frac{3.3}{3.0} = 1.1\text{ A}$$

9. (a) (i) Calorimetry is the science associated with determining the change in energy of a system by measuring the heat exchanged with surroundings.

(ii) Copper, wood

(iii) To avoid any heat utilise in making the temperature of sheet going up.

(b)



(c) Given,

Mass of water, $m_w = 104$ g

Temperature of water, $T_w = 30°$ C, $T_i = 0°$ C

Mass of copper, $m_c = 42$ g

Final temperature of mixture, $T = 10°$C

According to the principle of calorimetry

Heat lost = Heat gained

$$m_w S_w (T_w - T) + m_c S_c (T_w - T)$$
$$= m_i S_i + m_i S_w (T - T_i)$$

Here, S_w = Specific heat capacity of water
$= 4.2\text{ Jg}^{-1}\,°\text{C}^{-1}$

S_c = Specific heat capacity of copper
$= 0.4\text{ Jg}^{-1}\,°\text{C}^{-1}$

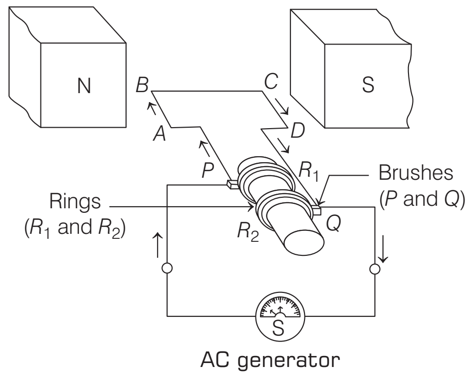
S_i = Specific latent heat of fusion of ice
$= 336\text{ Jg}^{-1}°\text{C}^{-1}$

$$104 \times 4.2 \times (30 - 10) + 42 \times 0.4(30 - 10)$$
$$= m_i (336) + m_i \times 4.2 \times (10 - 0)$$

i.e. $8736 + 336 = m_i [336 + 42]$

Mass of ice, $m_i = \dfrac{9072}{378} = 24$ g

10. (a)



(b) (i) Nuclear fission is the phenomenon of spliting of a heavy nucleus (usually $A > 230$) into two or more lighter nuclei.

(ii) $$Z_{LHS} = Z_{RHS}$$
$$92 = 36 + x + 0$$
$$92 - 36 = x \Rightarrow x = 56$$
$$A_{LHS} = A_{RHS}$$
$$235 + 1 = 144 + y + 3$$
$$y = 236 - 147 = 89$$

Now, the complete reaction is

$$^{235}_{92}\text{U} + ^{1}_{0}n \longrightarrow ^{144}_{56}\text{Ba} + ^{89}_{36}\text{Kr} + 3\,^{1}_{0}n + \text{Energy}$$

(c) (i) East direction

(ii) The needle align itself with the direction of magnetic field lines. Since the lines are perpendicular to the direction of current, the needle will try to align that way also.

(iii) The North pole of the compass needle deflects towards West.

(iv) Electric motor.

ICSE

EXAMINATION PAPER 2020

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 15 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. **Section A** is compulsory. Attempt any four questions from **Section B**.
4. The intended marks for questions or parts of questions are given in brackets [ ].

Section A [40 Marks]

Attempt all questions from this section.

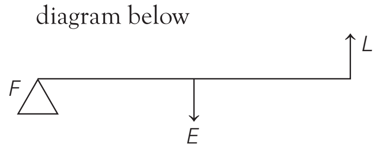
1. (a) (i) Define moment of force.

(ii) Write the relationship between the SI and CGS unit of moment of force. *[2]*

(b) Define a kilowatt hour. How is it related to joule? *[2]*

(c) A satellite revolves around a planet in a circular orbit. What is the work done by the satellite at any instant? Give a reason. *[2]*

(d) (i) Identify the class of the lever shown in the diagram below *[2]*



(ii) How is it possible to increase the mechanical advantage of the above lever without increasing its length?

(e) Give one example of each, when *[2]*

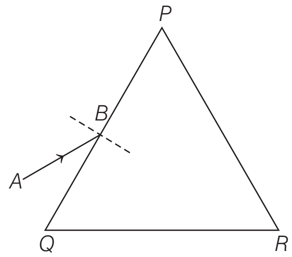
(i) chemical energy changes into electrical energy.

(ii) electrical energy changes into sound energy.

2. (a) Crane A lifts a heavy load in 5 s, whereas another crane B does the same work in 2 s. Compare the power of crane A to that of crane B. *[2]*

(b) A ray of light falls normally on a rectangular glass slab. Draw a ray diagram showing the path of the ray till it emerges out of the slab. *[2]*

(c) Complete the path of the monochromatic light ray AB incident on the surface PQ of the equilateral glass prism PQR till it emerges out of the prism due to refraction. *[2]*



(d) Where should be an object be placed infront of a convex lens in order to get *[2]*

(i) an enlarged real image

(ii) and enlarged virtual image?

(e) A pond appears to be 2.7 m deep. If the refractive index of water is $\frac{4}{3}$, find the actual depth of the pond. *[2]*

3. (a) The wavelengths for the light of red and blue colours are nearly 7.8×10^{-7} m and 4.8×10^{-7} m, respectively. *[2]*

(i) Which colour has the greater speed in a vacuum?

(ii) Which colour has a greater speed in glass?

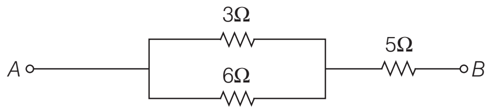
(b) Draw a graph between displacement from mean position and time for a body executing free vibration in a vacuum. *[2]*

(c) A sound wave travelling in water has wavelength 0.4 m. Is this wave audible in air? (The speed of sound in water $= 1400 \text{ ms}^{-1}$) *[2]*

(d) Why does stone lying in the sun get heated up much more than water lying for the same duration of time? *[2]*

(e) Why is it not advisable to use a piece of copper wire as fuse wire in an electric circuit? *[2]*

4. (a) Calculate the total resistance across *AB*. **[2]**



(b) Two metallic blocks *P* and *Q* having masses in ratio 2 : 1 are supplied with the same amount of heat. If their temperatures rise by same degree, compare their specific heat capacities. **[2]**

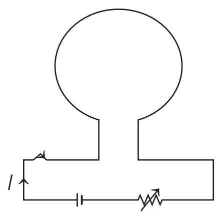
(c) When a current carrying conductor is placed in a magnetic field, it experiences a mechanical force. What should be the angle between the magnetic field and the length of the conductor, so that the force experienced is **[2]**

(i) zero

(ii) and maximum?

(d) A nucleus $_{84}X^{202}$ of an element emits an α-particle followed by a β-particle. The final nucleus is $_{a}Y^{b}$. Find the values of *a* and *b*. **[2]**

(e) The diagram below shows a loop of wire carrying current *I* . **[2]**



(i) What is the magnetic polarity of the loop that faces us?

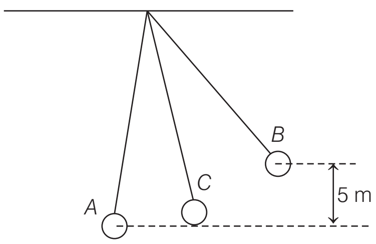
(ii) With respect to the diagram, how can we increase the strength of the magnetic field produced by this loop?

Section B **[40 Marks]**

Attempt any four questions from this section.

5.

(a) The figure below shows a simple pendulum of mass 200 g. It is displaced from the mean position *A* to the extreme position *B*. The potential energy at the position *A* is zero. At the position *B*, the pendulum bob is raised by 5 m. **[4]**



(i) What is the potential energy of the pendulum at the position *B*?

(ii) What is the total mechanical energy at point *C*?

(iii) What is the speed of the bob at the position *A* when released from *B*?
(Take, $g = 10 \text{ ms}^{-2}$ and there is no loss of energy)

(b) (i) With reference to the direction of action, how does a centripetal force differ from a centrifugal force during uniform circular motion? **[3]**

(ii) Is centrifugal force the force of reaction of centripetal force?

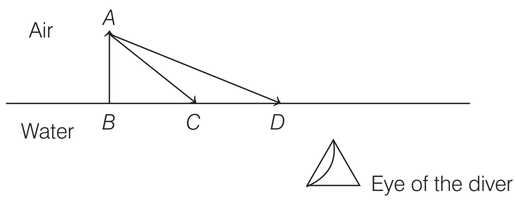
(iii) Compare the magnitudes of centripetal and centrifugal forces.

(c) A block and tackle system of pulleys has velocity ratio 4. **[3]**

(i) Draw a neat labelled diagram of the system indicating clearly the points of application and direction of load and effort.

(ii) What will be its velocity ratio, if the weight of the movable block is doubled?

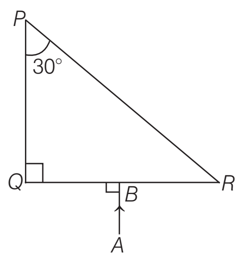
6. (a) A diver in water looks obliquely at an object *AB* in air. **[3]**



(i) Does the object appear taller, shorter or of the same size to the diver?

(ii) Show the path of two rays *AC* and *AD* starting from the tip of the object as it travels towards the diver in water and hence obtain the image of the object.

(b) Complete the path of the ray *AB* through the glass prism in *PQR* till it emerges out of the prism. Given the critical angle of the glass as 42°. **[3]**



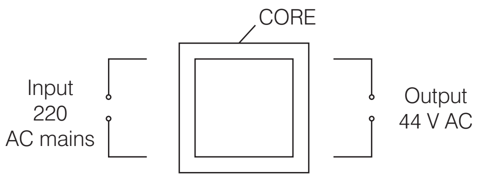
(c) A lens of focal length 20 cm forms an inverted image at a distance of 60 cm from the lens.

(i) Identify the lens. **[4]**

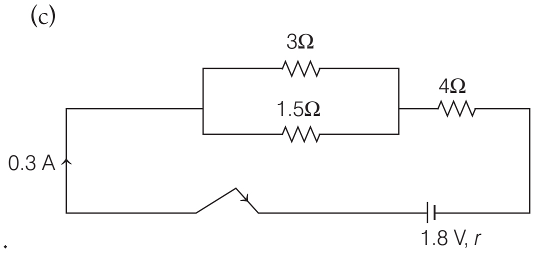
(ii) How far is the lens present infront of the object?
(iii) Calculate the magnification of the image.

7. (a) Give reasons for the following. *[3]*
During the day,
(i) clouds appears white
(ii) and sky appears blue.
(b) (i) Name the system which enables us to locate underwater objects by transmitting ultrasonic waves and detecting the reflecting impulse.
(ii) What are acoustically measurable quantities related to pitch and loudness? *[3]*
(c) (i) When a tuning fork (vibrating) is held close to ear, one hears a faint hum. The same (vibrating tuning fork) is held such that its stem is in contact with the table surface, then one hears a loud sound. Explain.
(ii) A man standing infront of a vertical cliff fires a gun. He hears the echo after 3.5 s. On moving closer to the cliff by 84 m, he hears the echo after 3 s. Calculate the distance of the cliff from the initial position of the man. *[4]*

8. (a) The diagram below shows the core of a transformer and its input and output connections. *[3]*

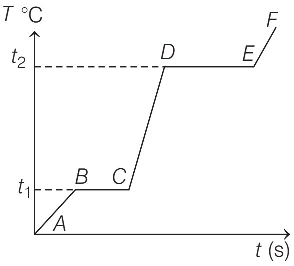


(i) State the material used for the core.
(ii) Copy and complete the diagram of the transformer by drawing input and output coils.
(b) (i) What are superconductors? *[3]*
(ii) Calculate the current drawn by an appliance rated 110 W, 220 V when connected across 220 V supply.
(iii) Name a substance whose resistance decreases with the increase in temperature.
(c) *[4]*



The diagram above shows three resistors connected across a cell of emf 1.8 V and internal resistance r. Calculate
(i) current through 3 Ω resistor
(ii) and the internal resistance r.

9. (a) (i) Define heat capacity of a substance. *[3]*
(ii) Write the SI unit of heat capacity.
(iii) What is the relationship between heat capacity and specific heat capacity of a substance?
(b) The diagram below shows the change of phases of a substance on a temperature *versus* time graph on heating the substance at a constant rate. *[3]*



(i) Why is the slope of CD is less than slope of AB?
(ii) What is the boiling and melting points of the substance?
(c) A piece of ice of mass 60 g is dropped into 140 g of water at 50°C. Calculate the final temperature of water when all the ice has melted. *[4]*
(Assume, no heat is lost to the surrounding)
Specific heat capacity of water = $4.2 \text{ J g}^{-1}\text{K}^{-1}$
and specific latent heat of fusion of ice = 336 Jg^{-1}.

10. (a) (i) Draw a neat labelled diagram of DC motor. *[3]*
(ii) Write any one use of a DC motor.
(b) (i) Differentiate between nuclear fusion and nuclear fission. *[3]*
(ii) State one safety precaution in the disposal of nuclear waste.
(c) An atomic nucleus A is composed of 84 protons and 128 neutrons. The nucleus A emits an α-particle and is transformed into a nucleus B. *[4]*
(i) What is the composition of B?
(ii) The nucleus B emits a β-particle and is transformed into a nucleus C. What is the composition of C ?
(iii) What is mass number of the nucleus A?
(iv) Does the composition of C change, if it emits γ-radiations?

ANSWERS

1. (a) (i) Refer to text on page no.2 (Torque or moment of a force).

(ii) Refer to text on page no. 2 (Torque or moment of a force).

(b) Refer to text on page no. 20 (Other important units of energy).

(c) Force of gravity of the planet provides necessary centripetal force to the satellite to revolve around the planet in circular orbit. When satellite revolves around the planet, then direction of force on the satellite is always perpendicular to its velocity or displacement, hence work done by the satellite at any instant is zero.

(d) (i) The lever given in the diagram is a class 3 lever because effort lies between the load and the fulcrum.

(ii) Mechanical advantage of a lever is the ratio of effort arm to load arm.

i.e. $$\text{MA} = \frac{\text{Effort arm}}{\text{Load arm}}$$

Therefore, MA of lever is increased by shifting the effort (E) towards the load.

(e) (i) Dry cell

(ii) Loudspeaker

2. (a) Time taken to lift load by crane $A, t_1 = 5\text{s}$

Time taken to same work by crane B, $t_2 = 2\text{s}$

$$\therefore \frac{\text{Power of crane } A}{\text{Power of crane } B} = \frac{W_1 / t_1}{W_2 / t_2}$$

$$\frac{P_A}{P_B} = \frac{t_2}{t_1}$$

$$\Rightarrow \frac{P_A}{P_B} = \frac{2}{5} \qquad [\because W_1 = W_2]$$

$$\Rightarrow P_A = \frac{2}{5} P_B$$

Thus, power of crane A is two-fifth of crane B.

(b) When a ray of light falls normally on a rectangular glass slab, then angle of incidence, $i = 0$.

$$\therefore \text{By Snell's law, } {}_a\mu_g = \frac{\sin i}{\sin r}$$

$${}_a\mu_g = \frac{\sin 0°}{\sin r} = \frac{0}{\sin r}$$

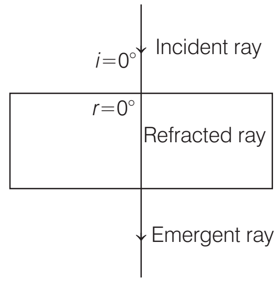
$$\Rightarrow {}_a\mu_g \times \sin r = 0$$

$$\therefore {}_a\mu_g \neq 0,$$

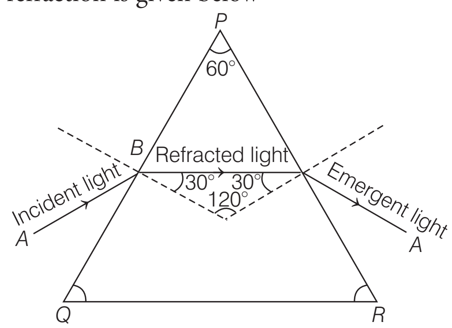
$$\therefore \sin r = 0$$

$$\Rightarrow r = 0°$$

Hence, when a ray of light falls normally on a rectangular glass slab, then it emerges out of the slab without any deviation which is shown in the figure.



(c) The complete path of monochromatic light AB is incident on the surface PQ of the equilateral glass prism PQR till it emerges out of the prism due to refraction is given below



(d) (i) Object is placed between F and $2F$.

(ii) Object is placed between optical centre and F.

(e) Apparent depth of pond, $d = 2.7$ m

Refractive index of water, $\mu = \frac{4}{3}$

$$\text{We know that, } \mu = \frac{\text{Actual depth}}{\text{Apparent depth}}$$

$$\Rightarrow \frac{4}{3} = \frac{\text{Actual depth}}{2.7}$$

$$\therefore \text{Actual depth} = \frac{4}{3} \times 2.7 = 3.6 \text{ m}$$

3. (a) Given, wavelength of light for red colour,

$$\lambda_R = 7.8 \times 10^{-7} \text{ m}$$

Wavelength of light for blue colour,

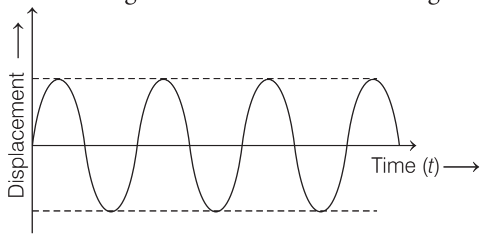
$$\lambda_B = 4.8 \times 10^{-7} \text{ m}$$

$$\therefore \lambda_R > \lambda_B$$

(i) Speed of light in vacuum is independent to the wavelength of light. Hence, red colour of light has equal speed in vacuum as the blue colour of light.

(ii) For same medium, speed of light is directly proportional to its wavelength. Therefore, speed of red colour of light is greater than speed of blue colour of light as $\lambda_R > \lambda_B$.

(b) The amplitude and frequency of a freely vibrating body in vacuum remains constant with respect to time. The displacement-time graph of a body executing free vibration in vacuum is given as



(c) Given, speed of sound in water, $v = 1400 \text{ ms}^{-1}$

Wavelength of sound wave in water, $\lambda = 0.4$ m

If f be the frequency of sound wave, then

$$v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{1400}{0.4} = 3500 \text{ Hz}$$

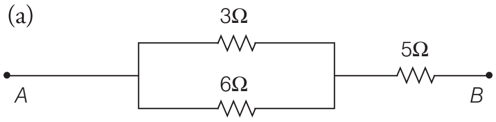
Since, frequency of sound wave remains same in water and air. Hence, $f_{\text{water}} = f_{\text{air}} = 3500$ Hz.

Since, 20 Hz $< f_{\text{air}} <$ 20 kHz, hence given sound wave is audible in air.

(d) The water does not get heated up, so quickly as compared to stone. It is because water requires about five times more heat energy than stone for the same rise in temperature, i.e. water has higher specific heat capacity than stone.

(e) Resistance of copper wire is very low and its melting point is very high but fuse wire must have high resistance and low melting point. Therefore, fuse wire is not made of copper.

4. (a)



Total resistance between A and B,

$$R_{AB} = (3||6) + 5 = \frac{3 \times 6}{3+6} + 5$$

$$= 2 + 5 = 7\ \Omega$$

(b) Masses ratio of blocks P and Q,

$$m_P : m_Q = 2:1$$

$$\Rightarrow \quad \frac{m_Q}{m_P} = \frac{1}{2} \quad \ldots \text{(i)}$$

We know that, heat supplied is given as

$$H = ms\Delta T$$

where, s is specific heat.

But $\quad H_P = H_Q$

$$\Rightarrow \quad m_P s_P \Delta T = m_Q s_Q \Delta T$$

$$\Rightarrow \quad \frac{s_P}{s_Q} = \frac{m_Q}{m_P} = \frac{1}{2} \quad \text{[from Eq. (i)]}$$

$$\Rightarrow \quad s_P : s_Q = 1:2$$

(c) (i) A current carrying conductor placed in uniform magnetic field experiences no force (zero force), if the angle between the magnetic field and the length of the conductor is 0° or 180°.

(ii) A current carrying conductor placed in uniform magnetic field experiences maximum force, if the angle between the magnetic field and the length of conductor is 90°.

(d) When an α-particle is emitted by a nucleus, then mass number of nucleus is decreased by 4 units while atomic number is decreased by 2 units. Similarly, for β-particle emission, atomic number is increased by one unit while mass number remains same.

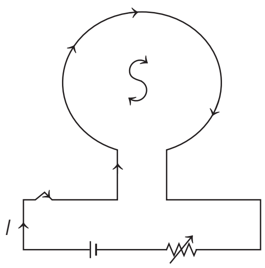
$$\therefore \quad {}_{84}X^{202} \xrightarrow{\alpha} {}_{82}Z^{198} \xrightarrow{\beta} {}_{83}Y^{198},$$

$$\therefore \quad {}_aY^b = {}_{83}Y^{198}$$

$$\Rightarrow \quad a = 83$$

and $\quad b = 198$

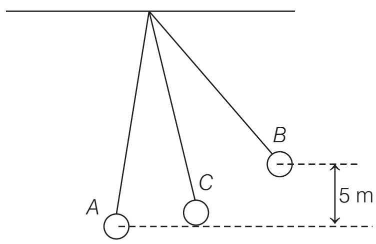
(e) (i) The direction of current flowing through the loop is shown below



Since, direction of current in the loop is clockwise, hence it behaves as a south pole.

(ii) The strength of magnetic field produced by the loop is increased by decreasing the resistance (or increasing the current) with the help of rheostat.

5. (a) Simple pendulum is as shown in the figure



Mass of simple pendulum, $m = 200$ g$= 0.2$ kg

(i) Since, B is extreme position, hence total energy at B is present in the form of its potential energy.

$\therefore$ Potential energy, $U = mgh$

$$= 0.2 \times 10 \times 5 = 10 \text{ J}$$

(ii) Since, total mechanical energy (E) remains conserved, hence total mechanical energy at C is

$$E = U = 10 \text{ J}$$

(iii) At point A, whole of the potential energy of the bob is converted into its kinetic energy.

So, $\frac{1}{2}mv^2 = U$

$\Rightarrow \frac{1}{2} \times 0.2 \times v^2 = 10$

$\Rightarrow v^2 = \frac{10}{0.1} = 100$

$\Rightarrow v = \sqrt{100}$

$\Rightarrow v = 10 \text{ m / s}$

(b) (i) In uniform circular motion, direction of centripetal force on the body is along the radius of the circular path, from the body towards the centre while the direction of the centrifugal force on the body is along the radius of the circle, from the centre towards the body, i.e. opposite to centripetal force.

(ii) Centrifugal force is caused by the inertia of the body, as the body's path is continually redirected, so it is not the force of reaction of centripetal force.

(iii) Magnitude of centripetal force and centrifugal force are equal.

(c) (i) Refer to Sol. of Q. 13 on page no. 54.

(ii) Given, velocity ratio (VR) = 4

$\therefore$ Efficiency, $\eta = \frac{\text{MA}}{\text{VR}} = \frac{\text{MA}}{4}$

$\Rightarrow \eta = \frac{\text{MA}}{4}$ ... (i)

When movable load is doubled, then MA is also increased to double, i.e. 2 MA.

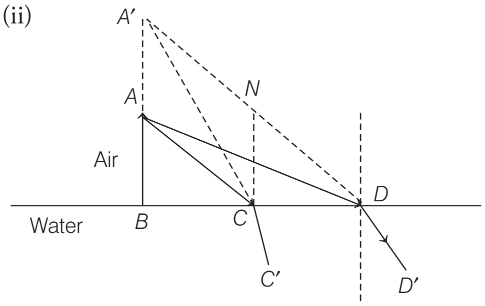
$\therefore$ Efficiency, $\eta = \frac{2\text{MA}}{\text{VR}}$ ... (ii)

From Eqs. (i) and (ii), we have

$$\frac{2\text{MA}}{\text{VR}} = \frac{\text{MA}}{4} \Rightarrow \text{VR} = 8$$

6. (a) (i) When a diver in water looks obliquely at an object AB in air, then object AB appears taller than its actual size, because when the ray coming from denser medium to rarer medium then they deviates away from the normal, hence they make larger image.

(ii)



When rays of light coming from rarer medium to denser medium, then it bends towards normal. Hence, path of rays AC and AD are shown above in figure.

The image of object AB is shown in the figure as $A'B$.

(b) Refer to text on page no. 74 [TIR through prism angles (30°, 60° and 90°)].

(c) (i) A convex lens forms both erect and inverted images while a concave alwasys forms erect image, hence the lens must be convex type.

(ii) Given $v = 60$ cm, $f = 20$ cm

By lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\Rightarrow \frac{1}{60} - \frac{1}{u} = \frac{1}{20}$

$\Rightarrow \frac{1}{u} = \frac{1}{60} - \frac{1}{20} = -\frac{2}{60} = -\frac{1}{30}$

$\Rightarrow u = -30$ cm

Hence, lens is at a distance of 30 cm infront of the object.

(iii) Magnification of the image, $m = \frac{v}{u} = \frac{60}{(-30)}$

$$= -2$$

7. (a) (i) As light passes through a cloud, it interacts with the water droplets, which are much bigger than the atmospheric particles that exist in the sky. Sunlight is scattered by much larger water droplets. These scatter all colours almost equally, so the sunlight appears to white, hence clouds appears white.

(ii) Refer to text on page no. 111 [Blue colour of sky].

(b) (i) Refer to text on page no. 126 [SONAR]

(ii) Refer to text on page no. 127 [Loudness] and page no. 128 [Pitch].

(c) (i) When a tuning fork is held close to ear, then one hears a faint hum because it produce damped vibration. When the stem of vibrating tuning fork is in contact with the table surface, then table surface starts vibrating with same frequency of tuning force. Hence, loud sound is produced due to resonance.

(ii) If v be the speed of sound and x be the distance of cliff from initial position of man, then according to first condition of man

$$\frac{2x}{v} = 3.5$$

$$\Rightarrow \quad v = \frac{2x}{3.5} \quad \dots (i)$$

When man is moved closer to the cliff by 84 m, then

$$\frac{2(x-84)}{v} = 3$$

$$\Rightarrow \quad v = \frac{2(x-84)}{3} \quad \dots (ii)$$

From Eqs. (i) and (ii), we have

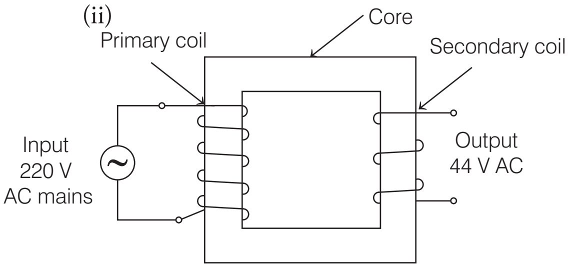
$$\frac{2x}{3.5} = \frac{2(x-84)}{3}$$

$$6x = 7x - 588$$

$$\Rightarrow \quad x = 588 \text{ m}$$

8. (a) (i) Core of transformer is made of soft iron sheets and these core sheets are laminated to prevent from eddy current.

(ii)



(b) (i) The conductors with infinite conductivity or zero resistivity are called superconductors.

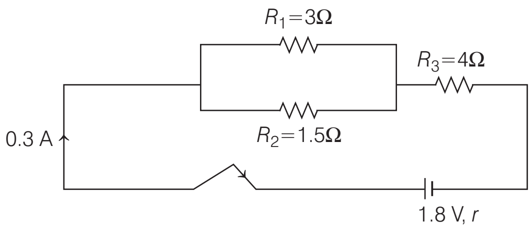
(ii) Given, power of appliance, $P = 110$ W

Supply voltage, $V = 220$ V

We know that, $P = VI \Rightarrow I = \frac{P}{V} = \frac{110}{220} = 0.5$ A

(iii) Semiconductor

(c) (i) The given circuit diagram is as shown below



According to current division rule, current through 3 Ω resistance,

$$I' = I \cdot \frac{R_2}{R_1 + R_2}$$

$$= 0.3 \times \frac{1.5}{3 + 1.5}$$

$$= \frac{0 \cdot 45}{4.5} = 0 \cdot 1 \text{ A}$$

(ii) From circuit diagram, equivalent resistance of circuit is given as

$$R = (3 \,||\, 1.5) + 4 + r$$

$$= \frac{3 \times 1.5}{3 + 1.5} + 4 + r$$

$$= \frac{4.5}{4.5} + 4 + r$$

$$\Rightarrow \quad R = 5 + r$$

$\therefore$ Current drawn through battery,

$$I = \frac{V}{R}$$

$$\Rightarrow \quad 0.3 = \frac{1.8}{5 + r}$$

$$\Rightarrow \quad 5 + r = \frac{1.8}{0.3}$$

$$\Rightarrow \quad 5 + r = 6$$

$$\Rightarrow \quad r = 6 - 5 = 1\,\Omega$$

9. (a) (i) Refer to text on page no. 204 [**Thermal (heat) capacity**].

(ii) Refer to text on page no. 204 [Units of heat capacity].

(iii) Refer to text on page no. 205 [Relationship between heat capacity and specific heat capacity].

(b) (i) According to given diagram, substance is at lowest temperature in initial state A, when temperature is given to the substance in its initial stage, then its temperature rises quickly with respect to time, i.e. less specific heat capacity. In the state BC, substance melts. Therefore, its temperature rises slowly with respect to time, i.e. high specific heat capacity. Hence, slope of CD is less than slope of AB.

(ii) From given diagram, at point B, the melting of substance starts. Hence, melting point $= t_1\,°$C. At point D, substance starts boiling, hence boiling point $= t_2\,°$C.

(c) Given, specific heat capacity of water,

$$C = 4.2 \text{ J g}^{-1}\text{K}^{-1}$$

$$= 4.2 \times 10^3 \text{ J kg}^{-1}\text{K}^{-1}$$

Specific latent heat of fusion of ice $= 336$ J g^{-1}

$$= 336 \times 10^3 \text{ J kg}^{-1}$$

Mass of ice, $m_i = 60$ g $= 0.06$ kg,

and mass of water, $m_w = 140 \text{ g} = 0.14 \text{ kg}$

Suppose T be the final temperature, then

Heat lost by 0.14 kg water, when its temperature falls from 50°C to T°C

$$= m_w C_w (50 - T)$$
$$= 0.14 \times 4.2 \times 10^3 \ (50 - T)$$
$$= 588 \ (50 - T)$$

Heat required to melt 0.06 kg ice into water at 0°C

$$= m_i L = 0.06 \times 336 \times 10^3$$
$$= 20.16 \times 10^3 \text{ J}$$

Heat required to raise temperature of 0.06 kg water from 0°C to T°C

$$= mC_w (T - 0)$$
$$= 0.06 \times 4.2 \times 10^3 T = 252 \ T$$

By the principle of calorimetry,

Heat gained = Heat lost

$20.16 \times 10^3 + 252T = 580 \ (50 - T)$

$20160 + 252T = 29000 - 580T$

$$832T = 8840 \Rightarrow T = \frac{8840}{832} = 10.625° \text{C}$$

10. (a) (i) Refer to text on page no. 186 [Electric motor].

(ii) DC motors are used in toys due to higher starting torque.

(b) (i) Refer to text on page no. 228 (Difference between nuclear fission and nuclear fusion).

(ii) Disposal of nuclear waste should be grounded in deep mines because there is a risk of nuclear accidents causing due to leakage of nuclear radiation.

(c) (i) Number of proton in atomic nucleus $A = 84$

$\therefore$ Atomic number of A, $Z = 84$

Number of neutron, $N = 128$

$\therefore$ Mass number of A,

$$M = Z + N = 84 + 128 = 212$$

$\therefore$ When an α-particle is emitted from a nucleus, then its mass number is decreased by 4 units and atomic number is decreased by 2 units.

$$\therefore \quad {}_{84}A^{212} \xrightarrow{\alpha} {}_{82}B^{208}$$

(ii) When a β-particle is emitted from a nucleus, then atomic number is increased by one unit and mass number is unaffected.

$$\therefore \quad {}_{82}B^{208} \xrightarrow{\beta} {}_{83}C^{208}$$

(iii) Mass number of nucleus $A = Z + N$

$$= 84 + 128 = 212$$

(iv) There is no change in the composition of C by the emission of γ-radiations.

LATEST

ICSE SPECIMEN QUESTION PAPER

(SEMESTER-I)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 10 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. All questions are compulsory.
4. The intended marks for questions or parts of questions are given in brackets [ ].
5. Select the correct option for each of the following questions.

Maximum Marks : 40 ***Time : 60 min***

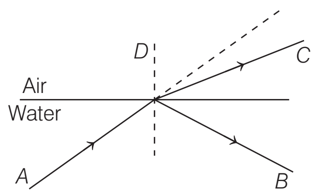
1. (a) Choose the correct statement with respect to refraction of light. ***[1]***

1. The frequency always changes when light enters from one optical medium to another.
2. Absorption of light when it strikes the surface of a medium is refraction.
3. Speed of light changes when it enters from one optical medium to another of different optical density.
4. Speed of light does not change when it enters from one optical medium to another of different optical density.

(b) When a light ray enters from a denser medium to a rarer medium ***[1]***

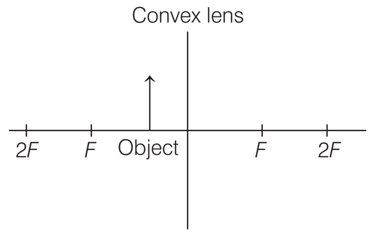
1. the light ray bends towards the normal
2. angle of incidence is less than angle of refraction
3. speed of light decreases
4. speed of light remains unchanged

(c) In the diagram shown below ***[1]***



1. *B* is incident ray and *C* is refracted ray
2. *A* is incident ray and *B* is refracted ray
3. *C* is incident ray and *B* is refracted ray
4. *A* is incident ray and *C* is refracted ray

(d) From the diagram shown below, identify the characteristics of the image that will be formed. ***[1]***



1. Real
2. Diminished
3. Formed within the focal length
4. Virtual

(e) The wavelength of light in a medium *A* is 600 nm. The wave enters medium *B* of refractive index 1.5 with respect to medium *A*. ***[2]***

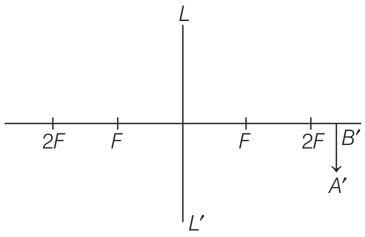
(i) Select the correct option from the following.

1. The wavelength of light becomes 1.5 times the initial wavelength.
2. The wavelength of light decreases.
3. The wavelength becomes half of initial wavelength.
4. The wave bends away from the normal.

(ii) The wavelength in medium *B* will be

1. 400 nm
2. 900 nm
3. 300 nm
4. Information is insufficient to calculate

(f) The diagram below shows an image formed at a distance 36 cm from the lens LL' of focal length 12 cm. With respect to this answer the questions that follow. ***[4]***



(i) The position of the object on the left hand side should be

1. between 12 cm to 30 cm from the lens
2. beyond 24 cm from the lens
3. between 12 cm to 24 cm from the lens
4. within 12 cm from the lens

(ii) Power of this lens is

1. − 8.33 D 2. + 8.4 D
3. + 8.33 D 4. − 8.4 D

(iii) The object distance with sign convention is

1. − 18 cm
2. − 15 cm
3. − 9 cm
4. + 18 cm

(iv) If the lens LL' is replaced by another lens of same type but focal length 15 cm then for the same object distance

1. the size of the image decreases
2. the size of the image increases
3. the size of the image remains the same
4. information is insufficient to conclude

2. (a) The usable form of mechanical energy is ***[1]***

1. elastic potential energy
2. kinetic energy
3. gravitational potential energy
4. None of the above

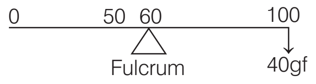
(b) One horsepower is equal to ***[1]***

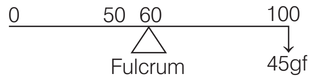
1. 100W 2. 735 W
3. 764 W 4. 746 W

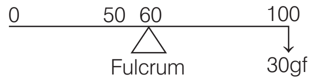
(c) If A and B of the same mass can climb the third floor of the same building in 3 min and 5 min respectively, then the ratio of their powers of *A* is to *B* in an ideal situation is ***[1]***

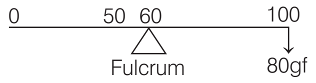
1. 1:1
2. 3:5
3. The information is insufficient to form a conclusion
4. 5:3

(d) If the centre of gravity of a metre scale of mass 80 g lies at the 45 cm mark, then which one of the following diagrams will show the balanced position of the scale? ***[1]***

1. 

2. 

3. 

4. 

(e) A body has kinetic energy 2500 J. If the mass of the body is 500 g. ***[2]***

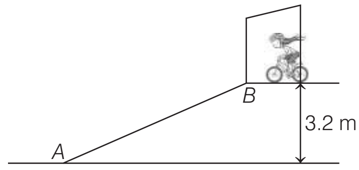
(i) The velocity of the body is

1. $\sqrt{10}$ m/s 2. 10 ms^{-1}
3. 20 ms^{-1} 4. 100 m/s

(ii) The momentum of the body will be

1. 10 $kgms^{-1}$
2. $500\sqrt{10}$ $kgms^{-1}$
3. 50 kg ms^{-1}
4. 5 $kgms^{-1}$

(f) A girl at rest at gate of her society which is 3.2 m above the road comes down the slope *AB* on a cycle without paddling. [Take, $g = 10$ N/kg] ***[4]***



(i) The mechanical energy possessed by the girl at *B* is

1. vibrational kinetic energy
2. translational kinetic energy
3. elastic potential energy
4. gravitational potential energy

(ii) The velocity with which girl reaches point *A* is

1. 32 m/s
2. 10 m/s
3. 8 m/s
4. Insufficient information to calculate velocity

(iii) If the mass of the girl is 40 kg, then the kinetic energy of the girl at *A* is [Assuming no loss of energy.]

1. 1280 J 2. 1600 J
3. 400 J 4. 3200J

(iv) The potential energy of the girl (of mass 40 kg) when she reaches the mid-point of the slope of *AB*

1. 800 J 2. 200J
3. 1600 J 4. 640 J

3. (a) Mechanical Advantage (M.A.), Load (L), and Effort (E) are related as *[1]*

1. $MA = L \times E$ 2. $MA = E/L$
3. $MA \times E = L$ 4. $MA \times L = E$

(b) Which one of the following statement is correct? *[1]*

1. A machine is used to have more output energy as compared to input energy.
2. Mechanical advantage of a machine can never be greater than 1.
3. If a machine gives convenience of direction, then its mechanical advantage should be greater than 1.
4. For a given design of a machine, even if the mechanical advantage increases, the velocity ratio remains the same.

(c) If a block and tackle system with convenient direction has 3 movable pulleys, then its velocity ratio *[1]*

1. is either 6 or 7 2. should be 6
3. should be 7 4. is 3

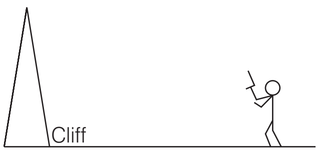
(d) Work done by a body moving on a circular track is zero at every instant because *[1]*

1. displacement is zero
2. displacement is perpendicular to the centripetal force
3. there is no force acting
4. Reason is not mentioned in the other options

(e) Identify the conditions required to hear a clear and distinct echo by humans, in air. *[2]*

1. The reflecting surface should be rough
2. The size of the reflecting surface should be smaller than the wavelength of sound
3. Sound should not be reflected back within 0.1 s
4. The incident sound should have frequency more than 25000 Hz
5. The size of the reflecting surface should be larger than the wavelength of sound

(f) A person standing in front of a vertical cliff fires a gun and hears its echo in 3s. The speed of sound in air is 340 m/s. *[4]*



(i) The distance at which the person is standing infront of the cliff is

1. 1020 m 2. 510 m
3. 340 m 4. 680 m

(ii) If the person wants to hear the echo 0.5 s earlier, then how much distance should he move, towards or away from the cliff?

1. 595 m away from the cliff
2. 255 m towards the cliff
3. 85 m towards the cliff
4. 255 m away from the cliff

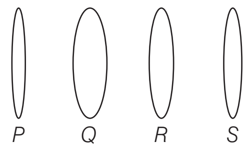
(iii) Another person stands behind this person, in the same line with him and the cliff, at a distance of 170 m and fires a gun in the air. What are the consecutive intervals of time at which the first person hears two sounds?

1. 0.5 s and 3 s 2. 1 s and 3 s
3. 1 s and 4 s 4. 0.5 s and 3.5 s

(iv) If the speed of sound changes to 350 m/s, then how much distance should the person move towards or away from the cliff, in order to hear the echo in the same time (i.e. in 3 s)?

1. 25 m away 2. 7.5 m away
3. 20 m away 4. 15 m away

4. (a) Assuming all lenses shown below are of the same material, state which lens has the maximum power. *[1]*

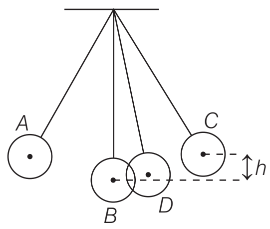


1. *R* 2. *P*
3. *Q* 4. *S*

(b) In an electric cell while in use, the change in energy is from *[1]*

1. chemical to mechanical
2. chemical to electrical
3. electrical to mechanical
4. electrical to chemical

(c) The diagram below shows a pendulum having a bob of mass 80 g. *A* and *C* are extreme positions and *B* is the mean position. The bob has velocity 5 m/s at position *B*. *[2]*
[Take, $g = 10$ N/kg]



(i) Which one of the following statement is correct?

1. At point A the bob has only kinetic energy.
2. At point B the bob will have only potential energy.
3. At point B the bob will have maximum kinetic energy.
4. At point D the bob will have more potential and less kinetic energy.

(ii) The height h is

1. 1.25 cm 2. 125 m
3. 1.25 m 4. 0.125 m

(d) (i) Select correct options for total internal reflection in a medium. ***[2]***

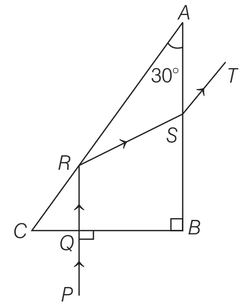
1. Can take place in an optically denser medium as compared to an optically rarer medium.
2. Takes place for any angle of incidence greater than 42 degree.
3. This reflection does not obey the laws of reflection.
4. Can take place if the angle of incidence in a denser medium is less than the critical angle.

(ii) Diamonds glitter in the dark because

1. they emit light
2. They have a very small critical angle due to very high refractive index
3. Due to the fluorescence
4. Chemical reaction in the diamond produces light energy

(e) The diagram shows the path of light through a right-angled prism of critical angle 42°. ***[4]***

Observe the diagram and answer the questions that follow.



(i) The phenomenon at the surface AC is

1. refraction
2. partial reflection
3. total internal reflection
4. scattering

(ii) The angle of incidence at the surface AC is

1. 30° 2. 45°
3. 60° 4. 90°

(iii) The angle of incidence at the surface AB is

1. 30° 2. 45°
3. 60° 4. 90°

(iv) Which of the following statement is wrong?

1. Speed of light ray PQ is equal to the speed of light ray ST.
2. Speed of light ray QR is equal to the speed of light ray RS.
3. Speed of light ray PQ is greater than the speed of light ray RS.
4. Speed of light ray RQ is greater than the speed of light ray ST.

Answers

1. (a) 3, (b) 2 (c) 4 (d) 4 (e) (i) 2, (ii) 1 (f) (i) 3 (ii) 3 (iii) 1 (iv) 2

2. (a) 2 (b) 4 (c) 4 (d) 3 (e) (i) 4, (ii) 3 (f) (i) 4 (ii) 3 (iii) 1 (iv) 4

3. (a) 3 (b) 4 (c) 4 (d) 2 (e) 5 (f) (i) 2, (ii) 3, (iii) 1, (iv) 4

4. (a) 3 (b) 2 (c) (i) 3, (ii) 3 (d) (i) 1, (ii) 2 (e) (i) 3 (ii) 3 (iii) 1 (iv) 4

LATEST

ICSE SPECIMEN QUESTION PAPER

(SEMESTER-II)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 10 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. Attempt **all** questions from **Section A** and **any 3** questions from **Section B.**
4. The intended marks for questions or parts of questions are given in brackets [ ].

Maximum Marks : 40 ***Time : 90 min***

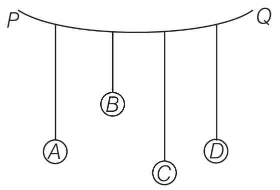
Section A

[10 Marks]

(Attempt **all** questions)

1. Choose the correct answers to the questions from the given options. (Do not copy the question, Write the correct answer only.)

(i) Pendulums A, B, C and D are tied to a flexible string PQ and are at rest. Pendulum C is disturbed. Which of the following statements is true? ***[1]***



(a) Only pendulum C will start vibrating.

(b) Pendulums A, B and D will also start vibrating but A and D will vibrate with the maximum amplitude.

(c) Pendulums A, B and D will also start vibrating.

(d) Vibrations of pendulum C are forced vibrations.

(ii) Which of the following is not a characteristic of parallel combination of resistors? ***[1]***

(a) If one resistor is fused, the circuit does not become open.

(b) The total resistance R is given by the formula $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ ....

(c) The total resistance becomes less than the least resistor, present in the combination.

(d) The current through each resistor always remains the same.

(iii) Which one of the following statements is correct? ***[1]***

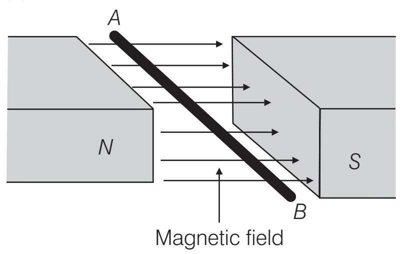
(a) Live wire has zero potential.

(b) Fuse is connected in a neutral wire.

(c) Potential of live and earth wires is always same.

(d) Earth wire is used to prevent electric shock.

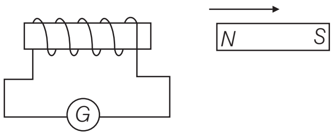
(iv) The diagram below shows a free conductor AB is kept in a magnetic field and is carrying current from A to B (To avoid confusion complete path of the circuit is not shown). The direction of the force experienced by the conductor will be ***[1]***

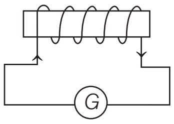


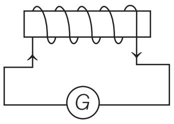
(a) up (b) down

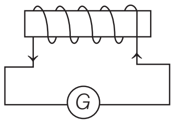
(c) towards N (d) towards S

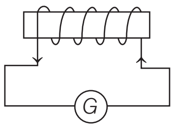
(v) The diagram below shows a magnet moved near a coil along its axis. Which of the diagram shows correct flow of current during this motion? *[1]*



(a)


(b)


(c)


(d)


(vi) The meaning of the statement 'Specific heat capacity of water is 4200 $Jkg^{-1}K^{-1}$ is *[1]*

(a) "Water needs 4200 J heat to raise its temperature by 1 K".

(b) "To raise the temperature of water, 4200 J of heat is absorbed".

(c) "1 kg water absorbs 4200J heat to increase its temperature by 1 K".

(d) "1 kg water needs 1 K temperature to absorb 4200 J heat".

(vii) 200 g of ice at 0°C needs ...... heat to melt. (Take, specific latent heat of ice = 336000 J kg^{-1}) *[1]*

(a) 6720 J

(b) 67200 J

(c) 672000 J

(d) 67.2 J

(viii) The radiation with maximum penetrating power is *[1]*

(a) γ (b) β

(c) X-radiation (d) α

(ix) Resonance is a forced vibration, in which *[1]*

(a) amplitude remains constant

(b) frequency of forced vibration is greater than the free vibrations of the body

(c) frequency of forced vibration is equal to the free vibrations of the body

(d) frequency of forced vibration is less than the free vibrations of the body

(x) The nuclear radiation which gets deflected towards negatively charged plate in an electric field is *[1]*

(a) gamma

(b) ultraviolet

(c) beta

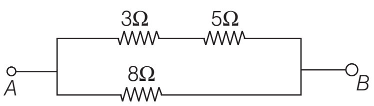
(d) alpha

Section B

[30 Marks]

(Attempt **any three** questions from this section)

2. (i) (a) Calculate the total resistance across *AB*.



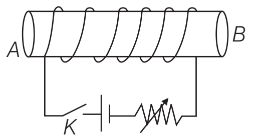
(b) If a cell of emf 2.4 V with negligible internal resistance is connected across *AB*, then calculate the current drawn from the cell. *[3]*

(ii) (a) Which will absorb more heat : 10 g of ice at 0°C or 10 g of water at 0°C?

(b) For the same mass of ice and ice-cold water, why does ice produce more cooling than ice-cold water? *[3]*

(iii) The diagram shows an insulated copper wire wound around a hollow cardboard cylindrical tube.

Answer the questions that follow.

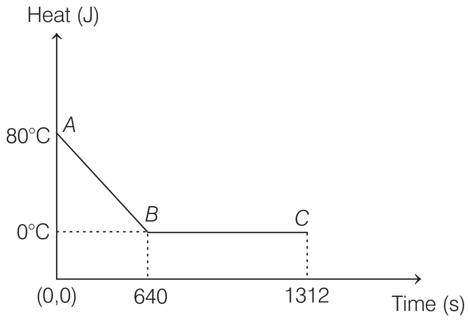


(a) What are the magnetic poles at *A* and *B*, when the key *K* is closed?

(b) State two ways to increase the strength of the magnetic field in this coil without changing the coil.

(c) If we place a soft iron bar at the centre of the hollow cardboard and replace the DC source by an AC source, then will it attract small iron pins toward itself when the current is flowing through the coil? *[4]*

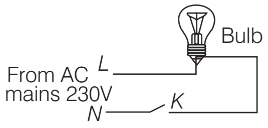
3. (i) The diagram below shows a cooling curve for 200 g of water. The heat is extracted at the rate of 100 Js^{-1}. Answer the questions that follow.



(a) Calculate specific heat capacity of water.

(b) Heat released in the region *BC*. *[3]*

(ii) (a) Observe the diagram given below and state whether the bulb will glow or not, when we switch ON *K*.



(b) Is it safe to handle the bulb, when the switch is OFF?

(c) Give a reason for your answer in (b). *[3]*

(iii) Two metals *A* and *B* have specific heat capacities in the ratio of 2 : 3. If they are supplied same amount of heat. Answer the questions that follow.

(a) Which metal piece will show greater rise in temperature given their masses are the same?

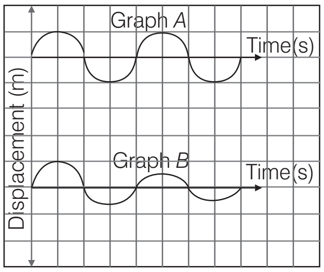
(b) Which metal piece will have greater mass, if the rise in temperature is the same for both metals?

(c) If the mass ratio of metal *A* and metal *B* is 3 : 5, then calculate the ratio in which their temperatures rise.

(d) If specific heat capacity of metal *A* is 0.26 $Jg^{-1}°C^{-1}$, then calculate the specific heat capacity of metal *B*. *[4]*

4. (i) (a) Which one of the following graphs *A* or *B* shows free vibrations in vacuum and which one shows free vibrations in a medium?

(b) How did you come to this conclusion?



[3]

(ii) (a) State the Faraday's laws of electromagnetic induction.

(b) Name one electrical device which works on this principle. *[3]*

(iii) A nucleus $^{194}_{82}X$ emits an alpha particle,

(a) what will be the atomic number of the daughter nucleus *Y*?

(b) what will be the number of neutrons in the daughter nucleus *Y*?

(c) write a nuclear reaction showing the emission of this particle. *[4]*

5. (i) (a) Name the electrical appliance shown in the diagram below.

(b) Name the material of the wire used in this device.

(c) Name two important characteristics of this wire. *[3]*

(ii) (a) Define pitch.

(b) Two wires *AB* and *CD* of same length are stretched by same amount, which wire will produce sound of greater pitch on plucking?

(c) Give a reason for your answer.

[3]

(iii) (a) Why is water used as a coolant in radiators of a car?

(b) Name the radioactive isotope used to find the age of fossils. Name the radioactive radiation which it emits? *[4]*

SOLUTIONS

1. (i) (*b*) When pendulum C is disturbed from its position, all pendulums start vibrating. But as the length of *A* and *D* are same, so both remain in same phase and resonance takes place. Hence, *A* and *D* will vibrate with maximum amplitude.

(ii) (*d*) Parallel combination of resistors divides the current among each resistors. So, the current through each resistor is different unless all resistors have same resistance. Instead potential difference across all resistors is same.

(iii) (*d*) Only statement given in option (d) is correct while all other are incorrect, which can be corrected as

(a) Live wire of a circuit is maintained at a potential of 220 V, while the neutral wire is at zero potential.

(b) Fuse is used as a safety device, so it should be connected to the live wire.

(c) Neutral and earth wires are connected together at the local sub-station. So, both wires will be at same potential.

(iv) (*a*) According to the Fleming's left hand rule, the direction of force experienced by the conductor will be up.

(v) (*c*) According to the Fleming's right hand rule, the direction of induced current in the coil near to *N*-pole will be clockwise. It is shown correctly in option (c).

(vi) (*c*) Specific heat capacity of water is $4200\ \text{Jkg}^{-1}\text{K}^{-1}$ means that 1 kg of water absorbs 4200 J heat to increase its temperature by 1 K.

(vii) (*b*) Given, mass of ice, $m_{\text{ice}} = 200$ g

$$= 200 \times 10^{-3}\ \text{kg}$$

Specific latent heat of ice, $L = 336000\ \ \text{Jkg}^{-1}$

Heat required to melt $= m_{\text{ice}} \times L$

$$= 200 \times 10^{-3} \times 336000$$
$$= 67200\ \text{J}$$

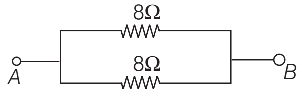
(viii) (*a*) γ-radiation has maximum penetrating power among given radiations.

(ix) (*c*) Resonance is a forced vibration, in which the frequency of (externally applied) force vibration is equal to the free or natural vibrations of the body.

(x) (*d*) Alpha particles carries two units of positive charges. So, when they are placed in a electric field between two charged plates, they are deflected towards negatively charged plate.

2. (i) (a) From figure, 3Ω and 5Ω resistances are in series. So, their equivalent resistance becomes $R' = 3 + 5 = 8\Omega$

The circuit is now reduced to



The two 8Ω resistances are in parallel, so equivalent or total resistance between *A* and *B*,

$$R'' = \frac{R' \times 8}{R' + 8} = \frac{8 \times 8}{8 + 8} = \frac{64}{16} = 4\Omega$$

(b) Given, emf, $E = 2.4$ V

$$\therefore \text{Current, } I = \frac{E}{R''} = \frac{2.4}{4} = 0.6\ \text{A}$$

(ii) (a) Since, heat absorbed $\propto$ specific heat capacity

The water has high value of specific heat capacity than that of ice at same temperature. So, 10 g of water at 0°C will absorb more heat than 10g of ice at 0°C.

(b) The ice has high specific latent heat capacity, which means it takes away more heat from the substance or surroundings. So, ice produces more cooling than ice-cold water.

(iii) (a) When key *K* is closed, the current starts flowing from end *A* to *B*.

In end *A*, the direction of current is anti-clockwise. So, it has north polarity, i.e. *N*-pole, while the current at end *B* is clockwise. So, it has south polarity, i.e. *S*-pole.

(b) The strength of an magnetic field can be increased by

I. increasing the amount of current flowing through the coil by decreasing resistance.

II. decreasing the air-gap between the poles or coils.

(c) When the DC source is replaced by an AC source, then the soft iron bar gets magnetised or demagnetised periodically as the polarity of current changes. Hence the circuit it sets into vibrations, so it will not attract the small iron pins.

3. (i) Given, mass of water, $m = 200\ \text{g} = 0.2\ \text{kg}$

Rated of heat extraction, $\dfrac{Q}{t} = 100\ \text{Js}^{-1}$

(a) Temperature changes in *AB* region,

$$\Delta T = (80 - 0)^\circ \text{C} = 80^\circ\ \text{C}$$

Time taken, $\Delta t = 640$ s

$$\therefore \qquad \frac{Q}{T} = mc\frac{\Delta T}{\Delta t}$$

$$\Rightarrow \qquad c = \frac{Q/t}{m \times \Delta T/\Delta t}$$

$$= \frac{100}{0.2 \times 80} \times 640$$

$$= 4000 \text{ Jkg}^{-1} {}^\circ\text{C}$$

(b) For region BC, the water at 0°C changes to ice at 0°C. So, heat released in coioling is given by

$$Q = m \times L = 0.2 \times 336000$$

$$(\because L_{ice} = 336000 \text{Jkg}^{-1})$$

$$= 67200 \text{ J}$$

(ii) (a) When the key is closed or the switch is ON, then the circuit is closed and a current start flowing and hence the bulb will glow.

(b) No

(c) If we handle the bulb keeping switch OFF, the live wire is still attached to the bulb and by touching it with barefoot or without using proper precautions, the circuit become closed and we can get electric shock.

(iii) Heat rise or fall, $\Delta Q = m \times c \times \Delta T$

Given , $c_A : c_B = 2:3$ and $\Delta Q_A = \Delta Q_B$

(a) If $m_A = m_B = m$,then

$$\frac{\Delta Q_A}{\Delta Q_B} = \frac{m_A \times c_A \times \Delta T_A}{m_B \times c_B \times \Delta T_B}$$

$$1 = \frac{2}{3} \times \frac{\Delta T_A}{\Delta T_B}$$

$$\Rightarrow \quad \frac{\Delta T_A}{\Delta T_B} = \frac{3}{2}$$

So, the rise of temperature is greater in metal A.

(b) If $\Delta T_A = \Delta T_B$, then

$$\frac{\Delta Q_A}{\Delta Q_B} = \frac{m_A \times c_A \times T_A}{m_B \times c_B \times \Delta T_B}$$

$$\Rightarrow \frac{m_A}{m_B} = \frac{C_B}{C_A} B = \frac{3}{2}$$

$\therefore$ Metal A will have greater mass.

(c) If $m_A : m_B = 3:5$, then

$$\frac{\Delta Q_A}{\Delta Q_B} = \frac{m_A}{m_B} \times \frac{c_A}{c_B} \times \frac{\Delta T_A}{\Delta T_B}$$

$$\Rightarrow \quad 1 = \frac{3}{5} \times \frac{2}{3} \times \frac{\Delta T_A}{\Delta T_B}$$

$$\Rightarrow \quad \frac{\Delta T_A}{\Delta T_B} = \frac{5}{2}$$

(d) If $c_A = 0.26 \text{ Jg}^{-1} \text{ C}^{-1}$, then

$$c_B = \frac{3}{2} \times c_A = \frac{3}{2} \times 0.26$$

$$= 0.39 \text{ Jg}^{-1} {}^\circ\text{C}^{-1}$$

4. (i) (a) Graph A shows free vibrations in vacuum and graph B shows free vibrations in a medium.

(b) In graph A, the amplitude or displacement of the vibration is constant for all time intervals. i.e. No resisting force is present here. So, it shows that the vibrations are in vacuum. In graph B, the amplitude of the vibration is decreasing with time i.e. Resistive forces are present here. So, it shows that the vibrations are in a medium.

(ii) (a) According to Faraday's laws of electromagnetic induction, whenever the magnetic field around a conductor changes, an emf is induced in it.

(b) Electrical generator works on the principle of electromagnetic induction.

(iii) (a) In alpha decay, the mass number A decreases by four while the atomic number Z decreases by two.

$\therefore$ Atomic number of

$$Y = Z - 2 = 82 - 2 = 80$$

(b) Here, for Y, $Z = 80$,

$$A = 194 - 4 = 190$$

$\therefore$ Number of neutrons,

$$N = A - Z = 190 - 80 = 110$$

(c) The process can be written as

$$^{194}_{82}X \longrightarrow {}^{190}_{80}Y + {}^4_2He$$

5. (i) (a) Electric fuse

(b) A fuse wire consists of an alloy of lead and tin.

(c) I. It should have low melting point.

II. It should have high resistivity.

(ii) (a) Pitch is that characteristic of sound by which we can distinguish between different sound of the same loudness.

(b) Wire AB will have sound of greater pitch.

(c) Since, the diameter of wire AB is less than that of wire CD. So on plucking by same force, the vibrations produced in AB moves faster and have higher frequency. Hence, wire AB will produce sound of greater pitch.

(iii) (a) Since, water has high specific heat capacity. So, it can absorb a large amount of heat energy from th engine of a car without changing its temperature to a high value.

Due to this reason, it is used as a coolant in radiators of a car.

(b) Carbon- 14 is used of find the age of fossils.It is an unstable isotope of carbon that decays into nitrogen-14 through beta decay.

ICSE

EXAMINATION PAPER 2021-22

(SEMESTER-I)

GENERAL INSTRUCTIONS

1. You will not be allowed to write during the first 10 minutes. This time is to be spent in reading the question paper.
2. The time given at the head of this paper is the time allowed for writing the answers.
3. All questions are compulsory.
4. The intended marks for questions or parts of questions are given in brackets [ ].
5. Select the correct option for each of the following questions.

Maximum Marks : 40 ***Time : 60 min***

1. The deviation produced by an equilateral prism does not depend on the ***[1]***

(a) angle of incidence
(b) size of the prism
(c) material of the prism
(d) colour of light used

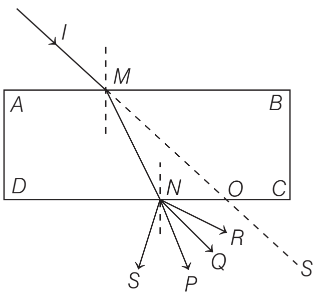
2. The refractive index of a diamond is 2.4. It means that, ***[1]***

(a) the speed of light in vacuum is equal to $\frac{1}{2.4}$ times the speed of light in diamond
(b) the speed of light in diamond is 2.4 times the speed of light in vacuum
(c) the speed of light in vacuum is 2.4 times the speed of light in diamond
(d) the wavelength of light in diamond is 2.4 times the wavelength of light in vacuum

3. An object of height 10 cm is placed in front of a concave lens of focal length 20 cm, at a distance of 25 cm from the lens. Is it possible to capture this image on a screen? Select a correct option from the following. ***[1]***

(a) Yes, as the image formed will be real.
(b) Yes, as the image formed will be erect.
(c) No, as the image formed will be virtual.
(d) No, as the image formed will be inverted.

4. A ray of light *IM* is incident on a glass slab *ABCD* as shown in the figure. The emergent ray for this incident ray is ***[1]***



(a) *NQ* (b) *NR* (c) *NP* (d) *NS*

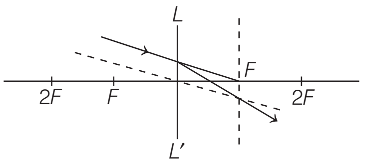
5. The colour of white light which is deviated least by a prism is ***[1]***

(a) green (b) yellow (c) red (d) violet

6. The wavelength range of visible light is ***[1]***

(a) 40 nm to 80 nm (b) 4000 nm to 8000 nm
(c) 4 nm to 8 nm (d) 400 nm to 800 nm

7. Observe the diagram which shows the path of an incident ray through an optical plane *LL′* of a lens. The focal length of the lens is 20 cm.



(i) If an object is placed at a distance of 30 cm in front of this lens, then the image will be ***[1]***

(a) virtual
(b) diminished and inverted
(c) diminished
(d) real and magnified

(ii) This type of lens can be used **[1]**

(a) to correct hypermetropia
(b) to correct myopia
(c) to diverge light
(d) in the front door peepholes

(iii) An object is placed in front of this lens at a distance of 60 cm, then the image distance from the lens with proper sign convention is **[1]**

(a) + 60 cm (b) + 30 cm
(c) – 30 cm (d) + 15 cm

(iv) An object is placed in front of this lens at a distance of 60 cm, then the magnification of the image is **[1]**

(a) 0.25 (b) 1.25
(c) – 0.5 (d) 1

8. The relation between CGS and SI unit of moment of force is **[1]**

(a) 1 N-m $=10^5$ dyne-cm (b) 1 N-m $=10^5$ dyne
(c) 1 N-m $=10^7$ dyne-cm (d) 1 dyne-cm $=10^7$ N-m

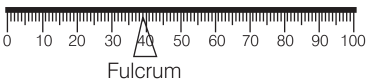
9. A coolie raises a load upwards against the force of gravity, then the work done by the load is **[1]**

(a) zero (b) positive work
(c) negative work (d) None of these

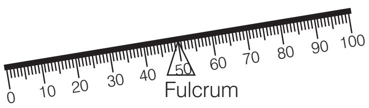
10. The energy change during photosynthesis in plants is **[1]**

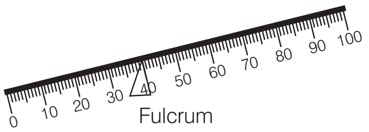
(a) heat to chemical (b) light to chemical
(c) chemical to light (d)chemical to heat

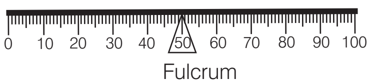
11. The diagram below shows the balanced position of a meter scale. **[1]**

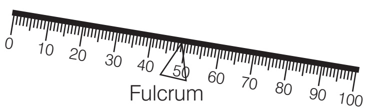


Which one of the following diagrams shows the correct position of the scale, when it is supported at the centre?

(a)


(b)


(c)


(d)


12. A stone tied at the end of a string is whirled by hand in a horizontal circle with uniform speed.

(i) Name the force required for this circular motion. **[1]**

(a) Centrifugal force
(b) Centripetal force
(c) Force of gravity
(d) Frictional force

(ii) What is the direction of the above mentioned force? **[1]**

(a) Towards the centre of the circular path.
(b) Away from the centre of the circular path.
(c) Normal to the radius at a point, where the body is present on the circular path.
(d) Direction of this force keeps on changing alternately towards and away from the centre.

13. A body of mass 200 g falls freely from a height of 15 m. (Take, $g = 10\ \text{ms}^{-2}$)

(i) When the body reaches 10 m above the ground, its potential energy will be **[1]**

(a) 20000 J (b) 10 J
(c) 10000 J (d) 20 J

(ii) The gain in kinetic energy of the body when it reaches 10 m above the ground is **[1]**

(a) 20 J (b) 10 J
(c) 30 J (d) 25 J

(iii) The total mechanical energy it will possess, when it is just about to strike the ground is **[1]**

(a) 30000 J
(b) 20000 J
(c) 30 J
(d) 20 J

(iv) The velocity in ms^{-1} with which the body will hit the ground is **[1]**

(a) 30
(b) 10
(c) $10\sqrt{3}$
(d) $10\sqrt{2}$

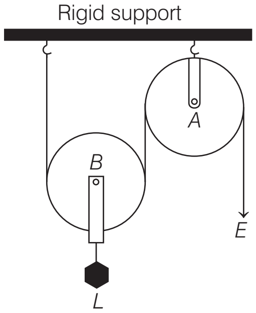
14. A woman draws water from a well using a fixed pulley. The mass of the bucket and the water together is 10 kg. The force applied by the woman is 200 N. The mechanical advantage is (Take, $g = 10\ \text{m/s}^2$) **[1]**

(a) 2 (b) 20
(c) 0.05 (d) 0.5

15. A single fixed pulley is used because **[1]**

(a) it changes the direction of applied effort conveniently
(b) it multiplies speed
(c) it multiplies effort
(d) its efficiency is 100%

16. In the diagram shown below, the velocity ratio of the arrangement is ***[1]***



(a) 1 (b) 2
(c) 3 (d) 0

17. Which one of the following is the correct mathematical relation? ***[1]***

(a) Power = Force/Velocity
(b) Power = Force × Acceleration
(c) Power = Force/ Acceleration
(d) Power = Force × Velocity

18. Select a correct option with respect to echo depth sounding. ***[1]***

(a) Infrasonic waves are used
(b) The frequency of the waves used is between 20 Hz and 20000 Hz
(c) Utrasonic waves are used
(d) Supersonic waves are used

19. Which one of the following diagnostic methods use reflection of sound? ***[1]***

(a) CT scan
(b) Electrocardiogram
(c) Echo cardiogram
(d) MRI

20. A boy standing in front of a wall produces two whistles per second. He notices that the sound of his whistling coincides with the echo. The echo is heard only once when whistling is stopped. Calculate the distance between the boy and the wall. (The speed of sound in air = 320 m/s)

(i) The time in which the boy hears the echo is ***[1]***
(a) 1 s (b) 0.5 s
(c) 1.5 s (d) 2 s

(ii) The distance at which the boy is standing from the wall ***[1]***
(a) 160 m (b) 240 m
(c) 320 m (d) 80 m

(iii) If the speed of sound is increased by 16 ms^{-1} and the boy moves 4 m away from the wall, then in how much time will he hear the echo of the first whistle? ***[1]***
(a) 0.525 s (b) 0.5 s
(c) 0.48 s (d) 0.3 s

(iv) In which of the following timings of reflection of the whistle, the echo cannot be heard? ***[1]***
(a) 0.05 s (b) 0.12 s
(c) 0.2 s (d) 0.11 s

21. The ratio of velocities of light of wavelength 400 nm and 800 nm in a vacuum is ***[1]***

(a) 1 : 1 (b) 1 : 2
(c) 2 : 1 (d) 1 : 3

22. 1 J = ... erg ***[1]***

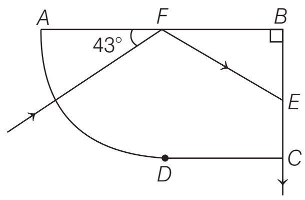
(a) 10^9 (b) 10^7
(c) 10^5 (d) 10^6

23. A light body *A* and a heavy body *B* have the same momentum.

(i) Choose a correct statement from the given options. ***[1]***
(a) Kinetic energy of body *A* and body *B* will be the same.
(b) Kinetic energy of body *A* is greater than kinetic energy of body *B*.
(c) Kinetic energy of body B is greater than kinetic energy of body *A*.
(d) Unless we know the velocity, we cannot find which body has greater kinetic energy.

(ii) If the ratio of kinetic energies of *A* and *B* is 5 : 2, then which one of the following gives the mass ratio of the bodies respectively? ***[1]***
(a) 5 : 2 (b) 25 : 4
(c) 2 : 5 (d) 4 : 24

24. A ray of light travelling from air into a glass material as shown below. Answer the questions that follow.



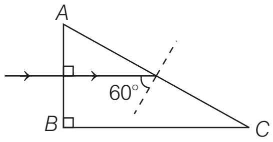
(i) The angle of incidence at the surface *AB* is ***[1]***
(a) 43° (b) 47°
(c) 90° (d) 0°

(ii) Select a correct statement from the following. ***[1]***
(a) The speed of light at the curved surface *AD* does not change while entering the block.
(b) The ray at the surface *AD* is not travelling along the radius of the curved part.
(c) The ray at the surface *AD* is travelling along the radius of the curved part.
(d) Light never refracts when it enters a curved surface.

(iii) The angle of incidence on the surface *BC* is ***[1]***
(a) 43° (b) 47° (c) 90° (d) 0°

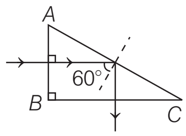
(iv) The critical angle of this material of glass is *[1]*
(a) 47° (b) 43° (c) 42° (d) 45°

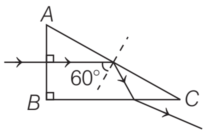
25. The diagram below shows the path of light passing through a right-angled prism of critical angle 42°.

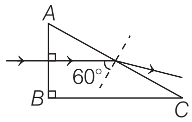


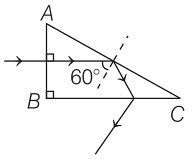
(i) The angle C of the prism is *[1]*
(a) 45° (b) 60°
(c) 90° (d) 30°

(ii) Which one of the following diagrams show the correct path of this ray till it emerges out of the prism? *[1]*

(a)


(b)


(c)


(d)


Answers

1. (b)	**2.** (c)	**3.** (c)	**4.** (a)	**5.** (c)	**6.** (d)	**7.** (i) (d), (ii) (a), (iii) (b), (iv) (c)	**8.** (c)
9. (c)	**10.** (b)	**11.** (a)	**12.** (i) (b), (ii) (a)	**13.** (i) (d), (ii) (b), (iii) (c), (iv) (c)	**14.** (d)	**15.** (a)	
16. (b)	**17.** (d)	**18.** (c)	**19.** (c)	**20.** (i) (b), (ii) (d), (iii) (b), (iv) (a)	**21.** (a)	**22.** (b)	
23. (i) (b), (ii) (c)	**24.** (i) (b), (ii) (c), (iii) (a), (iv) (b)	**25.** (i) (d), (ii) (b)					