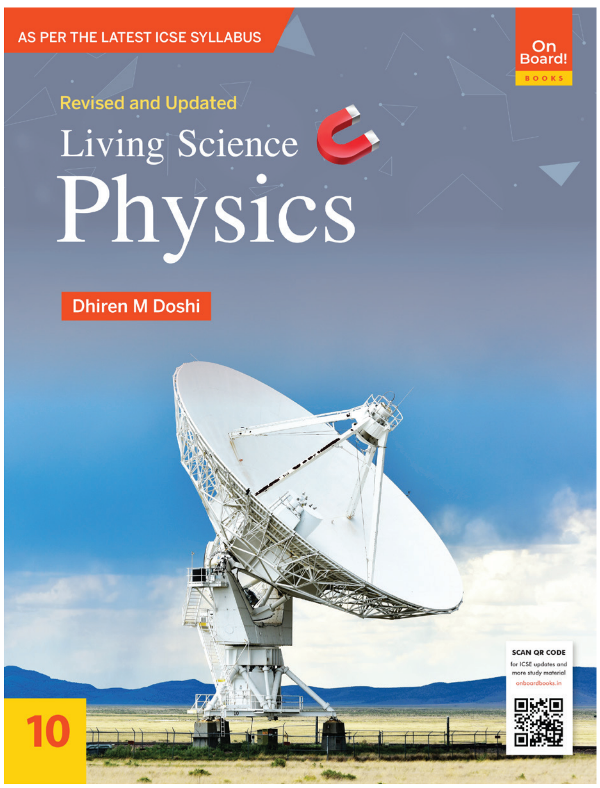
ICSE Living Science

PHYSICS

Book 10

TEACHER'S HANDBOOK



On Board!
BOOKS

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CHAPTER – 1

TURNING FORCES

Check Your Progress 1 (Page 15)

A. **1.** c **2.** b **3.** a **4.** b **5.** b **6.** c **7.** a

B. **1.** When a force acts on a rigid body which is free to move, the body starts moving in a straight line in the direction of the applied force. This is called translational motion. For example, the motion of a car travelling along a straight road is translational.

2. When a body is fixed at a point, then a force applied to that body will be unable to move it in a straight line in its direction of application (because the body is fixed at a point and not free to move). This force will rotate the body about the fixed point. This is called rotational motion. Example: When we apply a force at the handle of a door to open it, this force produces rotational motion in the door.

3. **Moment of force:** Torque (moment of force) produced by a force about an axis is equal to the product of the magnitude of the force and its moment arm about the axis. Its SI unit is newton metre. (N m).

4. **a.** **Point of action of force:** The point on a rigid body, where a force acts is called the point of action of force.

b. **Line of action of force:** An imaginary line passing through the point of action of force and drawn in the same direction in which the force acts is called the line of action of force.

c. **Moment arm:** The perpendicular distance from the axis of rotation to the line of action of force is called the moment arm of the force.

5. The following factors affect the turning effect of a body:

i. The magnitude of the force applied.

ii. The perpendicular distance from the axis of rotation to the line of action of force.

6. **a.** Relationship between SI unit and CGS unit of torque:

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

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

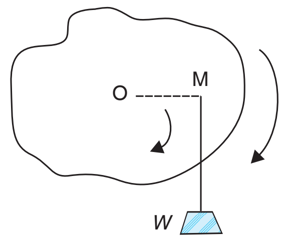
b. Relationship between SI unit of torque and gravitational unit in SI system:

We know that the SI unit of torque is N m whereas the SI unit of torque if force is measured in terms of force due to gravity (gravitational unit) is kgf m.

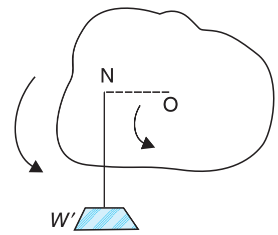
$$1 \text{ kgf m} = 9.8 \text{ N m}$$

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

7. Let us suspend a sheet of cardboard on a horizontal nail which passes through the point O of the board. The cardboard is capable of rotating about the point O. A nail M is fixed on the board from where a weight *W* is suspended. It is noticed that the force *W* has a tendency to turn the board clockwise. By convention, the clockwise moment is taken as negative.



a. Force *W* produces a clockwise moment (negative)



b. Force *W′* produces an anticlockwise moment (positive)

Similarly, a nail N is fixed on another board from where a weight *W′* is suspended. It is noticed that the force *W′* has a tendency to turn the board anticlockwise. By convention, the anticlockwise moment is taken as positive.

8. **a.** It is easier to open a door by applying the force at the handle provided near the free end of the door. It is because if the force is applied at the free end, i.e. at the handle, the moment of force (Force × Moment arm) is large, i.e. a small force can produce a large turning effect. But if we apply the force near the hinge, we will not be able to open the door howsoever large force is applied.

b. The hand flour grinder is provided with a handle near its rim to increase the moment arm so that even a small force applied can produce a large turning effect. It can be easily rotated by applying a small force.

c. A long spanner is used to loosen a tight nut. This is because by increasing the length of the spanner, the moment arm (distance of the line of action of the force from the axis of rotation) gets increased and even a small force can produce a large turning effect.

d. A jack screw is provided with a long arm as the turning effect of a force depends upon the perpendicular distance of the line of action of the applied force from the axis of rotation. Larger the perpendicular distance, less is the force required to turn the body. So, if the jack screw has a long arm, less force is needed to rotate the jack to lift the heavy load.

9. If a body under the action of a number of coplanar forces is in rotational equilibrium, then the algebraic sum of the moments of all forces about a given axis is zero.

Or

If a body is in rotational equilibrium, then the sum of all the clockwise moments about a given axis is equal to the sum of all the anticlockwise moments about the same axis. Example: A common balance (or a physical balance) is a good example of the application of the principle of moments.

10. Verification of principle of moments

i. Suspend a metre rule horizontally from a fixed support by means of a thread (See figure).

ii. Now suspend two spring balances on either side of the thread at different distances.

iii. Hang weights from each spring balance. Adjust the slotted weights in such a way that the scale again becomes horizontal.

iv. Let the weights suspended from the spring balance on the right side of the thread be W_1 at a distance OA = d_1. Let the weights suspended from the spring balance on the left side of the thread be W_2 at a distance OB = d_2.

v. The weight W_1 tends to turn the scale clockwise, i.e. clockwise moment = $W_1 \times d_1$.

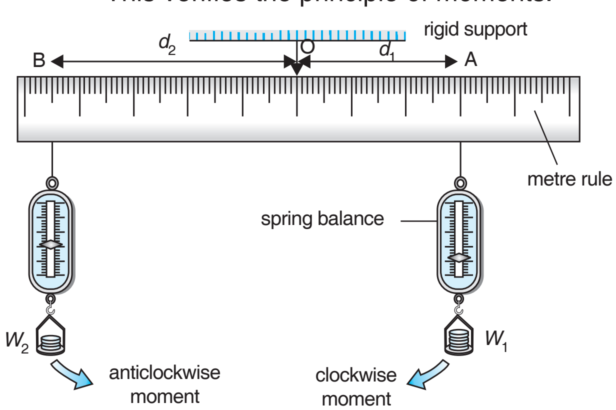
vi. The weight W_2 tends to turn the scale anticlockwise, i.e. anticlockwise moment = $2 \times d_2$.

In equilibrium, when the scale is horizontal, it is found that,

$$\begin{bmatrix}\text{Sum of the} \\ \text{clockwise movements}\end{bmatrix} = \begin{bmatrix}\text{Sum of the anti-} \\ \text{clockwise movements}\end{bmatrix}$$

i.e. $W_1 \times d_1 = W_2 \times d_2$

This verifies the principle of moments.



11. When a large number of external forces act on a body and when they produce no change in its state of rest or of uniform motion, then the body is said to be in equilibrium.

12. a. A couple is a pair of forces, equal in magnitude, oppositely directed, and displaced by perpendicular distance.

Or

Two equal, opposite and parallel forces whose lines of action are not same, acting on a body form a couple and produce a rotational effect.

b. In SI system, the units of couple are newton metre (N m) and kgf m. In CGS system, the units of couple are dyne cm and gf cm.

13. Let us now consider the moments:

Moment of force F at the end A = $F \times d_1$

Moment of force F at the end B = $F \times d_2$

Total moment of both the forces

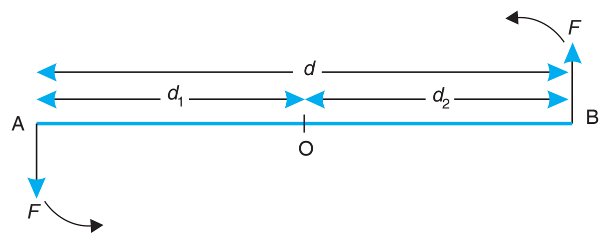
$= F \times d_1 + F \times d_2$

$= F \times (d_1 + d_2)$

$= F \times d$

= Either force × Perpendicular distance between the two forces

= Force × Couple arm



14. i. Opening or closing a water tap.

ii. Winding a clock with its key.

iii. Opening the cap of a bottle.

iv. Turning of a screwdriver.

C. 1. Moment of force (τ) = Force × Moment arm

$= 100\text{ N} \times \dfrac{50}{100}\text{ m} = 50\text{ N m}$

2. Moment of force (τ) = Force × Moment arm

500 N m = 750 N × Moment arm

Moment arm = $\dfrac{500\text{ N m}}{750\text{ N}} = 0.67\text{ m}$

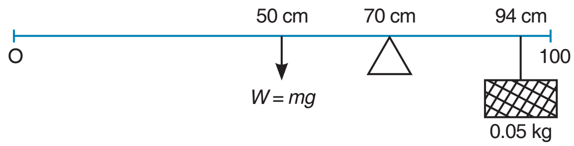
3. Moment of force (τ) = Force × Moment arm

$8\text{ N m} = \text{Force} \times \dfrac{40}{100}\text{ m}$

$\text{Force} = \dfrac{8\text{ N m}}{40\text{ m}} \times 100 = 20\text{ N}$

Questions Based on ICSE Examination (Page 16)

1. a. Diagram of the given arrangement:



b. We have a uniform metre scale, so its centre of gravity would be at 50 cm. Let the mass of scale be W kg.

By principle of moments,

$$m_1x_1 = m_2x_2$$

$$m_1 \times (70\text{ cm} - 50\text{ cm}) = 0.05 \times (94\text{ cm} - 70\text{ cm})$$

$$m_1 = \frac{0.05\text{ kg} \times 24\text{ cm}}{20\text{ cm}}$$

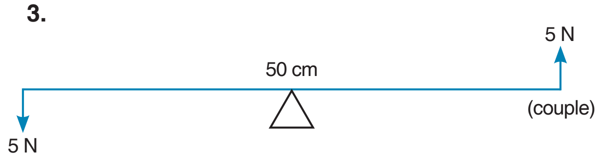
$$= 0.06\text{ kg} = 60\text{ g}$$

2. Given: distance (d) = 20 cm = $\frac{20}{100}$ m = 0.2 m

Moment of force = Force × Distance

= 2 N × 0.2 m = 0.4 Nm

3.



$$M = F \times \vec{d} \quad \text{or} \quad F \times S$$

$$M = 5 \times \frac{50}{100}\text{ m} = 5 \times 0.5 = 2.5\text{ N m.}$$

4. Let M be load.

Load arm = 90 cm – 60 cm = 30 cm

Since weight of the metre scale lies at the centre of gravity at the mid-point of the scale.

∴ Effort arm = 60 cm – 50 cm = 10 cm

Let weight of metre scale be W.

By principle of moments,

$$\text{Load} \times d_L = \text{Effort} \times d_E$$

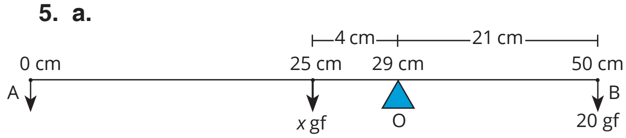
$$M \times 30\text{ cm} = W \times 10\text{ cm}$$

$$W = 3M$$

Since weight of metre scale is three times that of M.

∴ Weight of the scale is greater than weight of M.

5. a.



b. Let the weight of the half metre rule be x gf and it acts at the 25 cm mark (centre of gravity).

Anticlockwise moment = $x \times 4$ gf cm

Clockwise moment = 20 × 21 gf cm

In equilibrium,

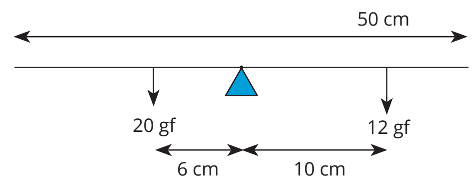
Anticlockwise moment = Clockwise moment

or, $x \times 4 = 20 \times 21$

$$\therefore \quad x = \frac{20 \times 21}{4}\text{ gf} = 105\text{ gf}$$

The weight of the half metre rule is 105 gf.

6.



a. 12 gf acting on the rigid rod causes clockwise moment.

b. Yes, the rod is in equilibrium because both clockwise and anticlockwise moments are the same.

Clockwise moment = 12 gf × 10 cm = 120 gf cm

Anticlockwise moment = 20 gf × 6 cm = 120 gf cm

c. If 20 gf is reversed, both forces of 12 gf and 20 gf give clockwise moment.

∴ Resultant moment = 120 + 120 = 240 gf cm.

7. a. We have a uniform meter scale, so its centre of gravity would be at 50 cm.

Let the weight of the meter scale be W.

∴ By principle of moments,

$$W \times (50–30)\text{ cm} = 40 \times (30–5)\text{ cm}$$

$$W = 40 \times \frac{25}{20} = 50\text{ gf}$$

b. F is shifted towards 0 cm.

Check Your Progress 2 (Page 21)

A. 1. c **2.** b **3.** d **4.** a **5.** b

6. b **7.** a. i b. iii

B. 1. Centre of gravity of a body is a point at which the resultant of the parallel forces called the weight of the body acts vertically downwards due to gravity, no matter in which position the body is placed.

2. The centre of gravity of a body is the point at which the body experiences the total gravitational pull.

3. The position of centre of gravity of a body of given shape and mass depends on the distribution of mass in the given shape. It may lie inside the body or outside the body.

4. a. **Rectangular lamina:** At the point of intersection of the diagonals.

   b. **Uniform rod:** At the midpoint of its axis.

   c. **Hollow cone:** At a height *h*/3 from the base on its axis.

   d. **Square lamina:** At the point of intersection of the diagonals.

   e. **Triangular lamina:** At the point of intersection of its medians.

   f. **Cylinder:** At the mid point on its axis.

   g. **Solid cone:** At a height *h*/4 from the base on its axis (*h* = height of cone).

   h. **Parallelogram lamina:** At the point of intersection of the diagonals.

5. To be done by the students.

6. Determination of centre of gravity of an irregularly shaped body

   i. Take an irregularly shaped piece of cardboard whose centre of gravity is to be determined (Fig).

   ii. Punch three fine holes a, b and c near the outer edge of the cardboard.

   iii. Suspend the cardboard from the hole 'a' along with a plumb line with the help of a nail. (Check that the cardboard is free to rotate about the point of suspension.) When the cardboard is at rest, draw a straight line 'ad' along the plumb line.

   iv. Repeat the experiment by suspending the cardboard through the hole 'b' to get a straight line 'be' and then through the hole 'c' to get a straight line 'cf' (Fig).

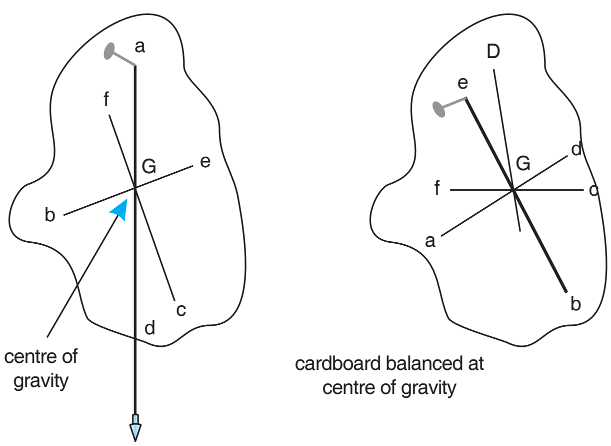


Fig. To find centre of gravity of irregular bodies

   v. It is observed that the plumb lines intersect each other at a common point 'G' which is the centre of gravity.

   vi. Remove the cardboard and insert a pin through 'G' (centre of gravity). It is found that the cardboard is balanced at G in the position of equilibrium.

   vii. Point G is the centre of gravity of the given irregularly shaped cardboard.

7. i. In case of L-shaped bodies, the centre of gravity lies outside the body. For example, boomerang.

   ii. The centre of gravity of a doughnut lies in the middle of the hole.

   iii. The centre of gravity of a horseshoe magnet does not lie within the body of the material.

8. When a body moves in a circular path with uniform speed (constant speed), its motion is called uniform circular motion.

9. Speed remains constant in uniform circular motion.

10. The direction of motion changes continuously in uniform circular motion.

11. When a body moves in a circle with uniform speed, its velocity changes continuously, so the motion in a circle is accelerated.

12. i. The motion of the earth and other planets around the sun.

   ii. The motion of the moon around the earth.

13. For a body moving with a uniform speed along a circular path that the direction of the velocity is along the tangent to the circle at any point in its motion. The direction of the velocity constantly changes.

14. Centripetal force makes a body move along a circular path with uniform speed.

15. i. Centripetal force is a centre-seeking force that causes an object to move in a circular path while the centrifugal force is outward-directed fictitious force exerted on a body when it is moving in a circular path.

   ii. Centripetal force is a real force, i.e. the force due to the influence of some object or field while centrifugal force is a fictitious force.

16. Centripetal force is a real force because it is the force due to the influence of some object or field.

17. A fictitious force is present only when a system is examined from an accelerating frame of reference. If the same system is examined

from a non-accelerating frame of reference, all the fictitious forces disappear. For example, a person on a rotating merry-go-round would experience a centrifugal force that pulls away from the centre of the ride. The person experiences this force only because he or she is on the rotating merry-go-round, which is an accelerating frame of reference. If the same system is analysed from the sidewalk next to the merry-go-round, which is non-accelerating frame of reference, there is no centrifugal force.

Questions Based on ICSE Examination (Page 23)

1. a. Speed remains constant in uniform circular motion.

   b. Centripetal force; It is directed towards its centre.

2. Direction of centripetal force is towards the centre of the circle whereas centrifugal force is directed radially outwards.

EXERCISES

Questions Based on ICSE Examination (Page 23)

1. a. Moment of force or torque produced by a force about an axis is equal to the product of the magnitude of the force and the perpendicular distance of the line of action of the force from the axis of rotation.

   b. 1 Nm = 10^5 dyne × 10^2 cm = 10^7 dyne cm

2. Refer to Check Your Progress (Page 16) section question **B.8(a).**
3. Refer to Check Your Progress (Page 16) section question **B.9.**
4. Refer to Check Your Progress (Page 16) section question **B.14.**
5. Refer to check your progress (Page 16) section question **B.11.**
6. a. **Static equilibrium:** When the body remains in the state of rest under the influence of various external forces, it is said to be in static equilibrium. Example of static equilibrium is the beam balance when there is no rotational motion in it.

   b. **Dynamic equilibrium:** When a body remains in the state of uniform motion (translational or rotational), it is said to be in dynamic equilibrium. For example, a car moving with a uniform velocity on a straight road is in dynamic equilibrium because the force due to the weight of the car acting vertically downwards is balanced by an equal reaction exerted on the car by the road acting vertically upwards.

7. We know that all bodies are made up of small particles called molecules. The relative position of these molecules (particles) with respect to each other are fixed. Let us consider the weight of each particle to be '*w*'. We know that the earth attracts every particle towards its centre by the force of gravity which is equal to the weight of the particle, i.e. '*w*'. Since the size of the body is very small as compared to the size of the earth and the centre of the earth is very far away, the pull of gravity '*w*' acting on these particles can be taken to be parallel to each other. All these parallel forces acting in the same direction (i.e. vertically downwards) can be replaced by a single resultant force called the weight of the body.

Additional Numericals (Page 24)

1. $d = 2$ m

   $F = 50$ N

   $\tau = F \times d = 50 \times 2 = 100$ N m

2. $F = 0.1$ N

   $d = 50 \text{ cm} = \frac{50}{100} = 0.5$ m

   $\tau = F \times d = 0.1 \times 0.5 = 0.05$ N m

3. $\tau = 30$ N m

   $d = 30 \text{ cm} = \frac{30}{100} = 0.3$ m

   $\tau = F \times d$

   $F = \frac{\tau}{d} = \frac{30 \text{ N m}}{0.3 \text{ m}} = 100$ N

4. $\tau = 10$ N m

   $d = 20 \text{ cm} = \frac{20}{100} = 0.2$ m

   $\tau = F \times d$

   $F = \frac{\tau}{d} = \frac{10}{0.2} = 50$ N

5. $F = 200$ N

   $\tau = 150$ N m

   $\tau = F \times d$

   $d = \frac{\tau}{F} = \frac{150}{200} = \frac{3}{4} = 0.75$ m

6. $F = 20$ N

   $d = 70 \text{ cm} = \frac{70}{100} = 0.7$ m

   $\tau = F \times d = 20 \times 0.7 = 14$ N m

7. $d = 30$ cm

   $F_1 = 90$ N

   $d_2 = ?$

$$F_2 = 54 \text{ N}$$
$$F_1 d_1 = F_2 d_2$$
$$90 \times 30 = 54 \times d_2$$
$$d_2 = \frac{90 \times 30}{54} = 50 \text{ cm}$$

8. $w \times 10 + 10 \times 40 = 30 \times 30$
$$w \times 10 = 900 - 400$$
$$w = \frac{500}{10} = 50 \text{ gf}$$

9. $50 \times 10 + w \times 5 = 100 \times 10$
$$w \times 5 = 1000 - 500$$
$$w \times 5 = 500$$
$$w = \frac{500}{5} = 100 \text{ gf}$$

10. $80 \times 70 = 60 \times x$
$$x = \frac{80 \times 70}{60} = 96.67 \text{ cm}$$

11. $30 \times 1.5 + 40 \times 3.5 = 60 \times x$
$$45 + 140 = 60x$$
$$x = \frac{185}{60} = 3.08 \text{ m}$$

CHAPTER – 2

WORK, ENERGY AND POWER

Check Your Progress 1 (Page 32)

A. **1.** b **2.** c **3.** c **4.** b **5.** b

6. c **7.** c **8.** d

B. **1.** We know that SI unit of work is joule (J) or newton-metre (Nm) and CGS unit of work is eng or dyne centimetre (dyne cm).

Relation between SI and CGS unit of work

$$1 \text{ N} = 10^5 \text{ dyne} \quad \ldots(i)$$

$$1 \text{ m} = 100 \text{ cm} \quad \ldots(ii)$$

now,

$$1 \text{ J} = 1 \text{ Nm} \quad \ldots(iii)$$

Substitute (i) and (ii) in (iii)

$$= 10^5 \text{ dyne} \times 100 \text{ cm}$$

$$1\text{J} = 10^5 \times 10^2 \text{ dyne cm}$$

$$1 \text{ J} = 10^{5+2} \text{ erg}$$

$$1\text{J} = 10^7 \text{ erg} \quad \ldots(\text{iv})$$

From equation (iv) we get, SI unit of work is 10^7 times of CGS unit of work.

2. Work done by a force on a body depends upon

i. the magnitude and direction of force.

ii. the displacement(s) produced by it.

3. A man holding a bucket in his hand does no work because the displacement made by him is zero.

4. A man pushing a wall does no work as the displacement made by him is zero.

5. $W = F \cos\theta \times S$

6. Work done by a force is

a. Positive; when θ is acute ($\theta < 90°$), $\cos\theta$ is positive. Hence, work done is positive.

b. Negative; when θ is obtuse ($\theta > 90°$), $\cos\theta$ is negative. Hence, work done is negative.

c. Zero; when θ is a right angle ($\theta = 90°$), $\cos\theta$ is zero. Hence, work done is zero.

7. Example of the work done by a force, when the work done is

a. Positive;

i. When a body is falling freely under gravity, $\theta = 0°$, $\cos\theta = +1$.

ii. When a spring is stretched, work done by the stretched force is positive.

b. Negative;

i. When a body is thrown upwards against the gravity,

$\theta = 180°$ then $\cos\theta = -1$.

ii. When brakes are applied on a moving body the work done is negative.

c. Zero;

i. When a coolie carrying a load on his head moves on a horizontal platform, $\theta = 90°$, $\cos\theta = 0°$.

ii. When a body is tied to a string and rotated in a circle, the centripetal force along the string is zero ($\theta = 90°$).

8. Energy of a body is defined as the capacity or ability of the body to do work. The unit of energy in SI system is joule (J). The unit of energy in CGS system is erg where 1 J = 10^7 ergs.

9. **a.** 1 J = 10^7 ergs

b. 1 kWh = 3600000 J = 3.6×10^6 J

c. 1 calorie = 4.18 J

d. 1 eV = 1.6×10^{-19} J

e. 1 Wh = 3600 J = 3.6×10^3 J

10. The rate of doing work is called power. Its unit is watt (W).

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

11.

Work	Power
When a body is displaced by a force, work is said to be done.	It is the rate of doing work.
Its unit is joule.	Its unit is watt.

12. The SI unit of power is watt. Watt is the ratio of the work done in joules to the time in seconds.

$$\text{Watt} = \frac{\text{Joule}}{\text{Second}}$$

13. Relation between SI and CGS units of power is

$$1 \text{ watt} = 1 \text{ joule s}^{-1} = 1 \text{ erg s}^{-1}$$

14. It is the unit of power used in engineering to measure the power of motors.

$$1 \text{ H.P.} = 746 \text{ watts}$$

C. **1.**

$$\text{Work} = 60 \text{ J}$$

$$\text{Time} = 10 \text{ s}$$

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{60}{10} = 6 \text{ W}$$

2.

$$F = 400 \text{ N}$$

$$S = 60 \text{ m}$$

$$t = 1 \text{ min} = 60 \text{ s}$$

$$W = F \times S = 400 \times 60 = 24000 \text{ J}$$

$$P = \frac{W}{t} = \frac{24000}{60} = 400 \text{ W}$$

3. Weight of man = 500 N

Load = 100 N

∴ Height = 4 m

$t = 5$ s

∴ Weight = mg = 500 + 100 = 600 N

$$W = U = mgh$$

$$= 600 \times 4 = 2400 \text{ J}$$

$$P = \frac{W}{t} = \frac{2400}{5} = 480 \text{ W}$$

4. a. Mass of water = 300 kg

$g = 9.8 \text{ m/s}^2$

Weight = $mg = 300 \times 9.8 = 2940$ N

$h = 50$ m

$t = 10$ s

$W = mgh = 2940 \times 50$

$= 147000$ J

b. $$P = \frac{W}{t} = \frac{147000}{10}$$

$= 14700$ W

5. $m = 25$ kg

$g = 9.8 \text{ m/s}^2$

$h = 10$ m

$t = 50$ s

$W = mgh = 25 \times 9.8 \times 10 = 2450$ J

$$P = \frac{W}{t} = \frac{2450}{50} = 49 \text{ W}$$

6. Man: $W_1 = 200$ J Boy: $W_2 = 100$ J

$t_1 = 10$ s $t_2 = 4$ s

a. $P_1 = \frac{200}{10} = 20$ W $P_2 = \frac{100}{4} = 25$ W

The boy delivers more power.

b. $\frac{P_1}{P_2} = \frac{20}{25} = \frac{4}{5}$

∴ Power Man : Power Boy = 4 : 5

Questions Based on ICSE Examination (Page 33)

1. When a body is displaced on the application of force, the work is said to be done. Its SI unit is joules (J).

2. $W = F \times S \cos\theta$

When force is along the direction of displacement

$\theta = 0°$

$\cos 0° = 1$

∴ $W = FS$ = Force × Displacement

3. When a coolie carries a load on his head and moves on a horizontal plane, no work is said to be done, because the angle between the force applied by the load (vertically downwards) and the displacement is 90°.

$\cos 90° = 0$

Hence, the work done is zero.

4. a. Work done by a force is measured by the product of force (F) and displacement (S) in the direction of force.

Work done = $F \times S$

b. Work done is measured by the product of force (F) and the component of displacement (S) in the direction of force.

$W = F \times S \cos\theta$

where θ = angle between the direction of the force and the direction of motion.

5. a. Work is said to be done if a body undergoes displacement, since it is moving on a circular path.

b. Work done is zero by the moon, as there is no displacement, since it is moving on a circular path.

6. Work done, $W = \frac{1}{2} m(v_2^2 - v_1^2)$

$$= \frac{1}{2} \times 20 \text{ kg } [(50 \text{ m})^2 - (40 \text{ m})^2]$$

$$= \frac{1}{2} \times 20 \times [2500 \text{ m}^2 - 1600 \text{ m}^2]$$

$$= \frac{1}{2} \times 20 \times 900 \text{ m}^2$$

$= 9000$ J = 9 kJ

7. As the fielder applies force on his hands against the force of the ball, so work done is negative.

8. Man having a box on his head who climbs up a slope does more work against the force of gravity because he has more potential energy by virtue of his position, i.e. height.

P.E. = Work done = $F \times S$

$= mg \times h$

9. Given, power of the motor,

P = 100 KW = 100 × 1000 w

$= 10^5$ = Watt

and force, $F = 50000$ N,

Now, from the definition of power,

$$P = Fv$$

$$V = \frac{100000}{50000} = 2\ \text{ms}^{-1}$$

Hence, the motor can lift the load with a speed of 2 ms^{-1}

10. Power exerted = Force × Average speed

= 150 N × 10 m/s = 1500 W.

11. Let the work done by both cranes be 'W'

Given,

Time taken by crane A to do work, $t_1 = 5$ s

Time taken by crane B to do work, $t_2 = 2$ s

Power of crane A, $P_A = \frac{W}{t_1}$

Power of crane B, $P_B = \frac{W}{t_2}$

$$\frac{P_A}{P_B} = \frac{Wt_2}{Wt_1}$$

$$\frac{P_A}{P_B} = \frac{t_2}{t_1}$$

$$\frac{P_A}{P_B} = \frac{2}{5}$$

$$P_A : P_B = 2 : 5$$

Check Your Progress 2 (Page 40)

A. **1.** b **2.** c **3.** b **4.** b **5.** b

6. a. ii b. iii.

7. a. iv b. ii c. iii d. iii

8. a. iv b. ii c. ii d. iii

B. **1.** Different forms of energy are:

- **i.** Chemical Energy
- **ii.** Sound Energy
- **iii.** Light Energy
- **iv.** Electrical Energy
- **v.** Heat Energy
- **vi.** Magnetic Energy
- **vii.** Nuclear Energy
- **viii.** Mechanical Energy

2. **a.** Chemical Energy **b.** Chemical Energy

c. Sound Energy **d.** Chemical Energy

3. The energy possessed by a body due to its state of motion or of position is called mechanical energy. It is of two types

i. Kinetic Energy **ii.** Potential Energy

4. The energy possessed by a body by virtue of its motion is called its kinetic energy.

5. The work done by a body is

$$W = \text{Force} \times \text{Displacement}$$

If a body of mass '*m*' initially at rest attains a velocity '*v*' when an acceleration '*a*' takes place on the application of a force '*F*' then

Initial velocity $u = 0$

Final velocity $v = v$

Acceleration $= a$

Then $v^2 = u^2 + 2aS$

$v^2 = 0 + 2aS$

or $v^2 = 2aS$

or $S = \frac{v^2}{2a}$

According to Newton's second law of motion

$F = ma$

or $a = \frac{F}{m}$

∴ $v^2 = \frac{2FS}{m}$

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

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

but the work done is equal to the gain in kinetic energy K

∴ $\boxed{K = \frac{1}{2}mv^2}$

6. Momentum of a body of mass '*m*' moving with velocity '*v*' is

$$p = m \times v \text{ or } v = \frac{p}{m}$$

and kinetic energy

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

∴ $K = \frac{1}{2}m\frac{p^2}{m^2}$

or $\boxed{K = \frac{p^2}{2m}}$

7. According to the work-energy theorem, the work done by the net force on a body is equal to the change in the kinetic energy of the body.

$$W = K_f - K_i$$

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

8. **a.** If the net force does positive work on a body, then K.E. of a body increases.

b. If the net force does negative work on a body, then the K.E. of a body decreases.

c. If the net work done on a body is zero, then the K.E. of a body is constant.

9. The three kinds of kinetic energy (K.E.) are:

i. **Translational K.E.:** When a body moves along a straight line path, it has translational K.E. For example, a ball rolling on the ground.

ii. **Rotational K.E.:** If a body rotates about its axis, it has rotational K.E. For example, a spinning top.

iii. **Vibrational K.E.:** When a body moves to and fro about its mean position, it has vibrational K.E. For example, motion of a stretched string when it is plugged.

10. The energy possessed by a body by virtue of its position is called its potential energy (U).

It is measured by $U = mgh$.

11. a. Chemical energy to Electrical energy

b. Electrical energy to Magnetic energy

c. Electrical energy to Sound energy

d. Electrical energy to Heat energy

e. Sound energy to Electrical energy

f. Electrical energy to Mechanical energy

g. Solar (light) energy to Electrical energy

h. Solar (light) energy to Chemical energy

i. Electrical energy to Heat energy to Light energy

j. Chemical energy to Heat energy

k. Electrical energy to Light energy and Sound energy

l. Mechanical energy to Electrical energy

m. Chemical energy to Heat energy

n. Chemical energy to Sound, Heat and Light energy.

12. The two forms of potential energy are:

i. Gravitational potential energy, for example, when a work is done on a body against the gravity, it has gravitational potential energy, such as a stone is lifted from ground and placed on the roof.

ii. Elastic potential energy, for example, when work is done in coil of spring, it is called elastic potential energy, like winding the alarm of a clock.

13. When a body of mass 'm' is raised to a height 'h' above the ground, then the force applied to overcome gravity is

$$F = m \times g$$

where g = acceleration due to gravity.

$$\text{Work done} = \text{Force} \times \text{Displacement} = m \times g \times h$$

Work done on the body is stored in it as gravitational potential energy.

$$\boxed{U = mgh}$$

14. Whenever, there is an interchange between the potential energy and the kinetic energy, the total mechanical energy (the sum of kinetic and potential energy) remains constant if no external force (friction) acts on it.

15. Refer Figure 2.15, Page 38 of the textbook.

16. Refer Figure 2.17, Page 40 of the textbook.

C. 1. $m = 5$ kg

$g = 9.8$ m/s^2

$h = 1.5$ m

$W = mgh = 5 \times 9.8 \times 1.5 = 73.5$ J

2. Mass of car = 1000 kg

$u = 30$ m/s

$v = 0$ m/s

$S = 50$ m

$$v^2 - u^2 = 2aS$$

$$\therefore \quad a = \frac{v^2 - u^2}{2S} = \frac{0 - 30^2}{2 \times 50} = \frac{-900}{100} = -9$$

$a = -9$ m/s^2,

i.e. Retardation = 9 m/s^2

Retarding force = $m \times a = 1000 \times 9 = 9000$ N

W = Force × Displacement = 9000 × 50

= 450000 J

= 45×10^4 J

3. Load = 100 kg ($g = 9.8$ m/s^2)

= 100 × 9.8 = 980 N

$h = 5$ m

$\therefore$ $W = mgh = 980 \times 5 = 4900$ J

4. $W = 2500$ J

$g = 9.8$ m/s^2

$h = 5$ m

$W = mgh$

$\therefore \quad m = \dfrac{2500}{9.8 \times 5} = 51.02$ kg

$m = 51$ kg

5. $m_1 : m_2 = 1 : 1$

$v_1 : v_2 = v : 3v = 1 : 3$

$k_1 : k_2 = \frac{1}{2}m_1v_1^2 : \frac{1}{2}m_2v_2^2$

$= \frac{1}{2}mv^2 : \frac{1}{2}m(3v)^2$

$k_1 : k_2 = 1 : 9$

6. $m = 10$ kg

$h = 5$ m

$g = 9.8$ m/s^2

Potential energy $= U = mgh$

$= 10 \times 9.8 \times 5 = 490$ J

According to principle of conservation of energy

K.E. = P.E.

$\therefore \quad K = 490$ J

But $\quad K = \frac{1}{2}mv^2$

$v = \sqrt{\dfrac{2K}{m}} = \sqrt{\dfrac{2 \times 490}{10}} = \sqrt{98}$

$\therefore \quad v = 9.9$ m/s

Questions Based on ICSE Examination (Page 42)

1. The principle of conservation of energy states that the total sum of energies of all kinds in an isolated system always remains constant, i.e. the energy is neither created nor destroyed but is transformed from one form to another.

2. Man A — mass $= m_A$, height $= h$, $g = 10$ m/s^2, $W_A = mgh = m_Agh$

Man B — mass $= m_B$, height $= h$, $g = 10$ m/s^2, $W_B = m_Bgh$

$\therefore \quad W_A : W_B = m_A : m_B$

If $\quad m_A = m_B$

then $W_A : W_B = 1 : 1$

3. $m_B = 20$ kg $\qquad m_C = 5$ kg

$v_B = 5$ m/s $\qquad v_C = 20$ m/s

a. $p_B : p_C = m_Bv_B : m_Cv_C$

$= 20 \times 5 : 5 \times 20$

$= 100 : 100 = 1 : 1$

$K_B : K_C = \frac{1}{2}m_Av_A^2 : \frac{1}{2}m_Bv_B^2$

$= \left(\frac{1}{2} \times 20 \times 5 \times 5\right) : \left(\frac{1}{2} \times 5 \times 20 \times 20\right)$

$= 1 : 4$

b. $K_B = \frac{1}{2}m_Bv_B^2$

$= \frac{1}{2} \times 20 \times 5 \times 5 = 250$ J

4. $\text{K.E.}_1 = \frac{1}{2}mv^2$

$\text{K.E.}_2 = \frac{1}{2}m\left(\frac{v}{3}\right)^2 = \frac{mv^2}{18}$

Change in K.E. $= \dfrac{mv^2}{2} - \dfrac{mv^2}{18}$

$= \dfrac{9mv^2 - mv^2}{18} = \dfrac{8mv^2}{18}$

Change in K.E. $= \frac{8}{9}$ times of the original K.E.

5. Given:

Ratio of masses of A and B,

$m_A : m_B = 5 : 1$

Ratio of kinetic energies of A and B,

$K_A : K_B = 125 : 9$

Let the velocities of bodies A and B be v_A and v_B respectively

Now, $\quad K = \frac{1}{2}mv^2$

$\therefore \quad K_A = \frac{1}{2}m_Av_A^2$ and $K_B = \frac{1}{2}m_Bv_B^2$

$\Rightarrow \quad \dfrac{\frac{1}{2}m_Av_A^2}{\frac{1}{2}m_Bv_B^2} = \dfrac{125}{9}$

$\Rightarrow \quad \dfrac{m_A}{m_B} \times \dfrac{v_A^2}{v_B^2} = \dfrac{125}{9}$

$\Rightarrow \quad \dfrac{5}{1} \times \dfrac{v_A^2}{v_B^2} = \dfrac{125}{9}$

$\Rightarrow \quad \left(\dfrac{v_A}{v_B}\right)^2 = \dfrac{125}{9} \times \dfrac{1}{5} = \dfrac{25}{9}$

$\Rightarrow \quad \left(\dfrac{v_A}{v_B}\right) = \dfrac{5}{3}$

$\therefore$ The ratio of $\quad v_A : v_B = 5 : 3$

6. Given: $\quad$ K.E. $= 500$ J, $W = 400$ N, $g = 10$ m/s^2

Using formula $= W = mg$

$$400\ N = m \times 10\ m/s^2$$

$$\therefore \quad m^2 = \frac{400\ N}{10\ m/s^2} = 40\ kg$$

Now, $\quad K.E. = \frac{1}{2}mv^2$

$$500\ J = \frac{1}{2} \times 40\ kg \times v^2$$

$$40\ kg \times v^2 = 500\ J \times 2$$

$$v^2 = \frac{1000\ J}{40\ kg}$$

$$\therefore \quad v = 5\ m/s$$

7. Given: Mass $= 200\ g = \frac{200}{1000} = 0.2\ kg$

$h = 5$ m, $g = 9.8\ m/s^2$

When the ball reaches the ground

$$K.E. = P.E.$$

$$K.E. = mgh$$

$$= 0.2\ kg \times 9.8 \times 5$$

$$= 9.8\ J$$

8. **a.** Compressed spring has potential energy.

b. Potential energy of the spring is imported to the ball in the form of kinetic energy.

9. Increase in gravitational potential energy

$$= mg\,(h_2 - h_1)$$

$$= 35\ kg \times 10\ ms^{-2}\ (12\ m - 4\ m)$$

$$= 350 \times 8$$

$$= 2800\ J$$

10. **a.** Electric energy to sound energy

b. Electric energy to heat energy to light energy.

11. Potential energy.

12. Kinetic energy changes to Potential energy. Kinetic energy becomes zero.

13. **a.** Potential energy of the pendulum at the position

$B = mgh$

We have $m = 200\ g = 0.2\ kg$, $g = 10\ m/s^2$,

$h = 5$ m

Potential energy $= 0.2 \times 10 \times 5 = 10$ J

b. Total mechanical energy at point C = Potential energy + Kinetic energy at point C = 10 J + 0 = 10 J

c. At point A, potential energy is converted into kinetic energy.

Kinetic energy at point C $= \frac{1}{2}mv^2 = 10$ J

So, $\quad \frac{1}{2} \times (0.2) \times v^2 = 10$

$$v^2 = 100$$

$$v = 10\ m/s$$

EXERCISES

Questions Based on ICSE Examination (Page 43)

1. **a.** **Energy:** It is defined as the capacity to do work. Its SI unit is joule.

b. **Work:** Work is said to be done only when the force acting on a body produces motion in it in the direction of force. Its SI unit is joule (J).

c. **Power:** It is the rate of doing work. Its unit is watt.

2. Refer Figure 2.17, Page 40 of the textbook.

At the highest point, the pendulum has only potential energy and no kinetic energy.

At the lowest point, the pendulum has only kinetic energy and no potential energy.

In between the two positions, the pendulum has both the kinetic energy and the potential energy.

At any instant the total energy is always the same (it is conserved).

3. $m = 0.25$ kg

$u = 10$ m/s

$v = 0$

Initial K.E. $= \frac{1}{2}mu^2$

$$= \frac{1}{2} \times 0.25 \times 10 \times 10 = 12.5\ J$$

At the highest point K.E. is zero ($v = 0$).

$\therefore \quad$ P.E. = K.E. = 12.5 J

4. $P = 30\ kW = 30{,}000\ W$

Load $= F = mg = 30{,}000$ N

$P = F \times v$

$$\therefore \quad v = \frac{P}{F} = \frac{30{,}000}{30{,}000} = 1\ m/s$$

5. Load = 1000 N

$h = 10$ m

$t = 5$ s

$W = \text{Load} \times h$

$= 1000 \times 10 = 10{,}000$ J

$$P = \frac{W}{t} = \frac{10000}{5} = 2000\ W$$

6. Volume of water = 20,000 L

1 L of water = 1 kg

$\because$ Density = 1000 kg/m^3

$\therefore$ Mass of water = 20,000 kg

$h = 30$ m

$t = 10$ min $= 10 \times 60 = 600$ s

$g = 10$ m/s^2

$W = mgh = 20{,}000 \times 10 \times 30$

$= 60{,}00{,}000$ J $= 6 \times 10^6$ J

$$P = \frac{W}{t} = \frac{60{,}00{,}000}{600} \text{ W}$$

$= 10{,}000$ W $= 10$ kW

7. Mass = 60 kg

Number of steps = 20

$t = 20$ s

Height of 1 step = 20 cm

Total height = $20 \times 20 = 400$ cm = 4 m

$g = 10$ m/s^2

$W = mgh$

$= 60 \times 10 \times 4 = 2400$ J

$$P = \frac{W}{t} = \frac{2400}{20} = 120 \text{ W}$$

Additional Numericals (Page 44)

1. Mass = 100 kg

$S = 5$ m

$g = 9.8$ m/s^2

$\therefore$ $W = mg \times S$

$= 100 \times 9.8 \times 5 = 4900$ J

2. Weight = 300 N

$h = 7$ m

Work $= F \times h$

$= 300 \times 7 = 2100$ J

3. Mass = 200 g = 0.2 kg

$h = 2$ m

$g = 9.8$ m/s^2

$W = U = mgh = 0.2 \times 9.8 \times 2 = 3.92$ J

4. Mass, $m = 2$ kg

$u = 0$

$g = 9.8$ m/s^2

$h = ?$

$t = 2$ s

$v = u + gt$

$= 0 + 9.8 \times 2 = 19.6$ m/s

$$\text{K.E.} = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 2 \times 19.6 \times 19.6 = 384.16 \text{ J}$$

5. Mass = 2 kg

$u = 20$ m/s

$g = 9.8$ m/s^2

$t = 2$ s

$$S = ut - \frac{1}{2}gt^2$$

$$= 20 \times 2 - \frac{1}{2} \times 9.8 \times 4$$

$= 40 - 19.6 = 20.4$ m

$U = mgh$

$= 2 \times 9.8 \times 20.4 = 399.84$ J

6. $m_1 : m_2 = 1 : 1$ ($m : m$)

$v_1 = v_2 = 1 : 2$ ($v : 2v$)

$$K_1 : K_2 = \frac{1}{2}m_1v_1^2 : \frac{1}{2}m_2v_2^2$$

$$= \left[\frac{1}{2} \times m \times v^2\right] : \left[\frac{1}{2} \times m \times (2v)^2\right]$$

$= 1 : 4$

7. Mass of man = 60 kg

$g = 9.8$ m/s^2

Number of steps = 30

Height of 1 step = 20 cm

$\therefore$ Total height = 30×20

= 600 cm = 6 m

$W = mgh$

$= 60 \times 9.8 \times 6$

$= 3528$ J

$t = 40$ s

$$P = \frac{W}{t} = \frac{3528}{40}$$

$= 88.2$ W

8. $m = 110$ kg

$v = 2$ m/s

F = weight $= mg = 110 \times 9.8 = 1078$ N

$P = F \times v = 1078 \times 2 = 2156$ W

9. $m = 30$ g $= 0.03$ kg

$u = 400$ m/s

$v = 0$

$S = 10$ cm $= 0.1$ m

$v^2 - u^2 = 2aS$

$$a = \frac{v^2 - u^2}{2S} = \frac{0 - 400 \times 400}{2 \times 0.1}$$

$\therefore \quad a = -8{,}00{,}000 \text{ m/s}^2$

Retarding force; $F = m \times a$

$= 0.03 \times 8{,}00{,}000$

$= 24{,}000$ N

10. $W = 2.4$ J

$t = 1$ min $= 60$ s

Total power $= 2$ W

$$P = \frac{n \times W}{t}$$

n is the frequency.

$$\therefore \quad n = \frac{P \times t}{W} = \frac{2 \times 600}{2.4} = 50 \text{ times}$$

11. $W = 1.5$ J

$t = 1$ min $= 60$ s

$P = 2$ W

n = frequency = ?

$$n = \frac{P \times t}{W} = \frac{2 \times 60}{1.5} = 80 \text{ times}$$

12. $m = 0.5$ kg

$u = 4$ m/s

At the highest point, $v = 0$ m/s

Initial K.E. $= K = \frac{1}{2}mu^2$

$= \frac{1}{2} \times 0.5 \times 4 \times 4 = 4$ J

Initial K.E. = Final P.E.

$u = 4$ J

13. $P = 25$ kW $= 25{,}000$ W

$F = 25{,}000$ N

$P = F \times v$

$$v = \frac{P}{F} = \frac{25000}{25000} = 1 \text{ m/s}$$

14. Load $= 1000$ N

$h = 10$ m

$t = 5$ s

$W = \text{Load} \times h$

$= 1000 \times 10 = 10{,}000$ J

$$P = \frac{W}{t} = \frac{10{,}000}{5} = 2000 \text{ W}$$

15. Volume of water = 40,000 L

$d = 1000 \text{ kg/m}^3$

$\therefore$ Mass of water $= \frac{40{,}000}{1000} \times 1000$

$= 40{,}000$ kg

$h = 60$ m

$t = 10$ min $= 10 \times 60 = 600$ s

$W = mgh$

$= 40000 \times 9.8 \times 60$

$= 2{,}35{,}20{,}000$ J

$= 2.4 \times 10^7$ J

$$P = \frac{W}{t}$$

$$= \frac{2{,}35{,}20{,}000}{600}$$

$= 39{,}200$ W

16. $m = 2$ kg

$h = 10$ m

$g = 9.8 \text{ m/s}^2$

$W = U = mgh$

$= 2 \times 9.8 \times 10 = 196$ J

17. $m = 50 \text{ g} = \frac{50}{1000} = 0.05$ kg

$u = 500$ m/s

$v = 0$

$S = 10$ m

$$a = \frac{v^2 - u^2}{2S}$$

$$= \frac{0 - 500 \times 500}{2 \times 10}$$

$= -12500 \text{ m/s}^2$

a. K.E. $= \frac{1}{2}mu^2$

$= \frac{1}{2} \times 0.05 \times 500 \times 500$

$= 6250$ J

b. Average retarding force

$F = m \times a$

$= 0.05 \times 12500$ N

$= 625$ N

CHAPTER – 3

SIMPLE MACHINES

CHECK YOUR PROGRESS 1 (PAGE 52)

A. **1.** a **2.** b **3.** c **4.** c **5.** b
6. b **7.** c **8.** a **9.** b

B. **1.** A simple machine is a device which is used to do work conveniently and more quickly. It is a device through which either the magnitude or the direction of application of force is changed to achieve a certain advantage or by which we can obtain a gain in speed.

2. The principle of an ideal machine is that there is no loss of energy in any manner. The work input will be equal to the work output, i.e. efficiency of an ideal machine is 100%.

3. Ideal machine differ from a practical machine in following two ways:

i. In practical machines, part of the work or energy supplied to the machine is wasted in moving parts of the machine as they are not weightless.

ii. Part of the work done or energy supplied is wasted in overcoming the friction as practical machines are not smooth.

4. The four ways in which machines are useful to us are:

i. As a force multiplier.

ii. Applying a force in a convenient direction.

iii. Applying a force at a convenient point.

iv. To obtain gain in speed.

5. **a.** A wheel-barrow **b.** A pulley
c. A crow bar **d.** Fire tong

6. **a.** **Load:** Load is the force applied by the machine on the body on which the work is done.

b. **Effort:** It is the force applied to a machine to do mechanical work.

c. **Mechanical Advantage (MA):** It is the ratio of the load to the effort, i.e.

$$MA = \frac{\text{Load}}{\text{Effort}}$$

d. **Velocity Ratio (VR):** Velocity ratio of a machine is the ratio of the velocity of the effort to the velocity of the load. It is also defined as the ratio of displacement of the effort to the displacement of the load.

7. Since mechanical advantage is the ratio of two similar quantities, it has no unit.

8. **a.** Load > Effort then $MA > 1$

b. Load < Effort then $MA < 1$

c. Load = Effort then $MA = 1$

9. Since velocity ratio is the ratio of two similar quantities, it has no units.

10. Efficiency of a machine is the ratio of the useful work done by the machine to the work done on the machine.

$$\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}} \times 100\%$$

11. In an ideal machine, there is no loss of energy. The work output will be equal to the work input, i.e. the efficiency of the machine is 100%.

12. $$\text{Efficiency } (\eta) = \frac{\text{Mechanical Advantage } (MA)}{\text{Velocity Ratio } (VR)}$$

13. Refer Table 3.1, Page 47 of the textbook.

14. A lever is a rigid, straight or bent bar which is capable of turning about a fixed point or an axis commonly called its fulcrum.

It works on the principle of moments, i.e. sum of clockwise moment of load about the fulcrum is equal to the sum of anticlockwise moment of effort about the fulcrum.

15. According to the principle of moments, clockwise moment of load about the fulcrum = anticlockwise moment of effort about the fulcrum.

$\therefore$ Load × Load arm = Effort × Effort arm

i.e., $$\frac{\text{Load}}{\text{Effort}} = \frac{\text{Effort arm}}{\text{Load arm}}$$

or $$MA = \frac{\text{Effort arm}}{\text{Load arm}}$$

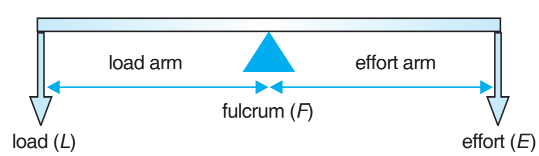
16. Different types of levers are classified into classes depending on the relative positions of their fulcrum (F), load (*L*) and effort (*E*).

i. Class I lever **ii.** Class II lever

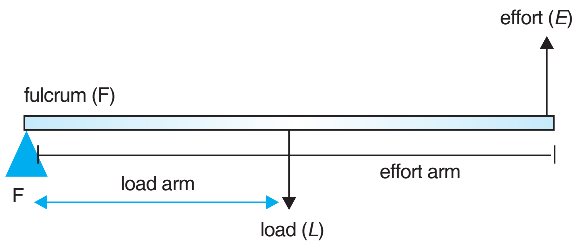
iii. Class III lever

17. The three classes of lever are:

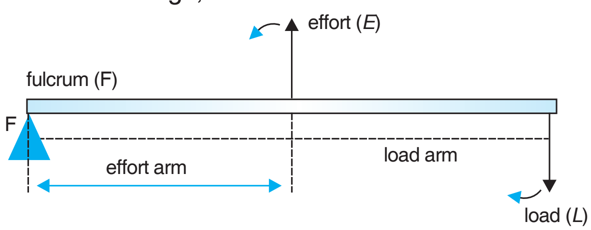
i. **Class I lever:** The fulcrum (F) is situated between the effort (*E*) and load (*L*), for example, a sea-saw, crow bar.



ii. **Class II lever:** The load (*L*) in between the fulcrum (F) and effort (*E*), for example, a wheel-barrow, a nut-cracker.



iii. **Class III lever:** The effort (E) in between the load (L) and the fulcrum (F), for example, fire tongs, bread knife.



18. Examples of class I lever where mechanical advantage is
    a. More than one – A plier
    b. Equal to one – A see-saw
    c. Less than one – A pair of scissors.
19. A lever with mechanical advantage less than 1 is used as a speed multiplier.
20. All class II levers are examples of force multipliers.

    Refer any one diagram of Figure 3.7, Page 49 of the textbook.
21. The velocity ratio of different classes of lever are
    i. **Class I lever:** Velocity ratio can have any value greater than 1, equal to 1 or less than 1.
    ii. **Class II lever:** Since the effort arm is always longer than the load arm, the velocity ratio of this lever is always more than 1.
    iii. **Class III lever:** Since the effort arm is always smaller than the load arm, the velocity ratio of this lever is always less than 1.
22. a. Refer diagram of See-saw, Figure 3.4, Page 49 of the textbook.
    b. Refer diagram of Nut-cracker, Figure 3.7, Page 49 of the textbook.
    c. Refer diagram of Balance class I lever, Figure 3.3, Page 48 of the textbook.
    d. Refer diagram of Scissors, Figure 3.4, Page 49 of the textbook.

C. 1. $MA = 5$

$\eta = 80\%$

$L = 200$ kgf

Height $= 20$ m

$g = 9.8\ m/s^2$

a. $MA = \dfrac{L}{E}$

$E = \dfrac{L}{MA} = \dfrac{200}{5}$

$\therefore$ Effort $= 40$ kgf

b. $\text{Efficiency} = \dfrac{\text{Work Output}}{\text{Work Input}}$

$\text{Work Input} = \dfrac{\text{Work Output}}{\text{Efficiency}}$

$= \dfrac{200 \times 9.8 \times 20}{80} \times 100$ J

$= 49000$ J

2. a. Load $= 10$ kgf

Load arm $= 20$ cm

Effort arm $= 100 - 20 = 80$ cm

$MA = \dfrac{\text{Effort arm}}{\text{Load arm}} = \dfrac{80}{20} = 4$

b. $MA = \dfrac{L}{E}$

$\therefore \quad E = \dfrac{L}{MA} = \dfrac{10}{4} = 2.5$ kgf

3. $L = 500$ gf $= 0.5$ kgf

Effort arm $= 8$ cm

Load arm $= 32$ cm

$MA = \dfrac{\text{Effort arm}}{\text{Load arm}} = \dfrac{8}{32} = \dfrac{1}{4} = 0.25$

$MA = \dfrac{L}{E} = 0.25$

$\therefore \quad E = \dfrac{L}{0.25} = \dfrac{0.5}{0.25} = 2$ kgf

Since friction is absent,

η (Efficiency) $= 1$ or 100%

$\therefore \quad \eta = \dfrac{MA}{VR} = 1$ or $MA = VR$

$\Rightarrow \quad VR = 0.25$

4. Load $= 120$ kgf

Load arm $= 0.3$ m

$\therefore$ Effort arm $= 1.5 - 0.3 = 1.2$ m

$MA = \dfrac{EA}{LA} = \dfrac{1.2}{0.3} = 4$

$MA = \dfrac{L}{E}$

$$4 = \frac{120}{E}$$

$$\therefore \quad E = \frac{120}{4} = 30 \text{ kgf} = 30\,\text{N}$$

5. Effort = 4 kgf

(d_E) displacement of effort = 100 cm

Load = 100 kgf

(d_L) displacement of load= 4 cm

$$\text{Velocity ratio } VR = \frac{d_E}{d_L} = \frac{100}{4} = 25$$

$$MA = \frac{L}{E} = \frac{100}{4} = 25$$

$$\eta = \frac{MA}{VR} = \frac{25}{25} = 1 \text{ or } 100\%$$

Questions Based on ICSE Examination (Page 54)

1. The efficiency of machine is never greater than 100% because according to the principle of conservation of energy, no energy is lost then for the ideal machine, the work done by the machine can never be greater than the work done on the machine.

2. The relation between mechanical advantage and velocity ratio for

a. an ideal machine

$$MA = VR$$

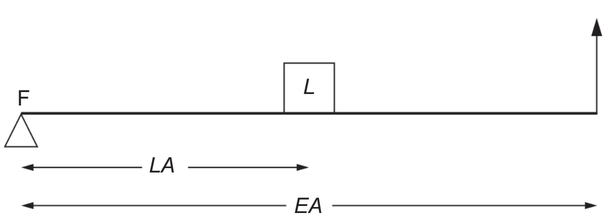
b. a practical machine

$$MA < VR$$

3. Cutting edge of scissors is much longer. This makes Effort Arm shorter than the Load Arm, i.e., the MA is less than 1, and is used as a speed multiplier whereas, in case of shears the Effort Arm is longer than the Load Arm hence the MA is greater than 1 and is used as a force multiplier.

4. For a machine to be used as force multiplier the *EA* > *LA* or *MA* > 1.

This is a case of class II lever.



For example, wheel-barrow, nut-cracker.

5. A jack screw is provided with a long arm in order to have the effort less than the load. According to the principle of moments, load × load arm = effort × effort arm. So, if the load arm is more, then the effort will be more than the load.

6. A Class II lever will always have *MA* > 1. This is because the load is between the fulcrum and the effort. So, the effort arm is always greater than the load arm.

Hence, Mechanical advantage, *MA* > 1.

7. In a class III lever, the effort is between the load and the fulcrum. Hence, effort arm is always less than the load arm. Therefore, the mechanical advantage is always less than one. It is used as a speed multiplier.

$$MA = \frac{\text{Effort arm}}{\text{Load arm}}$$

For class III lever Effort arm < Load arm

$$\therefore \quad \frac{EA}{LA} < 1$$

$$\text{or} \quad MA < 1$$

8. Refer Figure 3.8, Page 50 of the textbook.

9. For a machine to be force multiplier, effort arm is always longer than the load arm and for a machine to be speed multiplier, effort arm is always shorter than the load arm. Both these conditions are not possible simultaneously. Hence, a simple machine cannot act as a speed multiplier and force multiplier at the same time.

10. a. Class III lever

b. Class II lever

11. a. Wheelbarrow

b. Pulley

12. a. Class II lever

b. *LA* = 40 cm

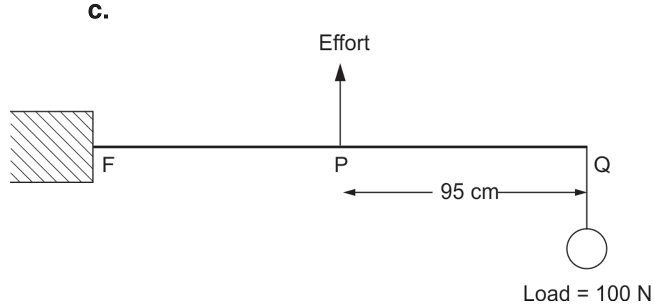
EA = FA + AB = 40 + 60 = 100 cm

$$MA = \frac{EA}{LA} = \frac{100}{40} = \frac{5}{2} = 2.5$$

13. a. According to the principle of moments, when the lever is in equilibrium, the clockwise moment of load about fulcrum is equal to anticlockwise moment of effort about the fulcrum, and assuming that the lever is weightless and friction is neglected.

b. Bread knife, Class III lever.

c.



$$PQ = 95 \text{ cm}$$
$$PF = 5 \text{ cm}$$
$$MA = \frac{EA}{LA} = \frac{PF}{FQ} = \frac{5 \text{ cm}}{100 \text{ cm}} = \frac{1}{20}$$
$$MA = \frac{L}{E}$$
$$\therefore \quad E = \frac{L}{MA} = \frac{100}{1/20}$$
$$E = 2000 \text{ N}$$

14. These belong to the following classes of lever.

a. Pliers – Class I lever
b. Human arm – Class III lever
c. Physical balance – Class I lever
d. Fire tongs – Class III lever
e. See-saw – Class I lever
f. A pair of scissors – Class I lever
g. Oar of a boat – Class I lever
h. Wheelbarrow – Class II lever
i. Lemon-crusher – Class II lever
j. Sugar-tongs – Class III lever
k. Claw hammer – Class I lever
l. Nut-cracker – Class II lever
m. Forceps – Class III lever
n. Knife – Class III lever
o. Railway signal – Class II lever
p. Nail cutter – Class II lever
q. Fishing rod – Class III lever.

15. a. The load (L) is in between the effort (E) and fulcrum (F). So, this is a class II lever.

b. If the load is shifted towards the fulcrum, the length of the load arm decreases.

Mechanical advantage of a lever

$$= \frac{\text{Effort arm}}{\text{Load arm}}$$

Hence, the mechanical advantage of the lever increases.

Check Your Progress 2 (Page 59)

A. 1. a **2.** c **3.** d **4.** a **5.** b
6. a. iv b. iii

B. 1. A single fixed pulley is one which is fixed to a support so that its axis of rotation remains fixed.

2. Single fixed pulley is used to change the direction of effort to a more convenient direction.

3. Mechanical advantage of an ideal single fixed pulley is one.

4. A single movable pulley is not fixed to any support. The load to be lifted is attached to the axis of the pulley.

5. Refer Table 3.2, Page 57 of the textbook.

6. The block and tackle system of pulley consists of two sets of pulleys, each set containing two or more pulleys. The set of pulleys fixed to the rigid support is called block whereas the set of pulleys which are movable and attached to the load is called tackle.

7. 5 pulleys

8. Refer Figure 3.17(a), Page 58 of the textbook.

9. Two assumptions to obtain 100% efficiency of a block and tackle system is:

i. There is no friction in the pulleys.

ii. The weight of the lower movable block is negligible as compared to that of the load.

10. The efficiency of the block and tackle system of pulleys can be increased by

i. the pulleys in the lower block should be as light as possible.

ii. reducing friction in the pulleys. Friction could be minimised by the use of lubricants.

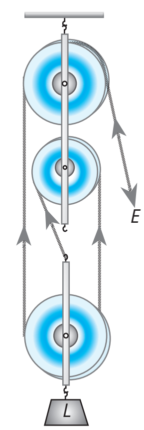
11. a. Refer to Fig. 3.17a, page 58 of the textbook.

b. Velocity ratio will remain the same, i.e. 4, even if the weight of the movable block is doubled.

12. a. and **b.**

$$\text{Efficiency} = \frac{M.A.}{V.R.} \times 100\%$$
$$\Rightarrow \quad \frac{80}{100} = \frac{M.A.}{3}$$
$$\Rightarrow \quad M.A. = \frac{240}{100} = 2.4$$

A system of n pulleys V. R is '*n*'



C. 1. a. Refer Figure 3.17(a), Page 58 of the textbook.

b. $VR = 4$

c. $MA = \frac{L}{E} = \frac{4T}{T} = 4$

d. $VR = \frac{d_E}{d_L}$

$d_L = 1$ m

$\therefore \; d_E = d_L \times 4 = 1 \times 4 = 4$ m

e. 4 stands

2. **a.** Refer Figure 3.17(b), Page 58 of the textbook.

   b. Show all arrows in the upward direction (Refer Figure 3.17(b), Page 58 of the textbook).

   c. $VR = 5$

   d. $MA = \frac{L}{E} = \frac{5T}{T} = 5$

   e. $VR = \frac{d_E}{d_L}$

   $d_L = 1$ m

   $\therefore \quad d_E = 1 \times 5 = 5$ m

   f. 5 stands

Questions Based on ICSE Examination (Page 61)

1. **a.** Single fixed pulley.

   b. There is no gain in mechanical advantage or velocity ratio of a single fined pulley, yet it is widely used for the following reasons:

   i. To lift a load, it is always easier to apply the effort in the downward direction rather than in the upward direction. Thus, a single fined pulley is used to change the direction of the effort.

   ii. One can use one's own body weight for the effort. While applying the effort in the downward direction. Thus, it is used for lifting small load.

2. The *MA* of a single movable pulley is always less than 100% because

   i. there is always some friction between the pulley, wheel and string used in the system,

   ii. the string in the system is not massless and inextensible.

3. The advantage of having a combination of a single fixed and movable pulley is that the single fined pulley allows the effort to be applied in the downward direction whereas the movable pulley doubles the effort force, i.e. it has $MA = 2$.

4. Refer Figure 3.15, Page 56 of the textbook.

5. $E = 72$ N g = 9.8 m/s^2

   $L = 6$ kgf = 58.8 N

   $MA = \frac{L}{E} = \frac{58.8}{72} = 0.82$

6. Refer Figure 3.15, Page 56 of the textbook.

EXERCISES

Questions Based on ICSE Examination (Page 62)

1. **Mechanical Advantage (*MA*):** It is the ratio of the load to the effort. It has no unit.

$$MA = \frac{\text{Load } (L)}{\text{Effort } (E)}$$

Velocity Ratio (*VR*): It is defined as the ratio of the velocity of effort to the velocity of the load. It is also defined as the ratio of the displacement of the effort to the displacement of the load. It has no unit.

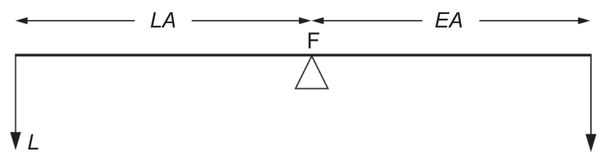
Efficiency (η): Efficiency of a machine is defined as the ratio of the work output to the work input or it is defined as the ratio of the *MA* to the *VR*.

Mechanical Advantage

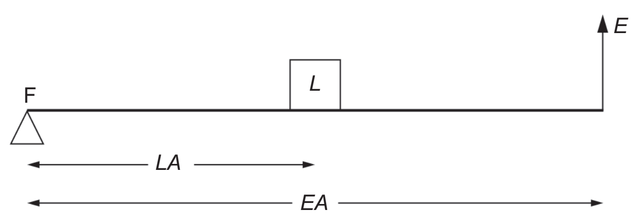
= Velocity Ratio × Efficiency

$MA = \eta \times VR$

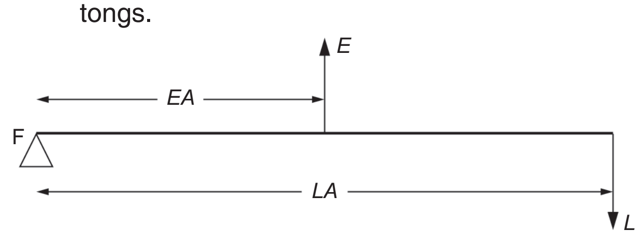
2. **Class I lever:** The Fulcrum (F) is in between the Load (*L*) and the Effort (*E*), for example, see-saw.



Class II lever: The Load (*L*) is in between the Fulcrum (F) and the Effort (*E*), for example, wheel-barrow.



Class III lever: The Effort (*E*) is in between the Load (*L*) and the Fulcrum (F), for example, fire tongs.



3.

$$MA = \frac{\text{Effort arm}}{\text{Load arm}} = \frac{125}{25} = 5$$

$\therefore \quad MA = 5$

4. In Class III levers, the effort is in between the fulcrum and load, the effort arm is always smaller than the load arm. Hence, the mechanical advantage of class III levers is always less than one.

$$MA = \frac{EA}{LA}$$

A bread knife is an example of class III lever.

5. Load = 30 kgf = 30 × 10 = 300 N (g = 10 m/s^2)

$$\text{Effort} = 400 \text{ N}$$

$$MA = \frac{LA}{E} = \frac{300}{400} = 0.75$$

6. The efficiency of a single movable pulley is never 100% because

   i. there is always some friction between the pulley wheel and the string.

   ii. the string used in the system is never massless and inextensible.

7. a. Refer Figure 3.17(b), Page 58 of the textbook.

   b. Percentage of η = 75%

$$E = 150 \text{ kgf}$$

$$\eta = \frac{MA}{VR}$$

$$MA = \eta \times VR = 0.75 \times 5 = 3.75$$

$$MA = \frac{L}{E}$$

$$L = MA \times E$$

$$= 150 \times 3.75 = 562.5 \text{ kgf}$$

8. Refer Figure 3.17(b), Page 58 of the textbook.

$$d_L = 60 \text{ cm}$$

$$VR = 5$$

$$d_E = ?$$

$$VR = \frac{d_E}{d_L} = 5$$

$$\therefore \quad d_E = 5 \times 60 = 300 \text{ cm} = 3 \text{ m}$$

Additional Numericals (Page 62)

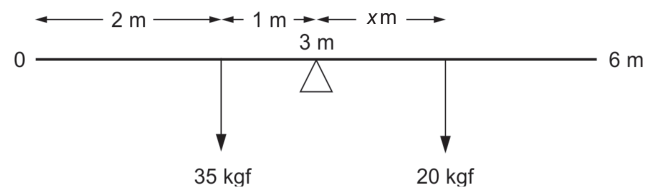
1.

$$EA = 120 - 30 = 90 \text{ cm}$$

$$LA = 30 - 0 = 30 \text{ cm}$$

$$MA = \frac{EA}{LA} = \frac{90}{30} = 3$$

2.



$$L \times LA = E \times EA$$

$$35 \times 1 = 20 \times x$$

$$\therefore \quad x = \frac{35}{20} = 1.75 \text{ m}$$

3.

$$LA = 0.5 \text{ m}$$

$$EA = 3 - 0.5 = 2.5 \text{ m}$$

$$L = 70 \text{ kgf}$$

$$MA = \frac{EA}{LA} = \frac{2.5}{0.5} = 5$$

$$MA = \frac{L}{E}$$

$$\therefore \quad E = \frac{L}{MA} = \frac{70}{5} = 14 \text{ kgf}$$

$$= 140 \text{ N } (g = 10 \text{ m/s}^2)$$

4.

$$LA = 2 \text{ cm}$$

$$EA = 20 \text{ cm}$$

$$MA = \frac{EA}{LA} = \frac{20 \text{ cm}}{2 \text{ cm}} = 10$$

$$MA = \frac{L}{E}$$

$$L = 30 \text{ kgf}$$

$$\therefore \quad E = \frac{L}{MA} = \frac{30}{10} = 3 \text{ kgf}$$

5.

$$EA = 18 \text{ cm}$$

$$LA = 2 \text{ cm}$$

$$\text{Effort } (E) = 3 \text{ kgf}$$

$$\text{Load } (L) = ?$$

$$MA = \frac{EA}{LA} = \frac{18 \text{ cm}}{2 \text{ cm}} = 9$$

$$MA = \frac{L}{E} = 9$$

$$\therefore \quad L = 9 \times E = 9 \times 3 = 27 \text{ kgf}$$

6.

$$\text{Effort } (E) = 3 \text{ kgf}$$

$$\text{Load } (L) = 30 \text{ kgf}$$

$$MA = \frac{L}{E} = \frac{30}{3} = 10$$

$$LA = 2 \text{ cm}$$

$$\therefore \quad EA = ??$$

$$MA = \frac{EA}{LA}$$

$\therefore \quad EA = MA \times LA$

$= 10 \times 2 = 20$ cm

7. Effort (E) = 8 kgf

$d_E = 60$ cm

Load (L) = 80 kgf

$d_L = 4$ cm

a. Velocity ratio $VR = \frac{d_E}{d_L} = \frac{60 \text{ cm}}{4 \text{ cm}}$

$VR = 15$

b. $MA = \frac{L}{E} = \frac{80 \text{ kgf}}{8 \text{ kgf}} = 10$

c. $\eta = \frac{MA}{VR} \cdot 100\% = \frac{10}{15} \cdot 100$

$= 66.67\%$

8. $L = 300$ N

$E = 100$ N

$d_L = 0.12$ m

$d_E = 0.48$ m

a. $VR = \frac{d_E}{d_L} = \frac{0.48 \text{ m}}{0.12 \text{ m}} = 4$

b. $MA = \frac{L}{E} = \frac{300}{100} = 3$

c. $\eta = \frac{MA}{VR} \times 100 = \frac{3}{4} = 75\%$

9. $LA = 2$ cm

Effort (E) = 6 kgf

$EA = 5.5$ cm

$L = ??$

$MA = \frac{EA}{LA} = \frac{5.5}{2} = 2.75$

$MA = \frac{L}{E} = 2.75$

$\therefore \quad L = 2.75 \times 6 = 16.5$ kgf

10. $\eta = 5$ (pulley)

$\eta = 75\%$

$\therefore \quad VR = 5$

a. $MA = \eta \times VR$

$= 0.75 \times 5$

$= 3.75$

b. $L = 875$ N

$E = ??$

$E = \frac{L}{MA} = \frac{875}{3.75} = 233.34$ N

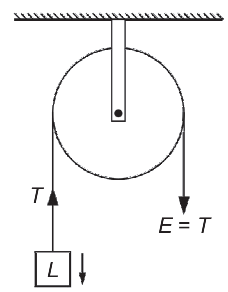
c. Resistance of movable parts is

$5 \times 233.34 - 875 = 291.65$ N

11. $L = 90$ N

$E = 100$ N

a.



b. $VR = \frac{d_E}{d_L} = 1$

c. $MA = \frac{L}{E} = \frac{90}{100} = 0.9$

d. $\eta = \frac{MA}{VR} \cdot 100\% = \frac{0.9}{1} \times 100\% = 90\%$

CHAPTER – 4

REFRACTION OF LIGHT

Check Your Progress 1 (Page 72)

A. **1.** a **2.** a **3.** c **4.** c **5.** d

6. d **7.** b **8.** c **9.** a

10. **a.** ii **b.** iii **c.** i **d.** ii

B. **1.** The bending of light when it passes obliquely from one transparent medium to another is called refraction of light.

2. The subjective property of light related to its wavelength is colour.

3. **a.** **Angle of incidence:** The angle between the incident ray and the normal is called angle of incidence.

b. **Angle of refraction:** The angle between the refracted ray and the normal is called angle of refraction.

c. **Rarer medium:** A medium in which the speed of light is more is known as an optically rarer medium.

d. **Denser medium:** A medium in which the speed of light is less is known as an optically denser medium.

4. The cause of refraction is that the speed of light is different for two media.

5. If the incident ray is travelling through vacuum and is then refracted in a medium then the ratio sin *i*/sin *r* is called the absolute refractive index of that medium.

6. Absolute refractive index of a medium is ratio of velocity of light in vacuum to the velocity of light in the medium. Since the velocity of light is maximum in vacuum. Hence, absolute refractive index of a medium can never be less than one.

7. Angle of incidence is equal to 0° as the angle between the normal and incident ray is zero.

8. Ordinary glass is optically rarer because its refractive index is lower than that of diamond.

9. The speed of light is more in glass because it is optically rarer and hence, the speed of light in it will be more than that of diamond.

10. **a.** Refer Figure 4.2, Page 65 of the textbook.

b. Refer Figure 4.3, Page 66 of the textbook.

11. According to the principle of reversibility of light, if a reflected or refracted ray is reversed in direction it will retrace its original path.

12. Refer Figure 4.5, Page 69 of the textbook.

13. $$^1\mu_2 = \frac{1}{^2\mu_1}$$

$$\therefore \quad ^2\mu_1 = \frac{1}{^1\mu_2} = \frac{1}{5/6} = \frac{6}{5}$$

14. Refer Figure 4.7, Page 71 of the textbook.

Now,

By applying Snell's law of refraction at point B, we get

$$^{glass}\mu_{air} = \frac{\sin i_2}{\sin r_2} \qquad \text{...(i)}$$

By applying Snell's law of refraction at point O, we get

$$^{air}\mu_{glass} = \frac{\sin i_2}{\sin r_1} \qquad \text{...(ii)}$$

Multiplying equations (i) and (ii), we get

$$^{air}\mu_{glass} \times {}^{glass}\mu_{air} = \frac{\sin i_1}{\sin r_1} \times \frac{\sin i_2}{\sin r_2}$$

But $^{air}\mu_{glass} \times {}^{glass}\mu_{air} = 1$ (Principle of reversibility of light)

$$\frac{\sin i_1}{\sin r_1} \times \frac{\sin i_2}{\sin r_2} = 1$$

Now, $\angle r_1 = \angle i_2$ (alternate angles, NN′ || MM′)

$$\therefore \quad \frac{\sin i_1}{\sin r_2} = 1$$

$$\sin i_1 = \sin r_2$$

$$\angle i_1 = \angle r_2$$

Since, angle of emergence (r_2) is equal to the angle of incidence (i_1), therefore, emergent ray of light is parallel to incident ray of light.

15. Refer Experiment 1, Page 69–70 of the textbook.

Refer Figure 4.6, Page 69 of the textbook.

16. **a.** The light bends when it passes obliquely from one transparent medium to another because the speed of light is different in the two media.

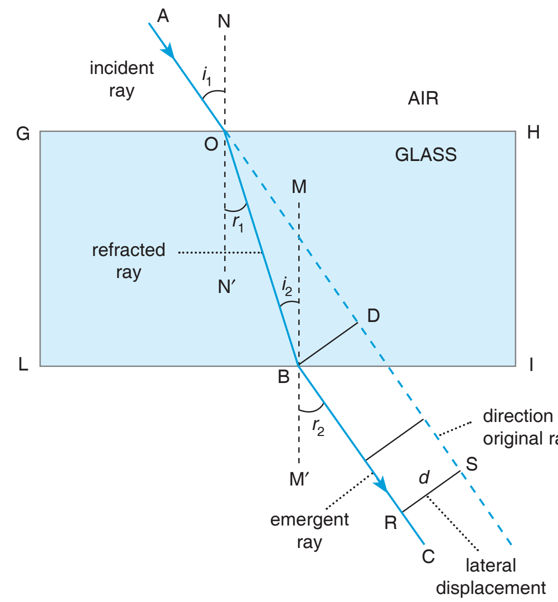
b. Refractive index has no unit because it is a ratio of two similar quantities. It is a pure number.

c. Glass is optically denser than water because the speed of light in glass is less than the speed of light in water.

d. No single value can be given for the refractive index of all types of glasses because different types of glasses have different chemical compositions due to which speed of light is different in different types of glasses.

e. The refractive index of a material for violet light is greater than that for red light because the wavelength of violet colour is less than that of red colour and the refractive index increases with decrease in wavelength.

f. The emergent ray of light is parallel to the incident ray of light because the angle of emergence is equal to the angle incidence.



17. a. Lateral displacement

Lateral displacement is the perpendicular distance between the incident ray and the emergent ray.

b. i. increases **ii.** Decreases

C. 1. $^{air}\mu_{water} = 1.33$

$^{air}\mu_{glass} = 1.5$

$^{water}\mu_{glass} = \frac{^{a}m_{g}}{^{a}m_{w}} = \frac{1.5}{1.33}$

$^{w}\mu_{g} = 1.13$

2. Speed of light in crown glass = 2×10^8 m/s

$$^{air}\mu_{crown\ glass} = \frac{\text{Speed of light in air}}{\text{Speed of light in crown glass}}$$

$$= \frac{3 \times 10^8}{2 \times 10^8} = 1.5$$

3. $^{a}\mu_{w} = 1.33$

Speed of light in air = 3×10^8 m/s

Speed of light in water = ?

$$^{a}\mu_{w} = \frac{\text{Speed of light in air}}{\text{Speed of light in water}}$$

$$\text{Speed of light in water} = \frac{\text{Speed of light in air}}{^{a}\mu_{w}}$$

$$= \frac{3 \times 10^8}{1.33}$$

$\therefore$ Speed of light in water = 2.26×10^8 m/s

4. $^{a}\mu_{g} = 1.6$

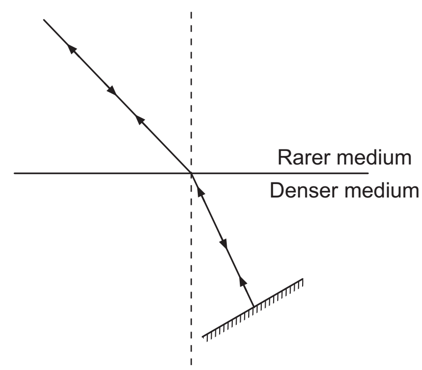
$$^{g}\mu_{a} = \frac{1}{^{a}\mu_{g}} = \frac{1}{1.6}$$

$$^{g}\mu_{a} = 0.625$$

Questions Based on ICSE Examination (Page 74)

1. Ray 2

2. a.



b. Principle of reversibility of light.

3. a. When a light travels from rarer medium to denser medium, it bends towards the normal.
Refer Figure 4.2, Page 64 of the textbook.

b. When a light travels from denser medium to rarer medium, it bends away from the normal.
Refer Figure 4.3, Page 65 of the textbook.

4. First law of refraction: The incident ray, the refracted ray and the normal at its point of incidence, all lie in the same plane.

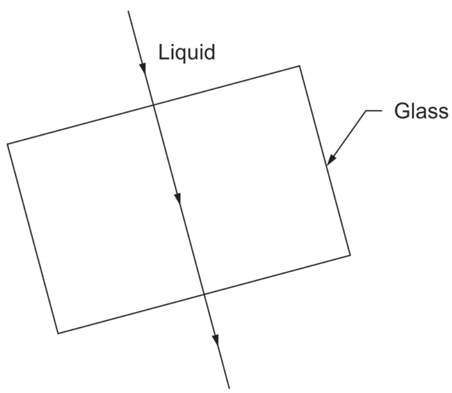
Second law of refraction of light: According to Snell's law of refraction of light, the ratio of sine of the angle of incidence to the sine of the angle of refraction is a constant for a given pair of media.

5. Factors affecting the refractive index of a medium
   - i. Nature of the material of the medium.
   - ii. Physical conditions.
   - iii. Wavelength of light used.
6. Refer Figure 4.4, Page 65 of the textbook.
7. **a.** The speed of light in vacuum is 3×10^8 m/s. For both the colours of light, the speed in vacuum is the same.

   b. The red colour light has greater wavelength. Hence, in glass, red light has a greater speed.
8. **a.** Speed of light decreases as it enters the glass.

   b. 0°

   c.



   d. $\dfrac{\text{Speed of light in liquid}}{\text{Speed of light in glass}} = 1$

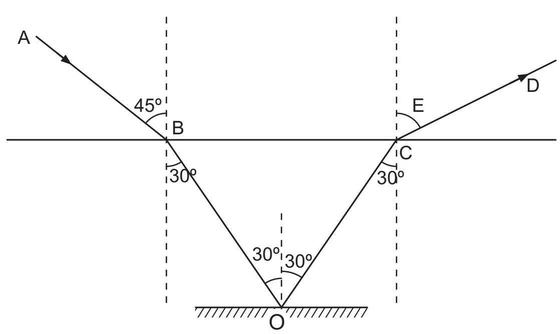
9. $\dfrac{\sin i}{\sin r} = {}^{i}\mu_g$

   a. Refer Figure 4.7, Page 71 of the textbook.

   b. $\angle i_1 = \angle r_2$

   Angle of incidence = Angle of emergence.

10. **a.**



   b.
$$\mu_{liquid} = \frac{\sin i}{\sin r} = \frac{\sin 45}{\sin 30} = \frac{1/\sqrt{2}}{2/\sqrt{2}} = \frac{2}{\sqrt{2}} = \sqrt{2} = 1.414$$

11. Red colour
12. The refractive index of a medium with respect to air (or vacuum) is called the absolute refractive index of a medium.
13. The perpendicular distance between the original path of the incident ray and the emergent ray coming out of the glass slab is called the lateral displacement of the incident light when it gets refracted through a rectangular glass slab.

    Lateral displacement depends on following factors:
    - i. Lateral displacement is directly proportional to the thickness of glass slab.
    - ii. Lateral displacement is directly proportional to the incident angle.
14. Given: ${}_a\mu_w = \dfrac{5}{3}$

    Since, ${}_w\mu_a = \dfrac{1}{{}_a\mu_w}$, ${}_w\mu_a = \dfrac{3}{5}$
15. ${}^{a}\mu_g = 1.5$

    Velocity of light in air = 3×10^8 m/s

    Velocity of light in glass = ?

$$\frac{\text{Speed of light in air } (C_a)}{\text{Speed of light in glass } (C_g)} = {}^{a}\mu_g$$

$$\frac{3 \cdot 10^8}{C_g} = 1.5$$

or $$C_g = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ m/s}$$

    Speed of light in glass = 2×10^8 m/s
16. Speed of light in air = 3×10^8 m/s

    Speed of light in diamond = 1.2×10^8 m/s

$$\therefore \quad \mu_{diamond} = \frac{\text{Speed of light in air}}{\text{Speed of light in diamond}} = \frac{3 \times 10^8}{1.2 \times 10^8}$$

$$\mu_{diamond} = 2.5$$

Check Your Progress 2 (Page 79)

A. **1.** b **2.** c **3.** b **4.** b **5.** b
6. c **7.** a **8.** a

B. **1.** A simple prism is a homologous transparent refracting medium bounded by at least two non-parallel plane surfaces inclined at some angle.

2. Refer Figure 4.13, Page 76 of the textbook.

3. The angle between the emergent ray and the direction of the incident ray is called the angle of deviation.

4. Refer Figure 4.14, Page 77 of the textbook.

According to Snell's law,

$$^{w}\mu_a = \frac{\sin\ i}{\sin\ r} \qquad \text{...(i)}$$

From ΔAOC,

$$\sin i = \frac{AC}{OC}$$

From ΔAIC,

$$\sin r = \frac{AC}{IC}$$

Substituting the values of sin *i* and sin *r* in equation (i), we get

$$^{w}\mu_a = \frac{\frac{AC}{OC}}{\frac{AC}{IC}} = \frac{AC}{OC}\times\frac{IC}{AC} = \frac{IC}{OC}$$

Since point C lies very close to A, so,

$$IC = AI \text{ and } OC = AO$$

$$^{w}\mu_a = \frac{AI}{AO}$$

Since, $\quad ^{a}\mu_w = \frac{1}{^{w}\mu_a}$

[Principle of reversibility of light]

$$\therefore \quad ^{a}\mu_w = \frac{AO}{AI} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

In general,

$$^{1}\mu_2 = \frac{\text{Real depth}}{\text{Apparent depth}}$$

5. Refer Experiment 2, Page 78 of the textbook.
   Refer Figure 4.15, Page 78 of the textbook.

6. a. The equilateral prism (A = 60°) produces a greater deviation than the Porro prism (A = 45°) because the angle of deviation increases with increase in the angle of prism.

   b. A flint glass having μ = 1.62 produces a greater deviation than the crown glass having μ = 1.53 because the angle of deviation increases with the increase in the refractive index of the prism.

   c. On entering the prism, the violet light (λ = 4000 Å) is diverted more than the red light (λ = 8000 Å) because the angle of deviation decreases with increase in wavelength of light.

7. a. Angle of minimum deviation = 37°
   corresponding angle of incidence = 46°

   b. by similarity $x = (46^\circ - 40^\circ) + 46^\circ = 52^\circ$

C. 1. Depth of coin = 12 cm

$$\mu_{water} = \frac{4}{3}$$

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$\text{Apparent depth} = \frac{\text{Real depth}}{\mu_{water}}$$

$$= \frac{12}{4/3}$$

$$= \frac{12\times 3}{4} = 9 \text{ cm}$$

The coin is raised through a height of 3 cm.

(Real depth – Apparent depth)

2. Apparent depth of pool = 2.7 m

$$\mu_{water} = \frac{4}{3}$$

$$\text{Real depth} = \text{Apparent depth} \times \mu_{water}$$

$$= \frac{4}{3}\times 2.7 = 3.6 \text{ m}$$

3. Real depth = 2.8 m

Apparent depth = 2.1 m

μ_{water} = ?

$$\mu_{water} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$= \frac{2.8}{2.1} = \frac{4}{3}$$

QUESTIONS BASED ON ICSE EXAMINATION (PAGE 80)

1. Refer Figure 4.11, Page 76 of the textbook.

2. Determination of the angle of deviation

   At surface AB of the prism, the incident ray PQ is deviated along QR.

   From Figure 4.11,

$$\angle OQR = \angle OQE - \angle RQE$$

   or $\quad \delta_1 = i - r_1 \qquad$ ... (i)

   δ_1 is the deviation produced by the surface AB of the prism.

   Similarly, at surface AC, the ray QR is deviated along RS.

   So, $\quad \delta_2 = e - r_2 \qquad$ ... (ii)

   δ is the deviation produced by the surface AC of the prism.

   $\therefore$ Total angle of deviation $\delta = \delta_1 + \delta_2 \qquad$ ... (iii)

[Exterior angle of a triangle is equal to the sum of the two interior opposite angles.]

$\therefore \quad \delta = i - r_1 + e - r_2$ [From (i) and (ii)]

$\delta = (i + e) - (r_1 + r_2)$ ... (iv)

From quadrilateral AQER,

$\angle A + \angle AQE + \angle QER + \angle ERA = 360°$ ...(v)

But $\angle AQE = \angle ERA = 90°$

[Angles made by normal]

$\therefore \quad \angle A + 90° + \angle QER + 90° = 360°$

or $\angle A + \angle QER + 180° = 360°$

or $\angle A + \angle QER = 360° - 180°$

$= 180°$ ...(vi)

From ΔQER,

$r_1 + \angle QER + r_2 = 180°$ ...(vii)

From equation (vi) and (vii), we get

$\angle A + \angle QER = r_1 + \angle QER + r_2$

$\angle A = r_1 + r_2$ ... (viii)

Substituting the value of equation (viii) in equation (iv), we get

$\delta = i + e - \angle A$

or $\boxed{\delta + \angle A = i + e}$

3. Factors affecting the angle of deviation are:

   i. Dependence of the angle of deviation on the angle of incidence: As the angle of incidence increases, the angle of deviation first decreases, becomes minimum for a particular angle of incidence and then again increases.

   ii. Dependence of the angle of deviation on the angle of prism: The angle of deviation increases with the increase in the angle of prism.

   iii. Dependence of the angle of deviation on the refractive index of the prism material: The angle of deviation increases with the increase in the refractive index of the prism material.

   iv. Dependence of the angle of deviation on the wavelength of light: The angle of deviation decreases with the increase in the wavelength of light.

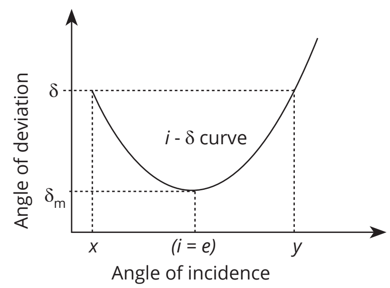
4. In rectangular glass slab, the emergent ray is parallel to the original path of the incident ray while in the triangular prism, the emergent ray is not parallel to the incident ray. This happens because the refracting surfaces in rectangular glass slab are parallel whereas in triangular glass prism, they are incident at an angle.

5. a. $\mu_{medium} = \dfrac{\text{Real depth}}{\text{Apparent depth}}$

b. Refractive index is the ratio of the velocity of light in vacuum to the velocity of light in a medium.

$$\mu = \frac{c}{v}$$

6. a. As the angle of incidence (i) increases, the angle of deviation (δ) first decreases, becomes minimum for a particular angle of incidence and then again increases.



Check Your Progress 3 (Page 83)

A. 1. b **2.** b **3.** b **4.** b **5.** c

6. a. ii b. i

B. 1. a. A straight stick appears to be bent when immersed in water because when a ray travels from an optically denser medium to a rarer medium, it bends away from normal. Refer Figure 4.16, Page 80 of the textbook.

b. A coin placed at the bottom of a vessel full of water appears to be raised. Rays like CP and CQ cannot reach the eye, so the coin was not visible. A ray of light, CB coming from the lower end C of the coin passes from water into air at a point B and gets refracted away from the normal in the direction BP′. Another ray of light, CD gets refracted in the direction DQ′. These refracted rays BP′ and DQ′ reach the eye of the observer who sees the coin raised to C′. Refer Figure 4.17(b), Page 81 of the textbook.

c. The sun is visible two minutes before the actual sunrise and two minutes after the actual sunset because the light rays coming from the sun, on entering the earth's atmosphere suffer atmospheric refraction from a rarer medium to a denser medium so they bend towards the normal at each refraction. Refer Figure 4.18, Page 82 of the textbook.

d. The stars seem to be higher than they actually are because of atmospheric radiation of light rays coming from them. Refer Figure 4.19, Page 82 of the textbook.

e. The twinkling of stars is due to the atmospheric refraction. When the atmosphere refracts more starlight towards us, the intensity of starlight is increased and the star appears to be bright. When the atmosphere refracts less starlight, the intensity of the starlight is decreased and the star appears to be dim. In this way, the amount of starlight reaching our eyes increases and decreases continuously. This causes the stars to be twinkling at night. On the other hand, planets do not twinkle at all because the continuously changing atmosphere is unable to cause variations in the light rays coming from a big sized planet.

f. In the morning and evening, the sun is near the horizon. The refractive index of the layers of the atmosphere decreases with the height. The rays of light from the lower edges of the sun are refracted more than those from the upper edges, due to the passage through great thickness of air. In other words, the rays of light from the upper and the lower edges of the sun bends unequally. Due to this unequal bending of light, the image of the sun appears oval and larger in size. Refer Figure 4.20, Page 82 of the textbook.

Questions Based on ICSE Examination (Page 83)

1. Refer Figure 4.17(b), Page 81 of the textbook.

2. Its depth remains the same because there is no refraction taking place when viewed normally above as the angle of incidence is zero and therefore angle of refraction is also zero which means no refraction took place.

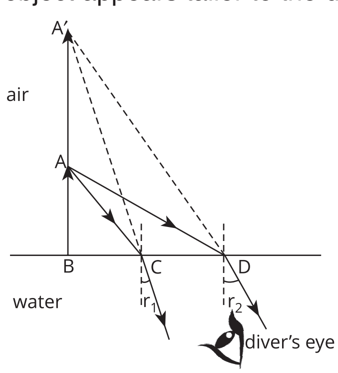
3. **a.** The pencil appears to be raised and bent at a point on the surface of water.

b. Refraction of light.

c. Refer Figure 4.16, Page 80 of the textbook.

4. **a.** The object appears taller to the diver.

b.



Check Your Progress 4 (Page 90)

A. **1.** b **2.** c **3.** d **4.** a

5. b **6.** a. ii b. iv c. iii

B. **1.** The critical angle for ordinary glass is about 42° with respect to air. This means that when the angle of incidence of a ray of light in glass is 42°, the angle of refraction in air is 90°.

2. When a ray of light goes from a denser medium to a rarer medium then according to Snell's law, we have,

$$^{2}\mu_{1} = \frac{\sin i}{\sin r}$$

For the incident ray A″O moving from a denser medium to a rarer medium, the angle of refraction is 90° and the refracted ray is parallel to the glass-air interface. Thus, $i = i_c$ = critical angle and $r = 90°$.

$$^{2}\mu_{1} = \frac{\sin i_c}{\sin 90°}$$

$$^{2}\mu_{1} = \sin i_c \qquad [\because \sin 90° = 1]$$

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

$$\therefore \quad \sin i_c = \frac{1}{^{1}\mu_{2}}$$

$$\text{or} \quad ^{1}\mu_{2} = \frac{1}{\sin i_c}$$

$$\text{or} \quad ^{1}\mu_{2} = \text{cosec } i_c$$

3. The factors affecting critical angle are as follows:

i. **Colour (or wavelength) of light:** Greater the wavelength of light, greater will be the critical angle for a pair of media.

ii. **Nature of the pair of media:** Greater the refractive index, lesser will be the critical angle.

iii. **Temperature:** On increasing the temperature, its refractive index increases so critical angle increases.

4. A prism having an angle of 90° between two refracting surfaces and the other two angles being equal to 45°, is called a total reflecting prism.

A total reflecting prism is used for the following purposes:

i. to deviate a ray of light through 90°.

ii. to deviate a ray of light through 180°.

iii. to erect the inverted image without deviation.

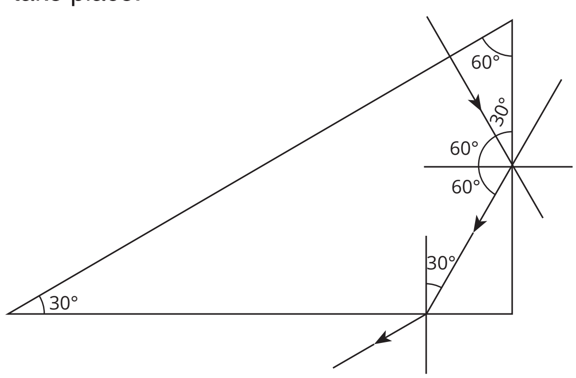
5. Refer Figure 4.25, Page 86 of the textbook.

6. a. The refractive index of diamond in very high (approximately 2.42). Therefore, the critical angle for diamond-air interface is very low, about 24°. The faces of a diamond are cut in such a way that once a ray of light enters into it, the angle of incidence is greater than the critical angle. So a ray of light entering the diamond suffers repeated total internal reflection at a large number of faces.

   b. The critical angle for water-air interface is 48°. When the light rays propagating in water (denser medium) is incident on the surface of the air bubble (rarer medium) at an angle greater than 48°, total internal reflection takes place. Hence, the air bubble in water shines brightly.

   c. An inverted image of a distant object is observed along with the object itself on a hot day in a desert due to the total internal reflection.

7. 60° > 42° therefore total internal reflection will take place.



30° < 42° therefore ray will come out of the prism.

Questions Based on ICSE Examination (Page 91)

1. The critical angle for a medium is the angle of incidence in the denser medium for which the angle of refraction in the rarer medium is 90°.

2. Two advantages of a right-angled glass prism over the plane mirror as a reflector are as follows:

   i. In a right-angled glass prism, reflection is complete while in a plane mirror the reflection is partial.

   ii. In a right-angled glass prism, there is no loss of intensity of light and the images formed are much brighter. While in mirror there will be some loss of intensity in light and the images formed are less bright.

3. **Reflection from plane mirror**

   i. Reflection is partial. Some light is reflected or absorbed incident by the surfaces of separation.

   ii. It produces a virtual image.

   Reflection from total internal reflecting prism

   i. Reflection is complete. The entire (i.e. 100%) light is reflected back into denser medium.

   ii. It produces a real image.

4. The two basic conditions that must be fulfilled so that total internal reflection of light may take place are as follows:

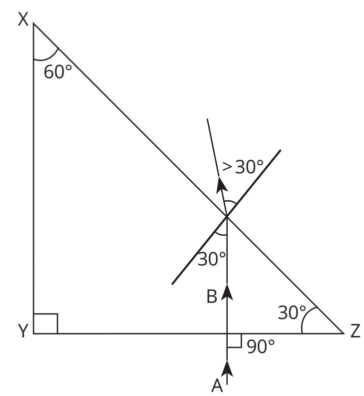
   i. The incident light must pass from a denser medium into a rarer medium.

   ii. The angle of incidence in denser medium must be greater than the critical angle for the given pair of media.

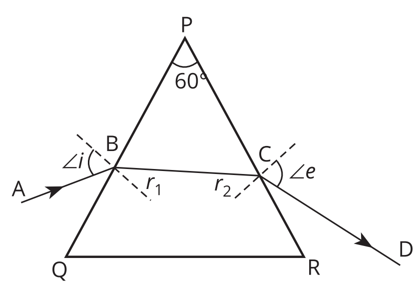
5. a. Refer Figure 4.23(a), Page 86 of the textbook.

   b. Refer Figure 4.24(a), Page 86 of the textbook.

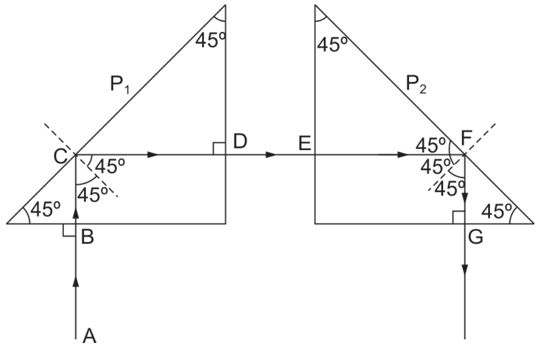
6. The following diagram shows a 60°, 30°, 90° glass prism of critical angle 42°.



7.

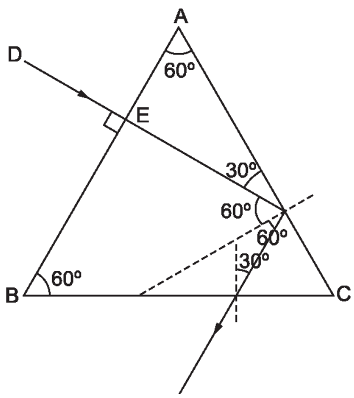


8.

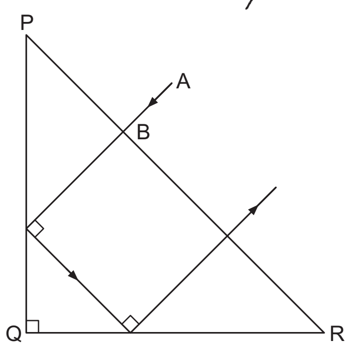


b. Total internal reflection.

9.



10. a.



b. Angle of deviation of the ray = 180°

c. Prism binoculars.

EXERCISES

Questions Based on ICSE Examination (Page 92)

1. The ratio of sine of the angle of incidence to the sine of the angle of refraction is a constant for given pair of media. This is also called Snell's law.

2. If the incident ray is travelling through medium 1 and is then refracted in a medium 2, then the ratio of velocity of light in medium 1 to velocity of light in medium 2 gives the refractive index of medium 2 with respect to medium 1.

3. $^{water}\mu_{glass} = \dfrac{^{air}\mu_{glass}}{^{air}\mu_{water}}$

$$= \frac{3/2}{4/3} = \frac{3\times3}{4\times2} = \frac{9}{8} = 1.125$$

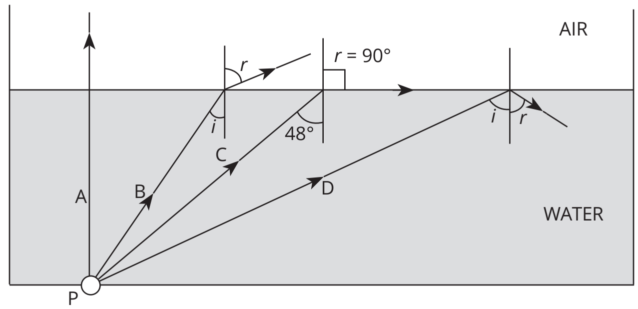
4. Greater the wavelength of light, greater will be the critical angle. Thus, red light has a higher critical angle as it has longer wavelength than green light.

5. Refer Figure 4.12, Page 76 of the textbook.

6. a. greater than 45°

b. less than 45°

7. a. Path of the rays after striking the water surface is shown below:



b. Ray B exhibits the phenomenon of refraction.

Ray D exhibits the total internal reflection.

8. a. $^{g}\mu_{a} = \dfrac{\sin r}{\sin i}$

b. critical angle.

c. It is the maximum angle below which the light will pass from a denser to a rarer medium and for any angle greater than the critical angle, total internal reflection will take place.

9. Refer Figure 4.16, Page 80 of the textbook.

10. Real depth = 2.5 cm

$$^{a}\mu_{g} = \frac{3}{2}$$

$$^{a}\mu_{g} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$\therefore \text{ Apparent depth} = \frac{\text{Real depth}}{^{a}\mu_{g}}$$

$$= \frac{2.5}{3/2} = 1.67 \text{ cm}$$

$\therefore$ Rise in height = Real depth – Apparent depth

= 2.5 – 1.67 = 0.83 cm

11. Diagram 1—Refer Figure 4.11, Page 76 of the textbook.

Angle of deviation depends upon

i. angle of prism

ii. angle of incidence

12. **a.** Diagram 2—Refer Figure 4.24(b), Page 86 of the textbook.

b. Such a prism is used in binoculars.

13. Refer Figure 4.16, Page 80 of the textbook.

14. When the angle of incidence of a ray of light travelling in a denser medium is greater than the critical angle for the pair of media, then there is no refraction of light into the rarer medium and the ray is reflected back into the same denser medium. This phenomenon is called total internal reflection.

The conditions necessary for total internal reflection are:

i. The incident light must pass from denser medium, to rarer medium.

ii. The angle of incidence in the denser medium must be greater than the critical angle for the given pair of media.

Additional Numericals (Page 93)

1. Angle of incidence (i) = 48°

Angle of refraction (r) = 35°

$$\mu = \frac{\sin i}{\sin r}$$

$$= \frac{\sin 48}{\sin 35} = \frac{0.684}{0.522} = 1.31$$

2. $\mu = 1.35$

Speed of light in vacuum = 3×10^8 m/s

Speed of light in medium = ?

$$\text{Speed of light in medium} = \frac{\text{Speed in vacuum}}{\mu}$$

$$= \frac{3\times10^8}{1.35} = 2.22 \times 10^8 \text{ m/s}$$

3. $^{a}\mu_{w} = 1.5$

$$^{w}\mu_{a} = \frac{1}{^{a}m_{w}} = \frac{1}{1.5}$$

$$^{a}\mu_{w} = 0.67$$

4. Here, $^{air}\mu_{medium} = 1.85$

$^{air}\mu_{liquid} = 1.25$

$^{liquid}\mu_{medium}$ = ? (to be calculated)

$$^{liquid}\mu_{medium} = {}^{air}\mu_{medium} \times {}^{liquid}\mu_{air}$$

$$= {}^{air}\mu_{medium} \times \frac{1}{^{air}\mu_{liquid}}$$

$$= 1.85 \times \frac{1}{1.25} = \frac{1.85}{1.25} = 1.48$$

So, the refractive index of the transparent medium with respect to that liquid is 1.48.

5. Here,

let the thickness of the glass block = t mm

∴ Apparent thickness = (t – 5) mm

$\mu = 1.5$

We know that,

$$\mu = \frac{\text{Real thickness}}{\text{Apparent thickness}}$$

$$1.5 = \frac{t}{t - 5}$$

$$1.5(t - 5) = t$$

$$1.5t - 7.5 = t$$

$$1.5t - t = 7.5$$

$$0.5t = 7.5$$

$$t = \frac{7.5}{0.5}$$

$$t = 15 \text{ mm}$$

So, the thickness of the glass block is 15 mm.

6. Here,

Refractive index of a material = 1.5

Velocity of light in vacuum= 3×10^8 ms^{-1}

Velocity of light in the material = ?

(to be calculated)

We know, refractive index,

$$\mu = \frac{\text{Velocity of light in vacuum}}{\text{Velocity of light in material}}$$

Putting the given values in the above equation, we get

$$1.5 = \frac{3 \cdot 10^8 \text{ ms}^{-1}}{\text{Velocity of light in material}}$$

∴ Velocity of light in material

$$= \frac{3\times10^8 \text{ms}^{-1}}{1.5} = 2 \times 10^8 \text{ ms}^{-1}$$

So, the velocity of light in material is 2×10^8 ms^{-1}.

7. Here,

Velocity of light in air = 3×10^8 m s^{-1}

Velocity of light in flint glass = 2.25×10^8 ms^{-1}

Refractive index of flint glass = ?

(to be calculated)

We know

$$^{air}\mu_{flint\ glass} = \frac{\text{Velocity of light in air}}{\text{Velocity of light in glass}}$$

$$^{air}\mu_{flint\ glass} = \frac{3 \times 10^8\ ms^{-1}}{2.25 \times 10^8\ ms^{-1}}$$

$$= 1.33$$

So, the refractive index of flint glass is 1.33.

8. Here,

Velocity of light in air = 3×10^8 ms^{-1}

Refractive index of glass = 1.5

Velocity of light in glass = ? (to be calculated)

We know $\quad ^{air}\mu_{glass} = \dfrac{\text{Velocity of light in air}}{\text{Velocity of light in glass}}$

Putting the given values in the above equation, we get

$$1.5 = \frac{3 \times 10^8 ms^{-1}}{\text{Velocity of light in glass}}$$

$$\therefore \text{ Velocity of light in glass} = \frac{3 \times 10^8 ms^{-1}}{1.5}$$

$$= 2 \times 10^8\ ms^{-1}$$

So, the velocity of light in glass is 2×10^8 ms^{-1}.

9. Here,

Refractive index of the glass = 1.5

Real depth (of the glass block) = 3 cm

Apparent depth = ? (to be calculated)

We know, $\quad \mu = \dfrac{\text{Real depth}}{\text{Apparent depth}}$

$$1.5 = \frac{3}{\text{Apparent depth}}$$

$$\therefore \quad \text{Apparent depth} = \frac{3}{1.5} = 2 \text{ cm}$$

So, the height through which the image of the stamp is raised = (3 – 2) cm = 1 cm.

10. Here,

Refractive index of water = 1.33

Real depth of coin = 10 cm

Apparent depth of coin = ? (to be calculated)

We know, $\quad \mu = \dfrac{\text{Real depth}}{\text{Apparent depth}}$

$$1.33 = \frac{10}{\text{Apparent depth}}$$

$$\text{Apparent depth} = \frac{10}{1.33} = 7.52 \text{ cm}$$

So, the height through which the image of coin is raised = 10 – 7.52 = 2.48 cm

11. Here,

Apparent depth = 7.5 cm

Refractive index = 1.33

Real depth of water = ? (to be calculated)

We know,

$$\text{Refractive index, } \mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$1.33 = \frac{\text{Real depth}}{7.5}$$

$$\text{Real depth} = 7.5 \times 1.33$$

$$= 9.98 \text{ cm}$$

So, the actual depth of water is 9.98 cm.

12. Here,

Refractive index of glass = 1.5

Image of the stamp raised = 8.0 mm

Let the thickness of the glass block = x

$\therefore$ Apparent thickness = $x - 8.0$ mm

We know, Refractive index,

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}}$$

$$1.5 = \frac{x}{x - 8.0 \text{ mm}}$$

$$1.5\,(x - 8.0) \text{ mm} = x$$

$$1.5x - 12 \text{ mm} = x$$

$$1.5\,x - x = 12 \text{ mm}$$

$$0.5x = 12 \text{ mm}$$

$$x = \frac{12 \text{ mm}}{0.5}$$

$$x = 24 \text{ mm}$$

So, the actual thickness of glass slab is 24 mm.

CHAPTER – 5

REFRACTION THROUGH LENSES

Check Your Progress 1 (Page 98)

A. 1. c **2.** d **3.** c **4.** b **5.** b

B. 1. A lens is a piece of transparent, optical material bounded by two refracting surfaces which are usually spherical, or one surface being spherical and the other plane.

2. i. Concave lens

ii. Convex lens

3. The prism in the upper part of the lens bends the incident ray downwards while the prism in lower part of the lens bends the incident ray upwards. The centre part of the lens, which is just like a rectangular glass block, allows the incident ray to pass undeviated.

Refer Figure 5.3 on Page 95 of the textbook.

4. The prism in the upper part of the lens bends the incident ray upwards while the prism in the lower part of the lens bends the incident ray downwards. The central part of the lens passes the incident ray undeviated.

Refer Figure 5.4 on Page 95 of the textbook.

5.

Convex lens	Concave lens
It is a converging lens.	It is a diverging lens.
It has a real focus.	It has a virtual focus.
A parallel beam of A parallel beam of light passing through this lens through this lens converges at a point appears to diverge after refraction.	A parallel beam of light passing through this lens appears to diverge from a point after refraction.

6. a. Centre of curvature: It is defined as the centre of the spherical surface from which the lens has being cut.

b. Radius of curvature: It is the radius of the sphere of which the lens surface is a part.

c. Principal axis: The line joining the centres of curvature of two refracting surfaces of the lens is called the principal axis of the lens.

d. Optical centre: The geometrical centre of the lens is called optical centre.

e. Principle focus: As the lens is made up of transparent material, therefore, light can pass through it in both directions. As a result, there are two principle foci at equal distances from the optical centre provided the medium on either side of the lens is same.

f. Focal length: The distance between the optical centre and the focal point.

Refer Figures 5.5(a) and (b), Page 96 of the textbook.

7. Real focus: In a convex lens, the parallel beam of light travelling parallel to the principal axis actually meets at a point called the real focus.

Virtual focus: In a concave lens, the parallel beam of light travelling parallel to the principal axis appear to diverge from a point called the virtual focus.

8. a. Refer Figure 5.12 on Page 98 of the textbook.

b. Refer Figure 5.13 on Page 98 of the textbook.

9. a. Refer Figure 5.6 on Page 96 of the textbook.

b. Refer Figure 5.6 on Page 96 of the textbook.

Questions Based on ICSE Examination (Page 99)

1. A ray of light incident on the optical centre of a thin lens passes through it underrated.

2. a. Convex lens

b. Refer Figure 5.3, on Page 95 of the textbook.

c. Principal axis.

d. Rays will meet XX′ at a point F. This point is called principal focus. The distance OF is called focal length of the lens.

e. It is also called a converging lens as it converges the parallel beam of light at a point.

3. a. Concave lens

b. Refer Figure 5.4 on Page 95 of the textbook.

c. XX′ is called principal axis.

d. The final emergent rays appear to meet from a point XX′. This point is called principal focus. The distance OF is called focal length of the lens.

e. It is also called a diverging lens as it diverges the parallel rays of light and the divergent rays appear as if they are coming from a point.

4. a. If a lens is placed in water instead of air, its focal length will increase.

b. Thin lens has greater focal length.

Check Your Progress 2 (Page 103)

A. 1. c **2.** d **3.** d **4.** a **5.** b

6. c

B. 1. a. Convex lens

Concave lens cannot form image on screen

b. Yes.

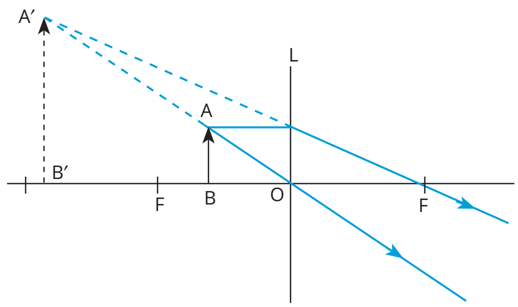
2. a. It is concave lens because only concave lens makes virtual and diminished image.

b.
$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$
$$\frac{1}{f} = \frac{1}{15} - \frac{1}{-50}$$
$$= \frac{-20+6}{300} = \frac{-14}{300}$$
$$\Rightarrow \quad f = \frac{300}{-14} = \frac{-150}{7}$$
$$= -21\frac{3}{7} \text{ cm}$$

In case of concave lens u and v both are negative.

3. a. It is converging (convex) lens.

b.



c. Simple microscope (Magnifying glass)

4. Refer Table 5.2 on Page 103 of the textbook.

5. a. Between focus and optical centre

b. At focus (F_1)

c. Between F_1 and $2F_1$ (Focus and centre of curvature)

d. At $2F_1$ (At centre of curvature)

e. Beyond $2F_1$ (Beyond centre of curvature)

f. At infinity

6. a. At infinity with rays parallel to each other and to principal axis

b. At centre of curvature (At $2F_1$)

c. At focus (At F_1)

d. At infinity and rays parallel to each other but not parallel to principal axis

e. Beyond centre of curvature (Beyond $2F_1$)

f. Between focus (F_1) and optical centre (O)

7. a. Given: $u = -12$ cm, $f = +8$ cm, we have the relation:
$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

After putting the values, we get, $v = 24$ cm

Hence, the image will be formed at 24 cm on the other side of the lens.

b. The image is inverted, real and magnified.

8. a. Refer Figure 5.24 on Page 103 of the textbook.

b. Refer Figure 5.25 on Page 103 of the textbook.

c. Refer Figure 5.26 on Page 103 of the textbook.

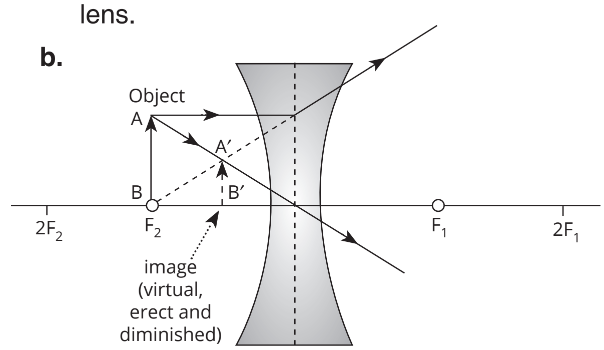
	Size	Nature	Position of image
a.	Diminished	Virtual, erect	At F_2, on the same side of lens as the object
b.	Highly diminished	Virtual, erect	On the same side of the lens as the object
c.	Diminished	Virtual, erect	Between optical centre (O) and focus (F_2), on the same side of the object

Questions Based on ICSE Examination (Page 105)

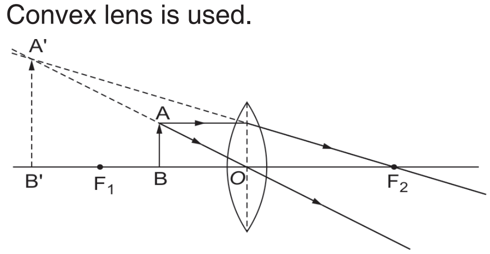
1. Convex lens

2. a. Concave lens. The image formed by the lens is virtual and between the object and the lens. Hence, the lens used is a concave lens.

b.



3. Convex lens is used.



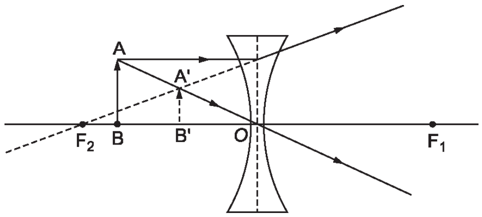
4. a. The object is beyond $2F_1$.

b. Refer Figure 5.21 on Page 101 of the textbook.

5. Refer Figure 5.17 on Page 100 of the textbook.

6. a. Concave lens

b.



7. Yes

Ray Diagram → Refer Figure 5.22 on Page 101 of the textbook.

8. Refer Figure 5.19 on Page 101 of the textbook.

9. No, it is not possible to obtain an image twice the size of the object. The image formed is always diminished regardless of the fact that object lies anywhere between infinity and the optical centre.

Check Your Progress 3 (Page 108)

A. 1. d 2. b 3. c 4. b 5. b

6. a 7. a. iv b. i c. ii d. iii

B. 1. The power of a lens is defined as the reciprocal of its focal length (in metres). The SI unit of power of a lens is dioptre.

2. Power of a lens depends upon its focal length.

3. One dioptre is the power of a lens whose focal length is 1 metre.

The power of a lens is measured by an instrument called dioptremeter.

4. a. Power of a concave lens is denoted with a negative sign.

b. Power of a convex lens is denoted with a positive sign.

5. The advantage of combination of lenses is that when a lens of greater power is used then instead of using one lens, two or more lenses of lesser power can be used.

They are used in instruments like camera, microscope, telescope, etc. A number of lenses are combined together to increase the sharpness of image.

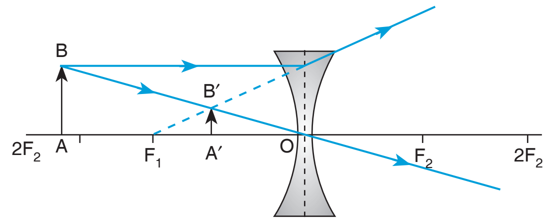
6. The magnifying power of a simple microscope is defined as the ratio of the angle subtended by the image at the eye to the angle subtended by the object at the eye, when placed at the least distance of distinct vision.

7. Magnifying power = $1 + \frac{D}{f}$ [When the image formed by a simple microscope is at least distance of distinct vision.]

8. The linear magnification is the ratio of the height of the image to the height of the object, i.e.

$$\text{Magnification} = \frac{\text{Height of the image}}{\text{Height off the object}}$$

9.



$$OF_1 = \text{focal length} = f$$

$$OA = \text{object distance} = u$$

$$OA' = \text{image distance} = v$$

ΔOAB and $\Delta OA'B'$ are similar

$$\angle BAO = \angle B'A'O$$

so $\angle AOB = \angle A'OB'$,

$\therefore$ $\angle ABO = \angle A'B'O$

$$\frac{A'B'}{AB} = \frac{OA'}{OA} \quad \text{...(i)}$$

ΔOCF_1 and $\Delta F_1A'B'$ are similar

$$\frac{A'B'}{OC} = \frac{A'F_1}{OF_1}$$

But from the ray diagram, we see that OC = AB

$$\frac{A'B'}{AB} = \frac{A'F_1}{OF_1} = \frac{OF_1 - OA'}{OF_1}$$

$$\frac{A'B'}{AB} = \frac{OF_1 - OA'}{OF_1} \quad \text{...(ii)}$$

From equation (i) and (ii) we get

$$\frac{OA'}{OA} = \frac{OF_1 - OA'}{OF_1}$$

$$\frac{-v}{-u} = \frac{-f - (-v)}{-f}$$

$$\frac{v}{u} = \frac{-f + v}{f}$$

$$-vf = -uf + uv$$

Divide the whole equation by uvf

$$\frac{-vf}{uvf} = \frac{-uf}{uvf} + \frac{uv}{uvf}$$

$$\frac{-1}{u} = \frac{-1}{v} + \frac{1}{f}$$

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

10. a. If magnification m has a positive value, the image is virtual and erect.

b. If magnification m has a negative value, the image is real and inverted.

11. Hold the lens near the page of a book and vary the distance between them.

i. If the words of the page appear enlarged or magnified on placing the lens near the book and inverted on increasing the distance between the lens and the book, then the given lens is a convex lens.

ii. If at every position, the words of the page appear diminished, then the given lens is concave lens.

12. a. In optical instruments like camera, microscope, telescope, etc., a number of lenses are combined together to increase the sharpness of the image.

b. The focal length of a convex lens in a simple microscope should be made as small as possible because shorter the focal length, larger would be the magnifying power of the simple microscope.

c. The magnifying power of a simple microscope can be increased only up to a certain limit because if a lens of very small focal length is used, the image formed will be distorted.

C. 1. Power of a lens = 2.5 D

Focal length (in metre)

$$= \frac{1}{\text{Power}} = \frac{1}{2.5} = 0.4 \text{ m or } 40 \text{ cm}$$

It is a convex lens since power is positive.

2. Focal length of concave lens = 50 cm = 0.5 m

$$\text{Power} = -\left(\frac{1}{f}\right) = -\frac{1}{0.5} = -2\,\text{D}$$

3. Power of 1st lens = + 3.5 D

Power of 2nd lens = – 2.5 D

$\therefore$ Net power of combination = $P = P_1 + P_2$

$$P = 3.5 - 2.5 = +1\,\text{D}$$

$\therefore$ Focal length = $\frac{1}{P} = \frac{1}{1}$ = 1 m = 100 cm

Questions Based on ICSE Examination (Page 109)

1. Hold the lens near the printed piece of paper and vary the distance between them.

i. If the words of the page appear enlarged on placing the lens near the book, then the given lens is convex lens.

ii. If at every position, the words of the page appear diminished, then the given lens is concave.

2. The power of a lens is defined as the reciprocal of its focal length (in metres)

$$P = \frac{1}{f \text{ (in metres)}}$$

3. f = 25 cm

$$= \frac{25}{100} \text{ m}$$

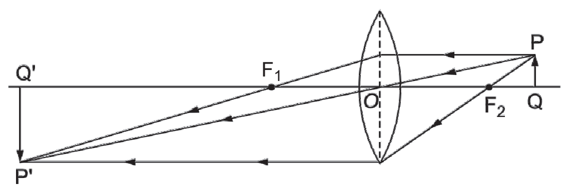
$$P = \frac{1}{f} = \frac{100}{25} = 4\,\text{D}$$

EXERCISES

Questions Based on ICSE Examination (Page 110)

1. If the incident ray is travelling through vacuum or air and is then refracted in a medium, then the ratio of sin i/sin r is called the refractive index of the medium with respect to air.

2.



3. $$\text{RI} = \frac{\text{Speed of light in air } (c)}{\text{Speed of light in medium } (v)}$$

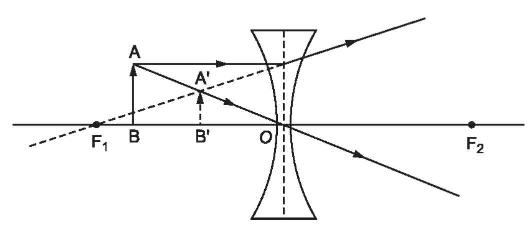
$$\therefore \quad v = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ m/s}$$

4. Optical fibre is a long, thin strand of very fine quality quartz glass (RI = 1.7) of about the diameter of human hair strand (radius of few microns).

Optical fibres are used in telecommunications for transmitting signals.

5. a. Concave lens

b.



6. a. Convex lens

b. Refer Figure 5.17, Page 100 of the textbook.

7. a. At $2F_1$

b. Refer Figure 5.20, Page 101 of the textbook.

Additional Numericals (Page 111)

1. $P = \dfrac{1}{f(\text{in metres})} = +4\,\text{D}$ (convex lens)

2. $P = \dfrac{1}{f}$ (in m) $= \dfrac{1}{-0.20} = -5\,\text{D}$ (concave lens)

3. $P = -10$ D

   $f = -\dfrac{1}{10} = -0.1$ m or -10 cm (concave lens)

4. Focal length of convex lens = 20 cm

   Focal length of concave lens = 10 cm

   a. Power of convex lens = $\dfrac{1}{0.2} = +5$ D

   Power of concave lens = $\dfrac{1}{-0.1} = -10$ D

   b. Power of combination = 5 – 10 = –5 D

   c. Focal length of combination = $\dfrac{1}{-5} = -0.2$ m

   = – 20 cm (concave)

   d. Behaves like a concave lens.

5. Focal length of concave lens = 20 cm

   Focal length of convex lens = 40 cm

   a. Power of concave lens = $\dfrac{1}{-0.2} = -5$ D

   Power of convex lens = $\dfrac{1}{0.4} = +2.5$ D

   b. Power of combination = 2.5 D – 5 D

   = –2.5 D

   c. Focal length of combination

   $= \dfrac{1}{-2.5}$

   $= -0.4$ m

   $= -40$ cm

   d. Behaves like a concave lens.

CHAPTER – 6

SPECTRUM

Check Your Progress 1 (Page 115)

A. **1.** b **2.** b **3.** c **4.** b **5.** c

6. b **7.** a. ii. b. i

B. **1.** **a.** A light ray passing through a glass slab is displaced but its direction is not changed.

b. A light ray passing through a prism is deviated.

2. **Newton's experiment:** Sir Isaac Newton allowed the sunlight to enter his dark room through a small hole in a window and placed a prism in the path of the light rays. He received the light emerging from the prism on a white screen. He had expected to see the white image of sun on the screen. He was surprised to see a band of colours of rainbow. Starting from the side of the base of the prism, he saw seven colours in the following order: violet, indigo, blue, green, yellow, orange and red (VIBGYOR).

Refer Figure 6.3, Page 113 of the textbook.

3. The band of colours obtained on a white screen, when white light splits into its constituent colours on passing through a prism, is called the spectrum of light.

4. The seven colours of the spectrum from top to bottom are red, orange, yellow, green, blue, indigo and violet.

5.

Pure spectrum	Impure spectrum
A spectrum in which various bands of colours have sharp, well-defined boundaries, and do not merge with each other is called a pure spectrum.	A spectrum in which various bands of colours have no sharp, well-defined boundaries, but merge with each other is called an impure spectrum.

6. **Newton's experiment to show that prism by itself produces no colours:** White light (sunlight) from a cardboard slit S is made to fall on an equilateral prism P, in a dark room. The prism P forms the spectrum RV on the screen AB. A narrow hole H is made in the screen AB to allow light of a particular colour to pass through it. Let us say green light is made to pass through this hole. This green light is made to pass through another prism Q, placed in an inverted position. The green light after passing through the second prism Q is received on another screen CD. It is observed that green light is obtained on the screen CD. This proves that the prism by itself produces no colours.

Refer Figure 6.6, Page 114 of the textbook.

7. **a.** *x* is violet and *y* is red colour.

b. Red colour

8. A spectrum in which various bands of colours have sharp well-defined boundaries, and do not merge with each other is called a pure spectrum.

The condition necessary for its production is that the boundaries of the various band of colours should be sharp without any overlapping.

Refer Figure 6.5, Page 114 of the textbook.

Questions Based on ICSE Examination (Page 116)

1. The phenomenon of splitting of white light into its constituent colours on passing through a glass prism is called dispersion of light.

2. The cause of dispersion is that the speed of various component colours of light is different in the same medium.

3. **a.** Violet light **b.** Red light

4. Refer Figure 6.3, Page 113 of the textbook.

5. A spectrum in which bands of colours have no sharp well-defined boundaries, but merge with each other is called impure spectrum.

6. Refer Figure 6.7, Page 114 of the textbook.

7. The beam is parallel to the base of the prism when it is minimum deviated inside the prism.

If white light is taken in place of the monochromatic beam of light, then it disperses and various component colours of white light are obtained on the screen (VIBGYOR).

Check Your Progress 2 (Page 123)

A. **1.** b **2.** d **3.** b **4.** b **5.** b **6.** d

7. a

B. **1.** Frequency

2. The waves associated with light are called electromagnetic waves because they consist of changing electric and magnetic fields.

Examples: Gamma rays, X-rays, radiowaves, etc.

3. The orderly classification of electromagnetic waves according to their wavelength or frequency is called the electromagnetic spectrum.

4. **a.** **Gamma rays:** Radioactive materials, nuclear reactions.

b. **X-rays:** X-ray tube and stars.

c. **UV radiations:** The sun, mercury vapour lamp, electric arc.

d. **IR radiations:** Very hot objects especially the sun.

e. **Radiowaves:** Electrons vibrated by electronic circuits, radio and TV transmitters, stars and galaxies.

5. The human retina contains some cells that are sensitive to a particular wavelength ranging from about 4×10^{-7} m to 8×10^{-7} m. This is called visible spectrum because we can see these colours with our eyes.

6. The electromagnetic radiations whose wavelength is longer than that of the visible red light are called infrared radiations and their spectrum is called infrared spectrum. Wavelength ranges from 4×10^{-7} m to 7×10^{-4} m.

7. a. **Gamma rays:** i. Treatment of cancer cells.
   ii. Measuring thickness and radiography.

   b. **X-rays:** i. To detect fracture in bones.
   ii. Detect gold, silver, weapons made of iron, etc.

   c. **UV radiations:** i. Sterilising purposes.
   ii. Detecting purity of ghee, eggs.

   d. **IR radiations:** i. Heating.
   ii. Night vision devices.

   e. **Radiowaves:** i. Communications —— radio, television.
   ii. Telephone links and RADAR.

   f. **Microwaves:** i. Used in microwave oven.
   ii. Communication in RADAR.

8. The electromagnetic radiations whose wavelength is shorter than the visible violet light are called ultraviolet radiations.

9. i. The exposure of our body to UV radiations can produce the change in colour of our skin.
   ii. The exposure of our body to too much UV radiations is dangerous to our health because of radiations ionising effect and it can cause skin cancer.

10. i. Do not require any material medium for their propagation.
    ii. Obey the laws of reflection and refraction.

11. Refer Table 6.2, Page 117 of the textbook.

12. i. Electromagnetic waves do not require any material medium for their propagation.
    ii. Electromagnetic waves travel in free space or vacuum with the same velocity, i.e. 3×10^8 m/s.

13. Blue

14. Red

15. Red

16. The atmosphere consists of particles like smoke water droplets, suspended dust particles and molecules of air. These particles have size smaller than the wavelength of visible light. These particles are more effective in scattering of light of shorter wavelengths. So fine particles in air scatter the blue-coloured light more strongly and effectively. Hence, the blue light enters our eyes and the sky looks blue.

17. If the earth had no atmosphere, no particles would have been present resulting in no scattering of light. Thus, sky wave have appeared dark.

18. Red, blue

19. **Red:** 6300–7000 Å
    Blue: 4640–5000 Å

20. **Dark:** As the passengers flying at high altitudes, the atmosphere becomes thinner. The particles present are very less. So, scattering of light is not prominent at such heights. So, the sky appears dark.

21. Red colour has the largest wavelength and hence, is least scattered. So, it can be seen from maximum distance.

22. When the white sunlight passes through earth's atmosphere, the molecules of air and other finer particles present in the atmosphere scatter light of shorter wavelength like the violet, indigo and blue colours. Although, violet and indigo lights are scattered more than blue light, our eyes are not very sensitive to both these colours. However, the white light gets deficient in violet, indigo and blue colour on account of scattering, and the resultant sunlight appears yellowish instead of white. When this resultant yellowish sunlight enters our eyes, then to us, sun appears yellowish instead of white. For similar reasons, the sunlight reaching the earth appears yellowish to us.

23. On a foggy day, the air has large amount of water droplets. If a motorist uses white light while driving in fog, then the water droplets present in the air scatter large amount of the blue light. This on reaching our eyes decreases visibility and hence driving becomes extremely difficult. The orange light has longer wavelength and hence it is least scattered. Thus, orange light can easily pass through fog without getting scattered and hence, is visible from maximum distance. So, the driver can see ahead clearly.

24. The orange light has longer wavelength and hence it is least scattered. Thus, orange light can easily pass through fog without getting scattered and hence, is visible from maximum distance. (Remember, red light is not permitted to be used by the motorist as it is the universal danger signal).

    So, school buses are painted orange but not red.

25. On a misty day, the air has large amount of tiny particles of water droplets, dust and smoke. These tiny particles present in the air scatter blue colour of the white light passing through it. When this scattered blue light reaches our eyes, the smoke appears blue.

26. At the time of sunrise and sunset, the sun is near the horizon. The light rays from the sun near the horizon have to pass through larger distance in the earth's atmosphere before reaching our eyes. Since the sunlight has to travel maximum distance inside the earth's atmosphere, it passes through maximum number of particles, suspended in the air. Near the horizon, most of the blue light and other lights of shorter wavelengths (green, yellow) are scattered away by these particles. The red colour which has the largest wavelength is scattered the least. Among the colours of sunlight, the colour scattered least, i.e. red colour enters our eye. This gives rise to reddish appearance of the sun, both at the time of sunrise and sunset.

27. The molecules of the smoke are bigger than the wavelength of light. So, the smoke from a fire looks white.

Questions Based on ICSE Examination (Page 124)

1. Gamma rays < X-rays < UV radiations < Visible light rays < IR radiations < Microwaves < Radiowaves.

2. Radiowaves < Microwaves < IR radiations < Visible light rays < UV radiations < X-rays < Gamma rays.

3. The regions of spectrum that do not sensitise human eye cells and hence are not visible are called invisible spectrum.

   Sun radiates infrared and UV radiations.

4. a. Both light of given wavelengths are electromagnetic waves. Electromagnetic waves will travel at the same speed in vacuum irrespective of its wavelength.

   b. Speed is the product of frequency and wavelength. Since speed is constant, light of lower wavelength 4000 Å will have higher frequency.

5. a. Infrared radiations are detected by electronic detectors, skin and special films.

   b. UV radiations are detected by fluorescence of chemicals, electronic detectors and tanning of skin.

6. a. Infrared radiations

   b. X-ray

   c. UV rays and visible light

7. i. Do not require material medium for propagation.

   ii. Travel in vacuum with the same speed of 3×10^8 m/s.

8. i. Both do not require material medium for propagation.

   ii. Both travel with the same speed of 3×10^8 m/s.

9. X-rays

10. Red

EXERCISES

Questions Based on ICSE Examination (Page 125)

1. a. P → Infrared radiation

      Q → Gamma radiation

   b. Speed of P is equal to the speed of Q in vacuum, i.e. 3×10^8 m/s.

2. a. Visible light → 4000 Å to 7000 Å

   b. UV light → 4×10^{-7} m to 6×10^{-10} m

3. Infrared radiations.

   IR radiations are detected by electronic detectors, skin and special films. They are used for heating purposes.

4. Red and violet are the colours on the extreme end of visible spectrum.

5. Ultraviolet rays → infrared rays → microwaves → radiowaves

6. **X-rays:** **i.** Radiography **ii.** CAT scan

   Gamma rays: **i.** Treating cancer

   ii. Measuring thickness.

7. **a. Microwaves:** Used in microwave oven for cooking.

   b. Ultra-violet radiation: Sterilising food.

   c. Infra-red radiation: Night vision devices.

8. Infra-red rays have a high penetrating power and least scattered by fog, mist, etc. As they have long wavelengths, so they are preferred over ordinary visible light for taking photographs in fog.

9. X-rays; these rays are also used for diagnostic purposes in medical science.

CHAPTER – 7

SOUND

Check Your Progress 1 (Page 131)

A. **1.** c **2.** b **3.** c **4.** d **5.** c

6. b **7.** c **8.** b **9.** a. ii b.iv c. ii d. i

10. a. ii. b. iii. c. i d. iv

B. **1.** Sound is a form of energy. It is produced by the periodic vibrations of a body.

2. Sound cannot travel through vacuum like light energy.

3. The change in direction of sound when it strikes a hard surface (like walls, cliffs, etc.) is called reflection of sound.

4. Refer Figure 7.1, Page 126 of the textbook.

When the sound produced by ticking of a clock travels through the tube A and strikes the metal plate, the sound striking the metal plate is reflected in a particular direction which can be heard distinctly by taking another tube B and moving it in such a way that is strikes the ears.

A screen is placed between the ear and the clock so that the sound of ticking clock does not reach the ears directly.

The ticking is heard loudest when tube A and tube B make equal angles with the screen, i.e. the laws of reflection are followed.

5. The laws of reflection of sound are:

i. The angle of incidence is equal to the angle of reflection of sound, i.e. $\angle i = \angle r$.

ii. The incident sound, the normal and the reflected sound, all lie in the same plane.

6. Simple devices which work on the principle of reflection of sound are:

i. Megaphone or speaking tubes

ii. Sound boards

iii. Ear-trumpet or hearing aid.

7. The phenomenon of reflection of sound from a rigid obstacle is called an echo.

8. The sensation of sound persists in our ear for 0.1 second or one-tenth of a second after the original sound dies off. This time is called persistence of hearing.

9. When a number of echoes of the original sound are heard, each echo being fainter than the preceding one, such multiple echoes are called reverberations. For example, thunder during a storm.

10. For determining the speed of sound in air, we can use echo method. For this,

i. The source of sound is kept at a distance say, *d* (more than 17 m) from the reflecting surface (wall, cliff, etc.).

ii. Start the stopwatch when the sound is produced by the source.

iii. Stop the stopwatch as soon as you hear the echo and record the time (*t*).

iv. As the sound waves travel from the source to the reflecting surface and back again, the total distance travelled in time '*t*' is '2*d*'.

v. The speed of sound can be calculated by the formula:

$$\text{Speed} = \frac{\text{Total distance travelled}}{\text{Time interval}}$$

$$v = \frac{2d}{t} \text{ m/s}$$

vi. Repeat the experiment 3 to 4 times and calculate v_1, v_2, v_3, ..., so on and take the average of the results.

vii. It is observed that the velocity of sound (in air) so obtained is equal to approximately 340 m/s.

11. SONAR (Sound Navigation and Ranging)

12. RADAR stands for Radio Detection And Ranging. It is based on the principle of echo.

13. Sonar scanners are used to look inside the human body called ultrasonography. The sonar scanners send out ultrasonic waves which are reflected by different tissues differently. These signals are picked up by the computer to build up images.

14. Echoes are used by engineers to detect flaws in machines. Echoes are also used by geologists to detect underground ores or oil deposits.

C. **1.** Given: $\lambda = 0.4$ m, $v = 1400$ ms^{-1}

$v = n\lambda$

$n = v\lambda = 1400 \times 0.4$

$= 3500$ Hz

The audible range of the human ear is 20 Hz to 20 kHz.

So, the sound wave of frequency 3500 Hz is audible in air.

2. $t_1 = 3$ s

$t_2 = 4$ s

$v = 340$ m/s

In case of an echo $d = \frac{vt}{2}$

$$t = t_1 + t_2 = 3 + 4 = 7 \text{ s}$$

$$d = \frac{340 \times 7}{2} = 1190 \text{ m}$$

$$d = 1190 \text{ m}$$

3. $t = 0.6$ s

$d = 102$ m

$$v = \frac{2d}{t} = \frac{2 \times 102}{0.6} \text{ m/s}$$

$$v = 340 \text{ m/s}$$

4. $t = 2$ s

$d = ?$

$v = 340$ m/s

$$d = \frac{vt}{2} = \frac{340 \times 2}{2}$$

$$d = 340 \text{ m}$$

5. a. $d_1 = 113.6$ m

$t_1 = 0.8$ s

$t_2 = 1.8$ s

$d_2 = ?$

$v = ?$

$$v = \frac{2d_1}{t_1} = \frac{2 \times 113.6}{0.8} = 284 \text{ m/s}$$

b. $$d_2 = \frac{ut_2}{2} = \frac{284 \cdot 1.8}{2}$$

$$d_2 = 255.6 \text{ m}$$

Distance between the two cliffs

$$d = d_1 + d_2$$

$$= 113.6 + 255.6 = 369.2 \text{ m}$$

6. a. $t_1 = 6$ s

$t_2 = 7$ s

Distance moved backwards = 170 m

Let the width of river be d m

Case 1:

$$v = \frac{2d}{t_1}$$

$$= \frac{2d}{6} \quad \text{...(i)}$$

Case 2: When the source moves 170 m backwards

$$v = \frac{2(d + 170)}{7} \quad \text{...(ii)}$$

Comparing equations (i) and (ii), we get

$$\frac{2d}{6} = \frac{2d + 340}{7}$$

$$14d = 12d + 2040$$

$$2d = 2040$$

$$d = 1020 \text{ m}$$

b. $$v = \frac{2 \times 1020}{6}$$

$$= 340 \text{ m/s}$$

7. $d = 25$ m

v = 340 m/s

a. $$t = \frac{2 \times d}{v} = \frac{50}{340} = 0.5 \text{ s}$$

b. Yes, the boy will be able to hear a distant echo because he is more than 17 m away from the reflecting surface and the sound takes more than 0.1 s to reach him.

8. $t_1 = 4$ s

$v_1 = 340$ m/s

$$d_1 = v_1 \times t_1$$

$$= 340 \times 4$$

$$= 1360 \text{ m}$$

$v_2 = 1450$ m/s

$d_2 = 1360$ m

$$t_2 = \frac{d_2}{v_2} = \frac{1360}{1450} = 0.94 \text{ s}$$

9. a. The first sound heard at 2 seconds comes directly from the observer to the man. Hence, the distance of the observer to the sea shore

$= v \times t_1$

$= 2\text{s} \times 320 \text{ m/s} = 640$ m

b. The second sound is due to an echo. Distance travelled by the sound is 640 + 2d, where d is the distance between the observer and the cliff.

Time taken, $t_2 = 3$ s

∴ Speed of sound = Total distance/time

$$320 = 640 + 2d/3$$

$$960 = 640 + 2d$$

$$2d = 320$$

$$d = 160 \text{ m}$$

10. $d_1 = 510$ m

$d_2 = ?$

$t_1 = 3$ s

$t_2 = 5$ s

a. $v = \frac{2d}{t} = \frac{510 \times 2}{3} = 340$ m/s

b. $d_2 = v \times t_2$

$= 340 \times 5 = 1700$ m

Questions Based on ICSE Examination (Page 133)

1. The phenomenon is called an echo.

   When a sound wave strikes a rigid obstacle, it is reflected back resulting in an echo.
2. The conditions for the formation of echoes are:
   - **i.** The minimum distance between the source of sound and reflector should be at least 17 m.
   - **ii.** The size of the reflector must be large.
   - **iii.** The intensity or the loudness of the sound should be sufficient.
3. When the sound is reflected in a small room, it is reflected back and this reflected sound takes less than 0.1 second to reach us, which our ears cannot distinguish due to persistence of hearing. Whereas, in a big room the reflected sound is heard after 0.1 second as a result. The echo is heard.
4. Two applications of an echo are:
   - **i. Sonar**: Sound Navigation and Ranging. This instrument is used to measure the depth of sea.
   - **ii. Radar**: Radio Detection and Ranging. This is used to detect aeroplanes in the air.
5. Ultrasonic waves are used for sound ranging:
   - **a.** Ultrasonic waves are not audible to us because they have frequency greater than 20,000 Hz (inaudible).
   - **b.** Sound ranging is used to find the depth of the sea.
6. Important property of waves used for echo depth sounding is that they can penetrate water to long distances because of their high frequency and short wavelength.

Check Your Progress 2 (Page 140)

A. **1.** d **2.** d **3.** c **4.** a **5.** b **6.** a

B. **1.** When a body capable of oscillating is made to vibrate with its own natural frequency, it is said to have natural (or free) vibrations.

2. Two examples of free vibrations are:
   - **i.** The bob of a simple pendulum is displaced from its mean position and left free.
   - **ii.** When a tuning fork is struck with a rubber pad and the tuning fork vibrates freely.

3. The natural frequency of oscillations of a simple pendulum depends upon
   - **i.** length of the pendulum
   - **ii.** acceleration due to gravity
   - **iii.** the intrinsic properties (shape, elasticity) of the body.

4. The natural frequency of oscillations of a vibrating string of a sitar depends upon
   - **i.** tension of the string
   - **ii.** length of the string
   - **iii.** mass per unit length of the string.

5. The natural frequency of a vibrating tuning fork depends upon
   - **i.** length of the tuning fork
   - **ii.** thickness of the fork
   - **iii.** material of the fork.

6. The medium exerts frictional force on a vibrating body in the medium, which gradually decreases the amplitude of the vibrating body though the frequency and the wavelength of the vibrating body remains constant.

7. The amplitude of a vibrating body continuously decreases during damped vibrations because of the frictional or resistive force due to the surrounding medium.

8. Refer Figure 7.7, Page 134, of the textbook.

9. A loud sound is heard when a violin string stretched across the wooden bridge is set into motion because, air molecules inside the hollow box are set into forced vibrations. This increases the intensity and amplitude of the sound.

10. The amplitude of forced vibrations depends upon the difference between the natural frequency of the body and the frequency of the applied force.

11. When a body oscillates with its own natural frequency with the help of an external periodic force whose frequency is equal to the natural frequency of the vibrating body, the oscillations of such a vibrating body with a large amplitude is known as resonance.

Refer any one example on Pages 137–138 of the textbook.

12. Aircraft designers make sure that all the mechanical structures do not match with the frequency of the engines in the flight. There is a possibility that at a certain speed, the frequency of the aircraft engine may be equal to the parts of the aircraft which may result in its collapse.

13. At a particular speed, the frequency of the vibrating engine of the motorcycle equals to the natural frequency of the parts of the motorcycle. They start vibrating more violently due to the phenomenon of resonance taking place.

14. A glass tumbler shatters at a particular musical note because the frequency produced by the musical note equals to the natural frequency of the glass tumbler resulting in resonance.

15. Every radio station broadcasts its programme at some particular frequency. When a radio is tuned, the frequency of the radio set is equal to the frequency of the broadcasting station resulting in resonance. Thus, ratio signals are amplified.

Questions Based on ICSE Examination (Page 140)

1. Refer Figure 7.6, Page 134 of the textbook.
2. A body can execute free vibrations in vacuum.
3. **a.** The vibrations in which the amplitude continuously decreases with time are called damped vibrations,

   b. A simple pendulum oscillating in air, sound waves in air.

   c. When the stem of a vibrating fork is pressed against the table top, the tuning fork forces the table top to vibrate with its own frequency. These forced vibrations send forth a greater energy and produce large sound. Now, if the natural frequency of the table is equal to that of the vibrating fork, resonance occurs and a louder sound is heard.
4. **a.** Damped vibrations.

   b. The amplitude of wave gradually decreases because of the frictional force the surrounding medium exerts on the vibrating body.

   c. After some time the vibrations will stop the body will come to rest.

   d. A simple pendulum oscillating in air.
5. **a**. As the amplitude is gradually decreasing in the given figure.

   So, it represents the damped vibration.

   b. Due to the presence of resistive force or frictional forces in the surrounding medium.

   c. Vibration of the bob of a simple pendulum.
6. Vibrations produced in a body due to an external periodic force are called forced vibrations, for example, the sound box of vibrating stretched strings, vibrations in the diaphragm of a gramophone sound box.
7. When a vibrating tuning fork is pressed against a table top, it forces the table top to vibrate (forced vibrations) which has a greater surface area and hence a greater loudness.
8. **a.** Frequency of a stretched string is inversely proportional to its length.

   $$f \propto \frac{1}{L}$$

   b. Frequency of a stretched string is directly proportional to the square root of the tension in the string.

   $$f \propto \sqrt{T}$$
9. Stringed objects are provided with a hollow box because on plucking the string, air molecules inside the hollow box are set into forced vibrations. This increases the intensity of the sound.
10. The conditions for the occurrence of resonance are:

    i. The vibrating body must produce sufficient external periodic force so as to set the body into vibrations.

    ii. The frequency of the external periodic force should be equal to the natural frequency of the vibrating body.
11.

Forced vibrations	Resonance
An external periodic force of any frequency makes another body vibrate.	The frequency of external periodic force is equal to the natural frequency of the vibrating body.
The amplitude of vibrations are small and for short time.	The amplitude of vibrations are large and for longer time.

12. Sound travels faster in solids than in air. Vibrations produced in the table have greater intensity than those produced in air.
13. 512 Hz
14. The factor which affects the frequency of sound emitted due to vibrations in an air column is the length of air column.
15. **a.** The characteristic of sound associated with the given observation is pitch.

b. The sound produced from a base drum is louder than the side drums. This is why, it can be heard distinctly from a distance as compared to the side drums.

16. a. Resonance

b. The sound becomes loud at some particular length because the frequency of tuning fork vibrating over the mouth of the burette is equal to the natural frequency of the vibrating air column in the burette.

17. a. Forced vibrations

b. Pendulum C vibrates with larger amplitude because it is oscillating in resonance with A.

c. Pendulum B is shorter than A, hence it has shorter time period and greater frequency than A. The external periodic force makes pendulum B to vibrate with smaller amplitudes. Pendulum C has the same length at pendulum A, hence, the external periodic force imparted to pendulum B through rubber band has same time period and frequency as A. Hence, pendulum C resonates.

18. a. The louder sound is produced when tuning fork B is placed on 4.

So, the frequency of tuning fork E is equal to B. i.e., 320Hz.

b. As frequency of both tuning forks E and B are same so when we kept tuning fork B on Y it feels resonance and in resonance it has greater amplitude that's why B produce a louder sound.

Check Your Progress 3 (Page 147)

A. 1. d 2. d 3. b 4. d 5. a
6. c 7. a 8. b

B. 1. Loudness is the characteristic of a musical sound by which a loud sound can be distinguished from a faint sound even though both have the same pitch.

2. Loudness depends upon the following factors:

i. Amplitude of the vibrating body
ii. Surface area of the vibrating body
iii. Distance from the vibrating body
iv. Density of the medium
v. Presence of resonant bodies
vi. Motion of the medium

3. When the drum is struck harder its amplitude is larger and this produces a loud sound.

4. Loudness is directly proportional to the square of amplitude.

5. The loudness varies inversely to the square of distance.

6. Loudness of sound is directly proportional to the density of the medium.

7. a. Loudness will increase 9 times.
b. Loudness will decrease.
c. Loudness will decrease to one-fourth.
d. Loudness will decrease.
e. Loudness increases.

8. The loudness of sound is measured in decibels (dB).

9. 10,000 times or 10^4 times.

10. 70 dB

11. The frequency or the wavelength determines the pitch of a sound.

12. a. grave or hoarse sound b. pitch is low

13. a. shrill sound b. pitch is high

14. The sound produced by moving bee is shrill and high pitched because their wings vibrate with high frequency.

15. The thinner strings of guitar produce greater frequency than the thicker strings so the thinner strings of guitar give out shrill sound than the thicker strings.

16. The frequency of a tightened tabla is greater than the loosened one and hence produces shrill sound.

17. a. The wave A has smaller wavelength or larger frequency and hence will produce higher pitch.

b. The wave B has longer wavelength or smaller frequency and hence will have grave or flat sound.

18. a. Amplitude
b. Waveform
c. Frequency

19. a. frequency – pitch
b. intensity – loudness
c. waveform – quality

20. The disturbance produced in the environment by undesirable loud and harsh sound from various sources is called noise pollution.

21. The harmful effects of noise pollution are:

i. It may lead to loss of hearing or deafness.

ii. It reduces concentration, increases stress, causes headache and nervous tensions resulting in loss of efficiency.

22. a. Because of the different quality (waveform) of voice produced, we can recognise our family members without seeing them.

b. Plucking the string from one end produces more harmonics and gives a richer sound.

c. Musical sound of piano is more richer than the flute because the piano produces more harmonics than a flute.

d. Two musical notes of the same pitch and same loudness played on a violin and on a piano are different because of their quality or waveform produced.

23. A continuous and uniform sound produced by regular and periodic vibrations which produces pleasing effect in our ears and mind is called musical sound.

24. a. Musical sound: Refer Figure 7.18, Page 145 of the textbook.

b. Noise: Refer Figure 7.19, Page 145 of the textbook.

Questions Based on ICSE Examination (Page 148)

1. Three characteristics of musical sound are:

   i. loudness **ii.** pitch **iii.** quality.

2. A sound appears to be much louder inside a hall than in open space because loudness increases with the presence of resonant bodies.

3. Loudness $\propto$ (Amplitude)^2

   $\therefore$ loudness will be in the ratio of 1 : 4.

4. The frequency of sound produced by children and ladies is larger than that of men, hence the shrillness of voice is greater in the voice of children and ladies as compared to men.

5. Drum (500 Hz)

   Pitch $\propto$ Frequency

6. a. As the water level in the pitcher rises, the length of air column decreases. The frequency of sound produced increase, which enables the boy to have an idea of when the pitcher is about to be filled.

   b. The sound changes and becomes shriller due to the decrease in length of air column, hence the frequency of sound increases.

7. a. The timbre or tone quality will not be same.

   b. $\because$ loudness is directly proportional to the square of amplitude.

   i.e, $L \propto A^2$

   Now, loudness of flute is become 4 times of piano

$$\Rightarrow \quad \frac{L_F}{L_P} = \frac{4}{1} \quad \text{...(i)}$$

$$\because \quad \frac{L_F}{L_P} = \frac{A_F^2}{A_P^2} \quad \text{...(ii)}$$

   Now, from eq. (i) and (ii)

$$\frac{A_F^2}{A_P^2} = \frac{4}{1}$$

$$\Rightarrow \quad \frac{A_F}{A_P} = \frac{2}{1}$$

   So, $A_F = A_P = 2 : 1$

   c. **Pitch**: Pitch is defined as the characteristic of sound which is used for differentiating between the shrill and flat sound.

8. a. Vibration P will produce louder sound because it has the maximum amplitude.

   b. String P will have maximum shrillness because it has shortest wavelength, hence will have the maximum frequency. Thus, P will have the highest pitch.

   c. 1 : 3.

9. Quality or timber is the characteristic of a musical sound that enables us to distinguish two sounds of the same pitch and loudness produced by two different sources. It depends upon the waveform of the sound.

10. Timbre

11. a. Timbre

    b. Loudness

12. Refer Table 7.4, Page 146 of the textbook.

13. Quality of sound or timbre.

EXERCISES

Questions Based on ICSE Examination (Page 149)

1. Two conditions necessary to hear an echo are:

   i. There should be a rigid obstacle.

   ii. The reflected sound should be heard after 0.1 s (one-tenth of a second).

2. Refer Table 7.4, Page 146 of the textbook.

3. We can distinguish between the sounds produced by different instruments in an orchestra, even though they produce the same tone with equal loudness. This property of musical sound is called its quality. It depends upon the waveform of the sound.

   Refer Figure 7.16, Page 144 of the textbook.

4. Two notes having same pitch and loudness have different quality due to the difference in their waveform produced by the two notes.

5. Conditions required for the resonance to take place are:

   i. The vibrating body must produce sufficient external periodic force.

   ii. The natural frequency of the vibrating body should be equal to the frequency of the external periodic force.

6. When a stretched string is set into vibrations the amplitude of vibrations is large enough to produce sensation of hearing in our ears which travels through the medium in between as it begins to vibrate.

   But there is no medium present on moon and as a result we cannot hear the sound of vibrating stretched strings.

7. $$I_1 : I_2 = a_1^2 : a_2^2$$

$$a_1 : a_2 = 4 : 9$$

$$\therefore \quad I_1 : I_2 = 16 : 81$$

8. $$d = 850 \text{ m}$$

$$v = 340 \text{ m/s}$$

$$t = \frac{2d}{v} = \frac{2 \times 850}{ü} = 5 \text{ s}$$

9. $$d = 25 \text{ m}$$

$$v = 330 \text{ m/s}$$

In case of an echo

$$t = \frac{2d}{v} = \frac{2 \times 25}{330} = 0.151 \text{ s}$$

10. $$t_1 = 3 \text{ s}$$

$$t_2 = 4 \text{ s}$$

$$v = 340 \text{ m/s}$$

$$d_1 = \frac{vt_1}{2} = \frac{340 \times 3}{2} = 510 \text{ m}$$

$$d_2 = \frac{vt_2}{2} = \frac{340 \times 4}{2} = 680 \text{ m}$$

Distance between the two cliffs

$$= d_1 + d_2$$

$$= 510 + 680$$

$$= 1190 \text{ m}$$

11. $$t = 2 \text{ s}$$

$$v = 340 \text{ m/s}$$

In case of echo,

$$2d = v \times t$$

$$d = \frac{vt}{2}$$

$$= \frac{340 \times 2}{2} = 340 \text{ m}$$

Additional Numericals (Page 150)

1. $$d = 425 \text{ m}$$

$$t = 2.5 \text{ s}$$

In case of an echo

$$v = \frac{2d}{t} = \frac{2 \times 425}{2.5} = 340 \text{ m/s}$$

2. $$v = 340 \text{ m/s}$$

$$t = 1.5 \text{ s}$$

In case of an echo

$$d = \frac{vt}{2} = \frac{340 \times 1.5}{2} = 255 \text{ m}$$

3. $$d = 127.5 \text{ m}$$

$$v = 340 \text{ m/s}$$

$$t = ?$$

In case of an echo

$$t = \frac{2d}{v} = \frac{2 \times 127.5}{350}$$

$$t = 0.75 \text{ s}$$

4. Time of two echos

$$t_1 = 0.4 \text{ s}$$

$$t_2 = 1.6 \text{ s}$$

$$v = 332 \text{ m/s}$$

$$t = t_1 + t_2 = 0.4 + 1.6 = 2 \text{ s}$$

In case of an echo

$$d = \frac{vt}{2} = \frac{332 \times 2}{2} = 332 \text{ m}$$

5. Distance between cliffs = 99 m

$$t_1 = 0.2 \text{ s}$$

$$t_2 = 0.4 \text{ s}$$

Let the distance of nearer cliff = x m

$\therefore$ the distance of farther cliff = $(99 - x)$ m

a. $$v = \frac{2d}{t}$$

$$v = \frac{2 \times x}{0.2} \quad \text{...(i)}$$

$$v = \frac{2(99 - x)}{0.4} \quad \text{...(ii)}$$

Comparing equations (i) and (ii), we get

$$\frac{}{0.2} = \frac{2(99 - x)}{0.4}$$

$$0.4x = 0.2\,(99 - x)$$

$$2x = 99 - x$$

$$3x = 99$$

$$x = 33 \text{ m}$$

Distance of person from nearer cliff = 33 m

b. Speed of sound, $v = \frac{2 \times 33}{0.2} = 330$ m/s

6. Distance from wall $d = 50$ m

Velocity of sound, $v = 340$ m/s

In case of echo

$$t = \frac{2d}{v} = \frac{2 \times 50}{340} = 0.29 \text{ s}$$

7. Distance of cliff, $d = 680$ m

Speed of sound, $v = 340$ m/s

In case of echo

$$t = \frac{2d}{v} = \frac{2 \times 680}{340} = 4 \text{ s}$$

CHAPTER – 8

CURRENT ELECTRICITY

Check Your Progress 1 (Page 159)

A. **1.** d **2.** b **3.** c **4.** a **5.** c

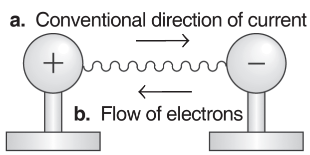
6. c

B. **1.** The flow of electrons in a definite direction constitutes electric current.

2. The rate of flow of charge in a circuit is called electric current. The SI unit of current is ampere and it is denoted by the letter 'A'.

3. The electric current is said to flow from the region of higher potential to the region of lower potential (conventional direction of electric current).

4.



c. The movement of electrons (or the flow of current) continues as long as there is a difference in potential between two conductors. Once the two conductors have the same potential, the flow of current stops.

5. Free electrons are responsible for current in conductors.

6. The potential difference (p.d.) between two points in an electric field is defined as the amount of work done in moving a unit positive charge from one point to the other point. The SI unit of potential difference is volt and is denoted by V. It is measured by a voltmeter.

7. Two factors on which the strength of electric current in a given conductor depends are: **i.** Resistance **ii.** Potential difference.

8. According to Ohm's law, 'The electric current (I) flowing through a conductor is directly proportional to the potential difference (V) across its ends, provided the temperature and other conditions of the conductor remain the same'.

$$I \propto V$$

9. The property of a conductor by virtue of which it opposes the flow of electric current through it is called its resistance. SI unit of resistance is ohm (Ω).

10. The factors on which resistance of a conductor depends are:

i. length of the conductor

ii. area of cross section of the conductor

iii. temperature of the conductor

iv. nature of the material of the conductor.

11. The reciprocal of resistance of a conductor is called its conductance (G), i.e. $G = 1/R$. The SI unit of conductance is mho.

12. In 1911, a Dutch physicist, H. Kamerlingh Onnes discovered superconductivity in mercury. He found that the resistance of mercury (Hg) drops abruptly to zero at 4.2 K (about –269 °C), i.e. it does not offer any resistance to the passage of electric current. It is said to have infinite conductivity, or superconductivity. The property by virtue of which a conductor shows almost zero resistance at a very low temperature is called superconductivity and the materials which show the property of super-conductivity are called superconductors. Tungsten (T_c = 0.01 K), aluminium (T_c = 1.18 K), mercury (T_c = 4.2 K), lead (T_c = 7.19 K) are some of the superconductors.

13. No resistance means no power loss, therefore, superconductors have a number of useful applications:

i. They may be used to produce very high speed and very small-sized computers.

ii. Superconducting electric power transmission lines for long distance with no power loss due to heating may be possible. Hence, superconductivity is a wide area of research in physics today.

14. The resistivity of silver is 1.6×10^{-8} Ω m. It means that if we take a silver wire 1 metre long and having an area of cross section of 1 m^2, then resistance of this piece of silver wire will be 1.6×10^{-8} Ω.

15. Resistivity is the property of a material and does not depend on the dimensions of the wire. Hence, it does not change with the change in the thickness of the wire.

16.

Resistance	Resistivity
The property of a material due to which it opposes the flow of current through it, is called resistance.	Resistivity of a material is the resistance offered by 1 m length of wire of the material having an area of cross-section of 1 m^2.
The resistance of a conductor depends on its length and thickness.	The resistivity of a material does not depend on its length or thickness and is the characteristic of the given material.
$R = \frac{V}{I}\left(\frac{\text{Potential difference}}{\text{Current}}\right)$	$\rho = \frac{R \times A}{l}\left(\frac{\text{Resistance} \times \text{Area of cross section}}{\text{Length of the material}}\right)$
SI unit is ohm (Ω).	SI unit is ohm-metre (Ω m).

17. This is so because tungsten has high resistance.

18. As we know that radius of A is twice the radius of B.

a. The wire A has greater resistance than the wire B

Will have greater resistance

- The wire which has the greater radius is expected to have more resistance than the wire B as it is more thicker than the other.
- And would be expected that the wire to depend upon the material out of which the wire is made.
- Hence, the resistance of a given material will increase with the length, which is directly proportional.
- But decrease with increasing cross-sectional area. which is inversely proportional.

b. the wires are expected to have greater resistivity

Will have greater resistivity

- Both the wires are expected to have the same resistivity.
- Electrical resistivity is an intrinsic property that quantifies how firmly a given material opposes the flow of electric current.
- A low resistivity indicates a material that easily allows the movement of electric charge.
- Resistivity is commonly represented by the letter ρ (rho).
- The SI unit of electrical resistivity is the ohm–meter(ohm meter).

C. 1. Work done = (128 × 2) J – (118 × 2) J

$$= 256 - 236 = 20 \text{ J}$$

2. Electric potential $= \frac{\text{Work done}}{\text{Charge}}$

$$= \frac{2\times10^{-3}\text{ J}}{10\times10^{-6}\text{ C}} = 200 \text{ V}$$

3. $$\frac{V}{I} = R$$

$$V = I \times R$$
$$= 2 \text{ A} \times 5\ \Omega$$
$$= 10 \text{ V}$$

4. $$R = \frac{20}{2} = 10\ \Omega$$

5. $$\frac{V}{I} = R$$

$$I = \frac{V}{R}$$
$$= \frac{24}{60} = 0.4 \text{ A}$$

6. a. $$R = \frac{8\times2}{8+2} = \frac{16}{10} = 1.6\ \Omega$$

Total current $= \frac{4}{1.6+0.4} = 2$ A

Voltage across resistance combination

$$V = iR = 2 \times 1.6 = 3.2 \text{ volt}$$

b. Current in 3 Ω resistance

$$= \frac{3.2}{5+3} = 0.4 \text{ A.}$$

Questions Based on ICSE Examination (Page 160)

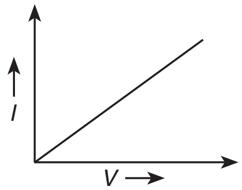
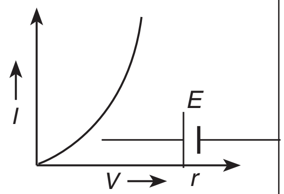
1. a. Ohm's law
   b. Resistance of the conductor.
2. a. If the length of the conductor (or wire) is halved, its resistance also gets halved.
   b. If the area of cross-section of the conductor is doubled, its resistance gets halved.
   c. The resistance of all pure metals increases with a rise in temperature and decreases on lowering the temperature.
   d. Resistance of vulcanised rubber decreases by 25% when heated from 0 °C to 24 °C.
3. Since the length is doubled therefore resistance gets doubled. Hence, the new resistance is 12 Ω.
4. a. The thinner wire will have more resistance.

$$\left(R \propto \frac{1}{A}\right)$$

   b. Both the wires will have same specific resistance because both of them are made of copper.
5. The resistor which obeys Ohm's Law is called Ohmic resistor.
6. Refer Figure 8.11, Page 158 of the textbook.

   The resistance of the resistor can be obtained from the graph by calculating the slope.
7. The resistors that do not obey Ohm's law are called non-ohmic resistors.
8. Differences between ohmic and non-ohmic conductors:

Ohmic conductor	Non-ohmic conductor
The conductors (resistors) which strictly obey Ohm's law are called ohmic conductors (resistors).	The conductors (resistors) that do not obey Ohm's law are called non-ohmic conductors (resistors).

Ohmic conductor	Non-ohmic conductor
The graph of current (*I*) against potential difference (*V*) is a straight line. 	The graph of current (*I*) against potential difference (*V*) is not a straight line. 
R is constant for different values of *V* or *I*.	*R* is not constant. It is different for different values of *V* or *I*.
The ratio of change in potential difference to the change in current, i.e. $\frac{\Delta V}{\Delta I}$ is called dynamic resistance. It is constant for different values of *I* or *V*.	The dynamic resistance $\frac{\Delta V}{\Delta I}$ is different for different values of *I* and *V*.
All metallic conductors such as silver, copper, etc. are ohmic conductors.	Vacuum tubes, transistors, electrolytes are non-ohmic conductors.

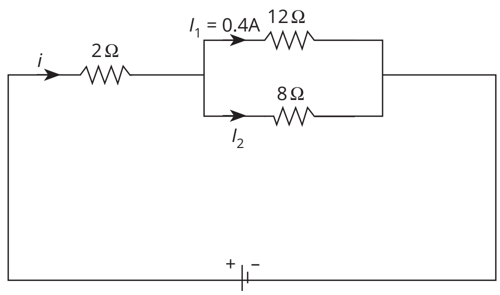
9. Specific resistance (or resistivity) of a material is the resistance offered by 1 m length of the wire of the material having area of cross section of 1 m^2. The SI unit of resistivity is ohm-metre which is written in symbol as Ω m.

10. With an increase in the temperature:

a. The specific resistance of a metal increases.

b. The specific resistance of a semiconductor decreases.

11.



a. Resistance in parallel form is calculated as

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots\ldots \frac{1}{R_n}$$

Here, two resistance 12 Ω and 8 Ω are in parallel

$$\therefore \quad \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$= \frac{1}{8} + \frac{1}{12} \qquad \text{(On putting values)}$$

$$= \frac{3+2}{24} = \frac{5}{24}\,\Omega$$

$$\Rightarrow \quad R_P = \frac{24}{5}\,\Omega = 4.8\ \Omega$$

Now, resistance in series form

$$R = R_1 + R_2 + \ldots\ldots R_n$$

Here, 2 Ω is in series.

So, external resistance of the circuit is 4.8 + 2 = 6.8 Ω

b. $I_2 = ?$

$\because \quad V = IR$ (let $R_1 = 12\ \Omega$)

$\therefore \quad V = I_1 \times R_1$

[$\because$ I_1 is flowing through resistance 12 Ω]

$= 0.4 \times 12 = 4.8$ volt

As, we know that voltage remains same in parallel resistance circuit.

$$\Rightarrow \quad I_2 = \frac{V}{R_2} \qquad \text{(let } R_2 = 8\ \Omega)$$

$$= \frac{4.8}{8}$$

$I = 0.6$ A

c. $I = ?$

$I = I_1 + I_2$

[$\therefore$ *I* is the current flowing in whole circuits]

$= 0.4 + 0.6 = 1.0$

$I = 1$ A

12. a. $\therefore \quad R = \rho \times \frac{1}{a}$

ρ = resistivity
l = length of wire
a = cross-sectional area of wire

$$\therefore \quad 20 = \rho \times \frac{l}{a} \qquad (\because \quad R = 2\ \Omega)$$

$$\Rightarrow \quad \rho = \frac{20a}{l} \qquad \ldots\text{(i)}$$

Now, $R = \rho \times \frac{l}{a}$

$$= \frac{20a}{l} \times \frac{3l}{a/3} \qquad \text{[From (}i\text{)]}$$

[$\because$ length becomes thrice, thus area becomes one-third]

$$= \frac{20a}{l} \times \frac{3 \times 3l}{a}$$

$R = 180$ W

So, new resistance will be 180 Ω.

b. Specific resistance of the wire remains the same because the material of wire is same in both conditions.

CHECK YOUR PROGRESS 2 (PAGE 169)

A. 1. a

B. 1. A cell is a device which provides the necessary potential difference to an electrical circuit to maintain a continuous flow of current in it.

It is denoted as .

2. Such a circuit where no current can be drawn from the cell is called an open circuit.

When the terminals of a cell are connected to a circuit and current is drawn from the cell then such a circuit is called a closed circuit.

3. The emf of a cell depends upon

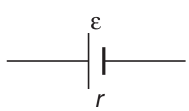
i. the material of the electrodes.

ii. the electrolyte used in the cell.

4. The potential difference between the electrodes of a cell in a closed circuit (i.e. when the current is drawn through the cell) is called terminal voltage. Its SI unit is volt.

5. $\varepsilon \rightarrow$ emf of cell.

$r \rightarrow$ internal resistance of the cell.



6. In an open circuit

$$I = 0$$
$$V = \varepsilon$$

In a closed circuit when current is drawn through the cell

$$I = \frac{\varepsilon}{R + r}$$

$\varepsilon \rightarrow$ emf of cell

$R \rightarrow$ external resistance of the circuit

$r \rightarrow$ internal resistance of the cell

$R + r \rightarrow$ the total equivalent resistance

then $\quad \varepsilon = I(R + r)$

or $\quad \varepsilon = IR + Ir$

But according to Ohm's law

$$IR = V$$

$\therefore \quad \varepsilon = V + Ir$

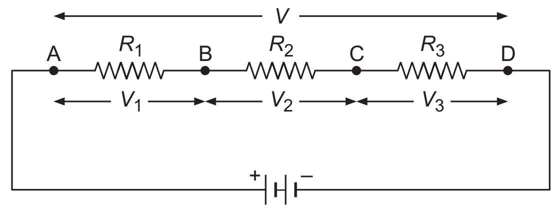
or $\quad V = \varepsilon - Ir$

V is the terminal voltage of the cell and Ir is the potential drop.

7. a. Two or more resistors are said to be connected in series if they are connected one after the other such that the same current flows in one path through all the resistors when some potential difference is applied across the combination.

b. Two or more resistors are said to be connected in parallel if one end of the resistor is connected to one end of the other resistor and the second end of the first connected to the second end of the other resistor such that the potential difference across each resistor is the same.

8.



Potential difference across resistors

$$V = V_1 + V_2 + V_3$$

By Ohm's law

$$V_1 = IR_1$$
$$V_2 = IR_2$$
$$V_3 = IR_3$$

$\therefore \quad V = IR_1 + IR_2 + IR_3 = I(R_1 + R_2 + R_3)$

If R_s is the equivalent resistance in series, then

$$V = IR_s$$

$\Rightarrow \quad IR_s = I(R_1 + R_2 + R_3)$

or $\quad R_s = R_1 + R_2 + R_3$

9. Characteristics of series circuit resistance is —

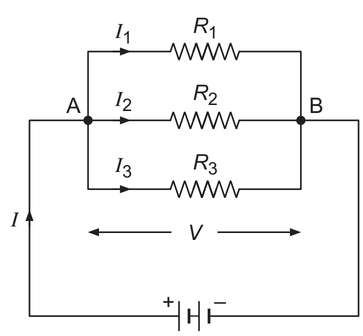
i. The current is same in each resistor.

ii. The total resistances is equal to the sum of individual resistances in the circuit.

iii. The total resistance is more than the maximum resistance in series.

10. The main disadvantage of series circuit is that if one device fails, the current in the whole circuit ceases to flow.

11. The current drawn from the cell I is equal to the sum of currents flowing in each resistor in parallel.



$$I = I_1 + I_2 + I_3$$

By Ohm's law

$$V = I_1R_1 \text{ or } I_1 = \frac{V}{R_1}$$

$$V = I_2R_2 \text{ or } I_2 = \frac{V}{R_2}$$

$$V = I_3R_3 \text{ or } I_3 = \frac{V}{R_3}$$

$$\therefore \quad I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

If R_p is the equivalent resistance in parallel then

$$V = IR_p \text{ or } I = \frac{V}{R_p}$$

$$\therefore \quad \frac{V}{R_p} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\text{or} \quad \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

12. An advantage of connecting electrical appliances in parallel combination is that each appliance works independently of other appliances. Even if one of the appliances is switched off or gets fused, it will not affect the working of other appliances in the circuit.

13. B represents series combination and A represents parallel combination because the slope of $V–I$ graph represents resistance, therefore B has higher resistance (series combination) and A has less resistance than B (parallel combination).

14. Resistivity of semiconductors decreases with the increase in temperature.

Questions Based on ICSE Examination (Page 169)

1. It is the maximum potential difference across the terminals of a cell when it is delivering no current, i.e. when the cell is open. Its SI unit is volt.

2. A cell is sending current in an external circuit which means the circuit is closed.

In a closed circuit, the potential difference or the terminal voltage of cell is less than the emf. It is given by

$$\varepsilon - V = Ir$$

where $\varepsilon \rightarrow$ emf of cell

$r \rightarrow$ internal resistance

$V \rightarrow$ terminal resistance

$I \rightarrow$ current

3. The resistance offered by the electrolyte of the cell to the flow of current is called internal resistance. Its unit is ohm (Ω).

4. The internal resistance of a cell depends upon:

i. The surface area of electrodes in contact with the electrolyte.

$$r \propto \frac{1}{A}$$

ii. The distance between the electrodes.

$$r \propto d$$

5. a. the internal resistance will decrease.

b. the internal resistance will decrease.

c. the internal resistance will increase.

d. the internal resistance will increase.

6. $R = 27\ \Omega$

After cutting into three pieces resistance of each pieces is equal to

$$R' = \frac{R}{3} = \frac{27}{3} = 9\ \Omega$$

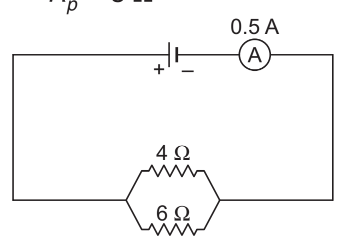
The resistance of parallel combination is given by

$$\frac{1}{R_p} = \frac{1}{R'} + \frac{1}{R'} + \frac{1}{R'}$$

$$\frac{1}{R_p} = \frac{1}{9} + \frac{1}{9} + \frac{1}{9} = \frac{3}{9} = \frac{1}{3}$$

$$R_p = 3\ \Omega$$

7. a.



b.

$$R_p = \frac{4 \times 6}{4 + 6} = \frac{24}{10} = 2.4\ \Omega$$

$$I_{4\,\Omega} = \frac{6}{6+4} \times 0.5$$

$$= \frac{6}{10} \times 0.5 = 0.3 \text{ A}$$

$$I_{6\,\Omega} = \frac{4}{6+4} \times 0.5$$

$$= \frac{4}{10} \times 0.5 = 0.2 \text{ A}$$

8. a. $$\frac{1}{R_{p_1}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

$$R_{p_1} = 1\ \Omega$$

$$\frac{1}{R_{p_2}} = \frac{1}{6} + \frac{1}{4}$$

$$R_{p_2} = 2.4\ \Omega$$

$$R_{net} = R_{p_1} + R_{p_2} + 5\ \Omega$$

$$= 1 + 2.4 + 5$$

$$= 8.4\ \Omega$$

b.

$$\frac{1}{R_p} = \frac{1}{4} + \frac{1}{6} + \frac{1}{12}$$

$$= \frac{3+2+1}{12} = \frac{6}{12} = \frac{1}{2}$$

$$R_p = 2\ \Omega$$

$$R_{net} = R_p + 2 + 5$$

$$= 2 + 2 + 5 = 9\ \Omega$$

c.

$$R_s = 10 + 10 = 20\ \Omega$$

$$\frac{1}{R_p} = \frac{1}{20} + \frac{1}{5}$$

$$= \frac{1+4}{20} = \frac{5}{20} = \frac{1}{4}$$

$$R_p = 4\ \Omega$$

$$R_{net} = R_p + 3 + 3$$

$$= 4 + 3 + 3$$

$$= 10\ \Omega$$

d.

$$R_{s_1} = 4 + 4 + 4$$

$$= 12\ \Omega$$

$$R_{s_2} = 2 + 2 + 2$$

$$= 6\ \Omega$$

$$\frac{1}{R_p} = \frac{ü}{R_{s_1}} + \frac{}{R_{s_2}} + \frac{}{4}$$

$$= \frac{ü}{12} + \frac{}{6} + \frac{}{4}$$

$$= \frac{1+2+3}{12} = \frac{6}{12} = \frac{1}{2}$$

$$R_p = 2\ \Omega$$

$$R_{net} = 5 + 6 + 2$$

$$= 13\ \Omega$$

e.

$$R_{s_1} = 3 + 2$$

$$= 5\ \Omega$$

$$R_{s_2} = 6 + 4$$

$$= 10\ \Omega$$

$$\frac{1}{R_p} = \frac{ü}{R_{s_1}} + \frac{}{R_{s_2}} + \frac{}{3}$$

$$\frac{1}{R_p} = \frac{1}{5} + \frac{1}{10} + \frac{1}{3}$$

$$= \frac{6+3+10}{30} = \frac{19}{30}$$

$$R_p = \frac{30}{19}\ \Omega = 1.58\ \Omega$$

f. Effective resistance of a parallel combination of 6 Ω and 3 Ω resistors is given by

$$R_1 = (6 \times 3)/(6 + 3) = 2\ \Omega$$

Effective resistance of a parallel combination of 4 Ω and 12 Ω resistors is given by

$$R_2 = (4 \times 12)/(4 + 12) = 3\ \Omega$$

Equivalent resistance between A and B (connected in series) = 2 Ω + 3 Ω = 5 Ω

9.

$$V = 6\text{ V}$$

$$I = 0.5\text{ A}$$

a.

$$V = IR_{net}$$

$$R_{net} = \frac{V}{I} = \frac{6}{0.5} = \frac{60}{5} = 12\ \Omega$$

$$R_{net} = R + 3$$

$$12 = R + 3$$

$$R = 9\ \Omega$$

b.

$$I = \frac{Q}{t}$$

$$Q = \text{I} \times t$$

$$= 0.5 \times 120$$

$$= 60\text{ C}$$

10. a. $R_{PQ} = \frac{R_P \cdot R_Q}{R_P + R_Q} = \frac{3 \cdot 6}{3+6} = \frac{18}{9} = 2\ \Omega$

b. $I = \frac{E}{R} = \frac{2}{2} = 1\text{ A}$

c. $P = VI = 2 \times 1 = 2\text{ W}$

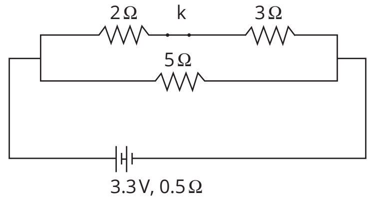
11. a. When the key k is open:

The resistance (R_1) of the circuit = 5 + 0.5

= 5.5 Ω

b. The current (I_1) drawn from the cell when the key k is open: $I_1 = \frac{V}{R_1} = \frac{3.3}{5.5} = 0.6\text{ A}$

c. When the key k is closed:



Now here, 2 Ω and 3 Ω will be in series.

∴ Equivalent resistance = (2 + 3) = 5 Ω

This equivalent resistance will be in parallel with 5 Ω as shown in the above figure.

So, $\frac{1}{R_P} = \frac{1}{5} + \frac{1}{5} = \frac{2}{5}$, $R_P = \frac{5}{2} = 2.5\,\Omega$

∴ The resistance (R_2) of the circuit when the key k is closed = (R_P + 0.5) Ω

= 2.5 + 0.5 = 3.0 Ω

d. The current (I_2) drawn from the cell when the key k is closed: $I_2 = \frac{V}{R_2} = \frac{3.3}{3} = 1.1$ A

12. Total emf = 1.5 V

Total internal resistance = $\frac{4}{4} = 1\,\Omega$

External resistance = 4 Ω

Total resistance = 4 + 1 ($R + r$) = 5 Ω

a. Total current = $\frac{E}{R+r} = \frac{1.5}{5} = 0.3$ A

b. $I = 0.3$ A

c. Potential drop = $Ir = 0.3 \times 1 = 0.3$ V

13. $V = 4$ V

$I = 0.8$ A

a. Total resistance $R_p = \frac{4}{0.8} = 5\,\Omega$

b. $\frac{1}{R_1} + \frac{1}{R_2} = \frac{1}{R_p}$

∴ $\frac{1}{R_1} = \frac{1}{5} - \frac{1}{20} = \frac{4-1}{20} = \frac{3}{20}$

$R_1 = \frac{20}{3} = 6.67\,\Omega$

c. $4V = I_R \times R$

$I_R = \frac{4}{20} \times 3 = \frac{3}{5} = 0.6$ A

14. a. $R_{BC} = \frac{R_B \times R_C}{R_B + R_C} = \frac{2 \times 3}{5} = 1.2\,\Omega$

b. $R = R_A + R_{BC} = 4 + 1.2 = 5.2\,\Omega$

c. $R + r = 5.2 + 0.8 = 6\,\Omega$

d. $I = \frac{\varepsilon}{R+r} = \frac{6}{6} = 1$ A

$I_A = 1$ A

$V_{BC} = 1 \times 1.2 = 1.2$ V

$\Rightarrow \quad V_{BC} = I_B \times R_B \Rightarrow I_B = \frac{1.2}{2} = 0.6$ A

$V_{BC} = I_C \times R_C \Rightarrow I_C = \frac{1.2}{3} = 0.4$ A

15. a. $R_p = \frac{2 \times 2}{2+2} = 1\,\Omega$

$R = R_p + 4 = 1 + 4 = 5\,\Omega$

$I = \frac{\varepsilon}{R+r}$

$I = 0.25$ A

$\varepsilon = 2$ V

$\Rightarrow \quad 0.25 = \frac{2}{5+r}$ or $5 + r = \frac{2}{0.25} = 8\,\Omega$

or $r = 8 - 5 = 3\,\Omega$

b. Drop in potential = $I_r = 0.25 \times 3 = 0.75$ V

c. $I_{2\Omega} = \frac{0.25}{2} = 0.125$ A

d. $V_{4\Omega} = 0.25 \times 4 = 1$ V

16. $R_p = \frac{8 \times 12}{8 \times 12} = \frac{96}{20} = 4.8\,\Omega$

a. $R_{eq} = 7.2 + R_p$

$= 7.2 + 4.8$

$= 12\,\Omega$

b. $I = \frac{V}{R}$

$= \frac{6}{12} = 0.5$ A

c. $V_{7.2\,\Omega} = I \times 7.2$

$= 0.5 \times 7.2$

$= 3.6$ V

17. $R_p = \frac{4.5 \times 9}{9 + 4.5} = \frac{40.5}{13.5} = 3\,\Omega$

$R_{eq} = R_p + 0.8 + 1.2$

$= 3 + 0.8 + 1.2$

$= 5\,\Omega$

a. $I = \frac{V}{R} = \frac{2}{5} = 0.4$ A

b. $V = \varepsilon - Ir$

$= 2 - 0.4 \times 1.2$

$= 2 - 0.48$

$= 1.52$ V

18. $R_p = \dfrac{12 \times 6}{12 + 6} = \dfrac{72}{18} = 4\ \Omega$

$R_{eq} = 8 + 4$

$= 12\ \Omega$

a. $I_{8\,\Omega} = \dfrac{V}{R} = \dfrac{12}{12} = 1$ A

b. $V_p = V - IR_{8\,\Omega}$

$= 12 - 1 \times 8$

$= 12 - 8$

$= 4$ V

c. $I_{6\,\Omega} = \dfrac{12}{18} \times 1 = \dfrac{2}{3}$ A

$= 0.66$ A

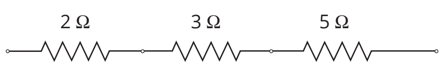
EXERCISES

Questions Based on ICSE Examination (Page 172)

1. A substance whose resistance decreases with increase in temperature is called a semiconductor.

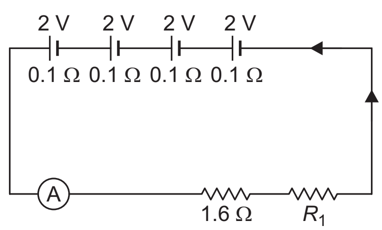
Examples: Silicon and Germanium

2. a. We have to connect them in a series to obtain the total resistance more than 7 Ω.



b. Equivalent resistance: $2\ \Omega + 3\ \Omega + 5\ \Omega = 10\ \Omega$

3. a.



b. $V = 8$ V

$I = 2$ A

$r = 4 \times 0.1 = 0.4\ \Omega$

$R_{eq} = \dfrac{V}{I} = \dfrac{8}{2} = 4\ \Omega$

c. $I = \dfrac{\varepsilon}{R_{eq}}$ or $\varepsilon = 4 \times 2 = 8$ V

$\varepsilon = IR_{eq}$

$= 2 \times 4 = 8$ V

d. $R_{eq} = 4 \times 0.1 + 1.6 \times R_1$

$= 0.4 + 1.6 \times R_1$

$= 2 + R_1$

$R_{eq} = 4\Omega$

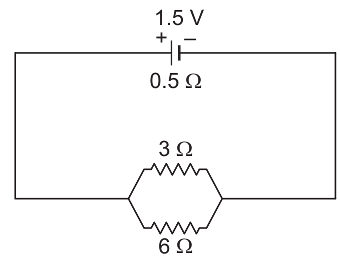
$2 + R_1 = 4\Omega$

$R_1 = 2\Omega$

e. $V_{R_1} = I\,R_1$

$= 2 \times 2 = 4$ V

4. $R_p = \dfrac{R_3 \times R_6}{R_3 + R_6} = \dfrac{3 \times 6}{3 + 6} = \dfrac{18}{9} = 2\ \Omega$



Total resistance $= R + r$

$= 2 + 0.5 = 2.5\ \Omega$

Current, $I = \dfrac{\varepsilon}{R + r} = \dfrac{1.5}{2.5} = \dfrac{3}{5}$

$I = 0.6$ A

5. r_3 and r_4 are parallel.

$\therefore\ R_p = \dfrac{r_3 \times r_4}{r_3 + r_4}$

r_1, r_2 and R_p are in series.

$\therefore\ R = r_1 + r_2 + \dfrac{r_3 r_4}{r_3 + r_4}$

$R = \dfrac{(r_1 + r_2)(r_3 + r_4) + r_3 r_4}{r_3 + r_4}$

6. R_1 and R_3 are in series.

$\therefore\ R_s = 1 + 3 = 4\ \Omega$

R_s and R_4 are in parallel.

$\therefore\ R = \dfrac{4 \times 4}{4 + 4} = \dfrac{16}{8} = 2\ \Omega$

$r = 2.0\ \Omega$

a. $R + r = 2 + 2 = 4\ \Omega$

b. $I = \dfrac{\varepsilon}{R + r} = \dfrac{2}{4} = 0.5$ A

c. $E_s = 2 + 2 = 4\ V$

$r_s = 2 + 2 = 4\ \Omega$

$R + r_s = 2 + 4 = 6\ \Omega$

$I' = \dfrac{\varepsilon_s}{R + r_s} = \dfrac{4}{6} = \dfrac{2}{3} = 0.67$ A

7. $I_1 = 0.6$ A $\quad I_2 = 0.3$ A

$R_1 = 2\ \Omega \quad R_2 = 8\ \Omega$

$\varepsilon = I_1(R_1 + r) \quad \varepsilon = I_2(R_2 + r)$

$\Rightarrow I_1(R_1 + r) = I_2(R_2 + r)$

$0.6(2 + r) = 0.3(8 + r)$

$4 + 2r = 8 + r$

$r = 4\ \Omega$

$\therefore \varepsilon = I_1 (R_1 + r)$

$= 0.6(2 + 4) = 0.6 \times 6$

$= 3.6$ V

8. R_B is parallel to R_C

$\therefore R_p = \frac{4 \times 6}{4 + 6} = 2.4\ \Omega$

R_A is in series to R_p

$\therefore R = 2 + 2.4 = 4.4\ \Omega$

$R + r = 4.4 + 0.6 = 5\ \Omega$

$I = \frac{\varepsilon}{R + r} = \frac{9}{5} = 1.8$ A

$I_A = 1.8$ A

$\therefore I_B = \frac{6}{10} \times 1.8 = 1.08$ A

$I_C = \frac{4}{10} \times 1.8 = 0.72$ A

9. $R = 4\ \Omega$

$\varepsilon = 2$ V

$r = 1\ \Omega$

$I = \frac{\varepsilon}{R + r} = \frac{2}{5} = 0.4$ A

$V = \varepsilon - Ir$

$= 2 - 0.4 \times 1 = 1.6$ V

10. $\varepsilon = 4$ V

$V = 3$ V

$R = 5\ \Omega$

a. $I = \frac{V}{R} = \frac{3}{5} = 0.6$ A

b. $I = \frac{\varepsilon}{R + r}$

$\therefore R + r = \frac{\varepsilon}{I} = \frac{4}{0.6} = 6.67\ \Omega$

$r = 6.67 - 5$

$r = 1.67\ \Omega$

Additional Numericals (Page 173)

1. a. $R_{PQ} = \frac{4 \times 4}{4 + 4} = \frac{16}{8} = 2\ \Omega$

b. $\varepsilon = 2 \times 2 = 4$ V

$\therefore I = \frac{4}{2} = 2$ A

c. $P = VI = 4 \times 2 = 8$ W

2. a. $R_{BC} = \frac{4 \times 4}{4 + 4} = \frac{16}{8} = 2\ \Omega$

b. $R = 6 + 2 = 8\ \Omega$

c. $R + r = 8 + 1 = 9\ \Omega$

d. $I = \frac{\varepsilon}{R + r} = \frac{9}{9} = 1$ A

$I_A = 1$ A

$V_{BC} = I_B R_B = I_C R_C = 2 \times 1 = 2$ V

$\therefore I_B = \frac{2}{4} = 0.5$ A

$I_C = \frac{2}{4} = 0.5$ A

3. $\varepsilon = 1.5$ V

$r = 0.5\ \Omega$

$R = 7\ \Omega$

$R + r = 7.5\ \Omega$

$I = \frac{\varepsilon}{R + r} = \frac{1.5}{7.5} = 0.2$ A

4. $\varepsilon = 1.5$ V

$r = \frac{4}{5} = 0.8\ \Omega$

$R = 4\ \Omega$

$R + r = 4.8\ \Omega$

a. $I = \frac{\varepsilon}{R + r} = \frac{1.5}{4.8} = 0.3125$ A

b. $I = 0.3125$ A

c. Drop in potential = $Ir = 0.8 \times 0.3125 = 0.25$ V

5. a. $\varepsilon = 6$ V

$I = 1.5$ A

$\therefore R' + r = \frac{6}{1.5} = 4\ \Omega$

$r = 0$

$\therefore R' = 4\ \Omega$

b. $R' = \frac{10 \times R}{10 + R} = 4$

$\Rightarrow 40 + 4R = 10R$

$6R = 40$

$$R = \frac{40}{6} = 6.67\ \Omega$$

c. $I_R \times R = I \times 4 = 1.5 \times 4 = 6$

$\therefore \quad I = \frac{6}{6.67} = 0.9\ A$

6. a. $R_{BAD} = 4 + 4 = 8\ \Omega$

$$R_{BD} = \frac{8 \times 8}{8 + 8} = \frac{64}{16} = 4\ \Omega$$

b. $R_{CE} = 3 + 4 + 5 = 12\ \Omega$

7. $R_{BD} = 3 + 5 = 8\ \Omega$

$$R_{BE} = \frac{8 \times 8}{8 + 8} = 4\ \Omega$$

$$R_{AE} = 6 + 4 = 10\ \Omega$$

$$R_{AF} = \frac{10 \times 5}{10 + 5} = \frac{50}{15} = \frac{10}{3} = 3.33\ \Omega$$

$$R_{PQ} = 4 + 3.33 = 7.33\ \Omega$$

8. a. Applying Ohm's Law, we get

$$V = IR$$

Let the current flowing through 3 Ω resistor be I_1 and the current flowing through 1.5 Ω be I_2.

Thus $V = I_1 \times 3$ …(1)

$V = I_2 \times 1.5 = I_2 \times 32$ …(2)

From equations (1) and (2), we get

$$I_1 \times 3 = I_2 \times 32$$

$$I_2 = 2 I_1$$

We have $I_1 + I_2 = 0.3$

$$I_1 + 2I_1 = 0.3$$

$$I_1 = 0.1\ A$$

Thus, current through 3 Ω resistor is 0.1 A.

b. Resistors in parallel connection

$$\frac{1}{R_P} = \frac{1}{3} + \frac{2}{3} = 1$$

$$R_P = 1\ \Omega$$

$$R_S = 1\ \Omega + 4\ \Omega = 5\ \Omega$$

Total resistance $= (5 + r)\ \Omega$

We know that $V = IR$

$$1.8 = 0.3 \times (5 + r)$$

Therefore $6 = 5 + r$

$r = 1\ \Omega$ is the internal resistance.

CHAPTER – 9

ELECTRICAL POWER AND HOUSEHOLD CIRCUITS

CHECK YOUR PROGRESS 1 (PAGE 180)

A. **1.** b **2.** c **3.** c **4.** b **5.** c

B. **1.** The work done by a source to maintain current in an electrical circuit is known as electrical energy.

2. $Q = I \times t$ ...(i)

$W = V \times Q$ ...(ii)

From equations (i) and (ii), we can write

$W = V \times I \times t$

Electrical work is equal to the energy consumed in the circuit

$E = V \times I \times t$

Q = Charge flowing in time t, V = Potential difference across the conductor.

3. **a.** Electrical energy = I^2Rt

b. Electrical energy (E) = V^2t/R

c. Electrical energy (E) = VIt

4. The SI unit of electrical energy is joule (J).

5. Electrical power (P) can be defined as the rate at which electrical energy is consumed in an electric circuit.

6. **a.** $P = V \times I$

b. $P = I^2R$

c. $P = \frac{V^2}{R}$

7. The SI unit of electric power is watt (W).

Electrical power is said to be 1 watt if 1 ampere current flows through an electric circuit when a potential difference of 1 volt is applied across it.

8. One kilowatt-hour is defined as the amount of work done or energy consumed when a device of power 1 kilowatt is used for an hour at rated voltage.

1 kilowatt hour = 3600 kilojoules

9. Power rating of 100 W on a bulb means it will consume 100 J of electrical energy (to the converted into heat and light) per second.

10. Commercial unit of electrical energy is kilowatt-hour (kWh), i.e.

1 kWh = 1000 Wh

1 kilowatt-hour is the amount of electrical energy consumed when an electrical appliance having a power rating of 1 kilowatt is used for 1 hour.

11. Current drawn by electric fan (I) = $\frac{\text{Power}}{\text{Voltage}} = \frac{P}{V}$

$(I_1) = \frac{110}{120}$ A

$I_1 = 0.5$ A = 0.5 A

Current drawn by TV (colour)

$I_2 = \frac{P}{V} = \frac{120}{220} = 0.55$ A

TV draws more current than a fan.

12. **a.** The above statement gives the information that when the electric bulb is put at 240 V of a potential difference it consumes 100 W of power.

b. The bulb will consume less power.

c. $R = \frac{v^2}{p}$

$= \frac{240 \times 240}{100}$

$= 576\ \Omega$

d. Electric energy (kWh) = kW × h

$= \frac{100}{100} \times \frac{10}{60}$

$= \frac{1}{60}$ kWh

C. **1.** **Bulb 1** **Bulb 2**

$P_1 = 100$ W $\quad P_2 = 60$ W

$V_1 = 220$ V $\quad V_2 = 100$ V

$P = \frac{V^2}{R}$

$R = \frac{V^2}{P}$

$R_1 = \frac{220 \times 220}{100} \quad R_2 = \frac{100 \times 100}{60}$

$= 484\ \Omega \quad = \frac{500}{3}\ \Omega$

$\frac{R_1}{R_2} = \frac{484}{500} \times 3$

$= \frac{2.904}{1}$

$R_1 : R_2 \Rightarrow 2.904 : 1$

2. $V = 220$ V

$P = 2200$ W

$T = 3$ h

$E \text{ (kWh)} = \frac{2200 \times 3}{1000} = 6.6$ kWh

$$I = \frac{P}{V} = \frac{2200}{220} = 10 \text{ A}$$

3. $I = 5$ A, $R = 2\ \Omega$, $t = 30 \times 60 = 1800$ s

$E = I^2Rt = 5 \times 5 \times 2 \times 1800 = 90{,}000$ J = 90 kJ

4. $V = 220$ V

$I = 5$ A

a. $P = VI = 220 \times 5 = 1100\text{ W} = 1.1$ kW

b. $$E\,(\text{kWh}) = \frac{P(\text{W}) \cdot t(\text{h})}{1000} = \frac{1100 \cdot 1}{1000}$$

$= 1.1$ kWh

$\therefore$ Cost @ ₹ 2.40 per unit

$= 1.1 \times$ ₹ 2.40 = ₹ 2.64

5. $P = 4$ kW = 4000 W

$V = 220$ V

a. $$I = \frac{P}{V} = \frac{4000}{220} = 18.18 = 18.2 \text{ A}$$

b. $$R = \frac{V^2}{P} = \frac{220 \times 220}{4000} = 12.1\ \Omega$$

c. $$E\,(\text{kWh}) = \frac{P \cdot t(\text{h})}{1000} = \frac{4000 \cdot 2}{1000} = 8 \text{ kWh}$$

d. Cost @ ₹ 2.40 per unit = 8×2.40 = ₹ 19.20

6. $V = 220$ V $\quad \theta_1 = 20$ °C

$R = 220\ \Omega \quad \theta_2 = 75$ °C $\quad \therefore\ \theta = 55$ °C

$$\frac{V^2}{R} \times t = mC\theta$$

$$\therefore \quad t = \frac{mC\theta \times R}{V^2}$$

$$= \frac{1 \times 4200 \times (75 - 20) \times 220}{220 \times 220}$$

= 1050 s = 17 min 30 s

7. $P = 2$ kW = 2000 W

$V = 220$ V

$M = 15$ kg $\quad (15 \times 10^{-3} \times 10^{+3})$ kg

$C = 4200$ J/kg °C

$\theta_1 = 20$ °C

$\theta_2 = ?$

$t = 15$ min $= 15 \times 60 = 900$ s

$P \times t = mC\theta$

$$\therefore \quad \theta = \frac{P \times t}{mC}$$

$$= \frac{2000 \times 900}{15 \times 4200} = 28.57 \text{ °C}$$

$\therefore \quad \theta_2 = 20 + 28.57 = 48.57 \cong 48.6$ °C

8. $P = 220$ W

$V = 220$ V

$$I = \frac{P}{V} = \frac{220}{220} = 1 \text{ A}$$

$$R = \frac{V^2}{P} = \frac{220 \times 220}{220} = 220\ \Omega$$

$$E = \frac{P(\text{W}) \cdot t\ (\text{h})}{100}\ (\text{kWh})$$

$$= \frac{220 \times 5}{1000} = 1.1 \text{ kWh}$$

$\therefore$ E in 1 month = $1.1 \times 30 = 33$ kWh

Cost @ ₹ 2.40 per unit

$= 33 \times 2.40$ = ₹ 79.20

9. $V = 200$ V

$P = 100$ W

$$R = \frac{V^2}{P} = \frac{200 \times 200}{100} = 400\ \Omega$$

$$E(\text{kWh}) = \frac{100 \times 4}{1000} = 0.4 \text{ kWh}$$

In case of 5 bulbs

$E = 0.4 \times 5 = 2$ kWh

Cost @ ₹ 2.40 per unit

$= 2 \times 2.40$ = ₹ 4.80

10. Two tubelights

$P_1 = 2 \times 40 = 80$ W

$T_1' = 5$ h

For 1 month (30 days)

$T_1 = 5 \times 30 = 150$ h

$$E_1 = \frac{80 \times 150}{1000} = 12 \text{ kWh}$$

One Fan

$P_2 = 80$ W

$T_2' = 12$ h

$T_2 = 12 \times 30 = 360$ h

$$E_2 = \frac{80 \times 360}{1000}$$

$E_2 = 28.8$ kWh

One TV

$P_3 = 60$ W

$T_3' = 8$ h

$T_3 = 8 \times 30 = 240$ h

$$E_3 = \frac{60 \times 240}{1000}$$

$E_3 = 14.4$ kWh

$E = E_1 + E_2 + E_3 = 12 + 28.8 + 14.4 = 55.2$ kWh

Cost of 1 kWh = ₹ 3.10/kWh

∴ Total cost = 55.2 × ₹ 3.10 = ₹ 171.12

Questions Based on ICSE Examination (Page 181)

1. Electrical energy = I^2Rt

2. Current drawn by the bulb, $I = 0.4$ A

Resistance of the bulb, $R = 300\ \Omega$

Power of the bulb is

$$P = I^2R$$

So, $P = (0.4)^2 \times 300 = 48$ W

Potential difference at the ends of the bulb is

$$V = IR$$

Therefore, $V = 0.4 \times 300 = 120$ V

3. Energy consumption (kW) in one week

= power (kW) × time (h)

= 2 × 7 × 2 = 28 kWh

∴ Running cost = 28 kWh × Rs 4.25 = Rs 119

4. a. $P = 100$ W

$V = 250$ V

This shows that the bulb consumes 100 J of energy every second when applied voltage is 250 V.

b. $P = VI$

$$I = \frac{P}{V} = \frac{100}{250} = \frac{2}{5} = 0.4 \text{ A}$$

5. $V = 220$ V, $P = 60$ W

a. $$R = \frac{V^2}{P} = \frac{220 \times 220}{60} = 806.67\ \Omega$$

b. $$I = \frac{P}{V} = \frac{60}{220} = 0.27 \text{ A}$$

6. $R = 4\ \Omega$, $I = 3$ A, $t = 80$ s

$E = I^2Rt = 3 \times 3 \times 4 \times 80 = 2880$ J

7. a. $P = 1000$ kW $v = 220$ V

$= 10^6$ W

$$\text{Energy} = \frac{P \times t}{1000} \text{ kWh}$$

$$= \frac{\text{ü}\ ^6 \times}{1000} \text{ kWh} = 2 \times 10^3 \text{ kWh}$$

b. 1 kWh = 3.6×10^6 J

2×10^3 kWh = $2 \times 10^3 \times 3.6 \times 10^6$ J

$= 7.2 \times 10^9$ J

8. $P = 1000$ W

$V = 200$ V

a. $$R = \frac{V^2}{P} = \frac{200 \times 200}{1000} = 40\ \Omega$$

b. $$I = \frac{P}{V} = \frac{1000}{200} = 5 \text{ A}$$

9. $P = 100$ W

$V = 220$ V

$t = 16$ h

$$E = \frac{100 \times 16}{1000} = 1.6 \text{ kWh}$$

$= 1600$ Wh

10. $t = 2$ h

$I = 8$ A

$V = 110$ V

$$\text{Energy} = \frac{\text{ü} \times \times}{1000} = \frac{110 \times 2 \times 8}{1000}$$

$= 1.76$ kWh

1 kWh = ₹ 2.50

1.76 kWh = 1.76 × 2.50 = ₹ 4.4

11. Given: $P = 440$ W

$V = 220$ V

a. ∵ Power = Current × Potential difference

i.e, $P = VI$

⇒ $I = \frac{P}{V} = \frac{440}{220}$

$= 2$ A (On putting values)

b. ∵ $P = VI$ …(i)

and $I = \frac{V}{R}$ …(ii)

⇒ $P = \frac{V^2}{R}$ [From (i) and (ii)]

⇒ $R = \frac{220 \times 220}{440} = 110\ \Omega$

Check Your Progress 2 (Page 185)

A. 1. d **2.** c **3.** b **4.** b **5.** b

6. d

B. 1. Step up transformer.

2. Electrical power from the generating station is transmitted at a high voltage because the current becomes low at a high voltage ($P = VI$) (if the power remains constant, current decreases with increase in voltage) and therefore, loss of energy due to heating (I^2Rt) in wires become less.

3. a. Grid substation — 11 kV to 132 kV
   b. Main substation — 132 kV to 33 kV
   c. City substation — 11 kV to 220 V

4. The main supply of electrical power is done at our homes using a three core cable. The three cables are:
   i. Live wire (L)
   ii. Neutral wire (N)
   iii. Earth wire (E)

   The live wire (L) is at a high voltage (220 V) and brings in the current. If we touch the live wire accidentally, we may get an electric shock.

   Neutral wire (N) provides the return path for the current and is kept at 0 potential by connecting it to the earth at the power station itself.

   The earth wire (E) from the metres is locally earthed (in the compound of the house).

5. 50 Hz

6. The wires coming out of the electric meter are connected to the main switch because the main switch is used to completely cut-off the electric supply beyond the electric meter when required so as to repair any fault in the internal wiring.

7. There are two main circuits one of 5 A and another of 15 A in domestic distribution because the domestic light (5 A line) is used for running appliances of low rating such as bulbs, tubelights, fans, radios, television, etc. The domestic power (15 A) line is used for running appliances of high ratings such as electric irons, geysers, refrigerators, etc.

8. Advantages of the tree system of distribution of power are as follows:
   i. When the distribution circuits are in parallel then each circuit operates separately. So, if one of the distribution circuits gets overloaded, only the fuse in that circuit will blow off.
   ii. When two or more appliances are used at the same time, each appliance will be able to draw the current as needed. The appliances having low resistance will draw higher current and that having higher resistance will draw smaller current.
   iii. Each circuit will have same potential difference that is equal to the potential difference in the supply lines. As a result, each electrical appliance will work under constant voltage.

9. Disadvantages of tree system of distribution of power are as follows:
   i. It requires plugs and sockets of different current values for different appliances.
   ii. Different branch lines are taken from distribution board to different parts of the house hence requiring long length of wires. As a result cost of wiring is expensive.
   iii. When a fuse in one distribution circuit melts, it disconnects all the appliances in that distribution circuit.
   iv. If a new appliance is to be installed, then it is necessary to connect through new wiring up to the distribution box. This could be quite expensive and inconvenient.

10. Electric lamps in a building should be connected in parallel across live wire and neutral wire.

11. a. Yes
    b. No

12. a. In the given figure, it is observed that the bulb is connected with live wire and the key is connected with Neutral wire when the key or switch is ON, the path of current flow is completed, hence the bulb will glow.
    b. It is NOT safe to handle the bulb when the switch is off as bulb is directly connected to live wire.
    c. In the OFF position, the bulb remains connected to the high potential terminal through the live wire, but no current flows through the bulb, as the return path is incomplete. In this condition, it is not safe to touch the bulb even from outside. As a result. if the switch is connected to the neutral wire, it might be deceiving and even harmful to the user.

Questions Based on ICSE Examination (Page 186)

1. 220 V
2. Earth and neutral wire.
3. Refer Figure 9.5, Page 184 of the textbook.

   Ring system of distribution of power:

   Refer Points 1, 2, 3, 4 from pages 184–185 of the textbook.
4. Advantages of ring system are:
   i. Every appliance has a separate fuse therefore in case of short circuit or overloading individual appliance is disconnected.
   ii. Cost of wiring is less.

iii. Plugs and sockets of same size can be used.

iv. It is economical and convenient to install new appliance.

5. a. In set *P* the bulbs are connected in series that is why when one of the bulb gets fused, the other three also stop working.

   On the other hand the bulbs in set *Q* are connected in parallel, therefore the fused bulb will not affect the other three bulbs.

   b. We prefer arrangement as in set *Q* (parallel) because

      i. the same supply voltage is available for all electrical appliances.

      ii. each device works independently. Even if one of the appliance is switched off or gets fused, it will not affect the working of other appliances.

6. Electrical appliances are connected in parallel because:

   i. The same supply voltage is available for all electrical appliances.

   ii. Each appliance works independently. Even if one appliance gets fused, it will not affect the working of other appliances.

CHECK YOUR PROGRESS 3 (PAGE 191)

A. 1. a 2. c 3. c 4. a 5. c

6. c

B. 1. An electric fuse is a safety device consisting of a piece of thin wire of material having low melting point and a high resistance, which melts and breaks the circuit if the current exceeds a safe value, hence preventing the electrical appliances in the circuit from getting damaged.

2. Two characteristics of the fuse wire are as follows:

   i. The fuse wire should be of low melting point.

   ii. The fuse wire should be of high resistivity.

3. A fuse is always connected in the live wire and in series with the electrical circuit to protect it from overloading.

4. a. Cut-out type fuse

   b. The material used for making fuse wire is an alloy of tin and lead.

   c. It has high melting point and low specific resistance.

5. The fuse is connected to the live wire.

6. The material used for making fuse wire is an alloy of tin and lead.

7. Your common types of fuses are:

   i. Cut-out type fuse

   ii. Cartridge type fuse

8. In the arrangement of cut-out type fuse, there are **a.** porcelain socket **b.** porcelain holder.

   i. Porcelain socket is fixed on the board. It is connected in the live wire of the circuit.

   ii. Porcelain fuse holder consists of two metallic terminals T1 and T2. The fuse wire is stretched between the two terminals.

   Refer Figure 9.6, Page 187 of the textbook.

9. Cartridge-type fuse consists of a glass tube having a thin fuse wire sealed inside it. The glass tube has two metal caps at its two ends. The two ends of the fuse wire are connected to these metal caps. The metal caps connect the fuse in the circuit in a suitably made bracket.

   Refer Figure 9.9(a), Page 188 of the textbook.

   Cartridge-type of fuse is used in electrical appliances like music systems, computers, TV, etc. for providing additional safety to the appliances. When a short circuit or overloading takes place, the current becomes large and heats the fuse wire. The fuse wire thus melts and breaks the circuit before any damage occurs to the electrical appliances.

   Refer Figure 9.9(b), Page 188 of the textbook.

10. The current rating of a fuse is 5 A, means the maximum current of 5 A can flow through a fuse without melting it.

11. A fuse wire is connected to the live wire and in series with the electrical circuit. It melts and breaks the circuit if the current exceeds a safe value, hence, preventing the electrical appliances in the circuit from getting damaged.

12. A switch is a device that is used to allow current to flow in a circuit or in an electrical appliance and to cut it off when desired.

    The two types of switches are:

    i. Single pole switch—used in homes, etc.

    ii. Dual control switch—used in switches, etc.

13. The switch should always be connected in the live wire because if the switch is connected in the neutral wire, then even if the switch is off, the appliance remains connected to the live wire and is at the same supply voltage. If anyone touches the live wire of the appliance accidentally, he may get a fatal electric shock.

14. An electric switch should not be touched with wet hands because water (containing dissolved minerals) is a good conductor of electricity. Water forms a conducting wire between the hand and the live wire of the switch through which the current passes to our body and we may get a fatal electric shock.

15. Dual control switches are the switches through which the appliance can be switched on or off from two different places. These are used for staircases, etc.

Working of a dual control switch

i. Let a switch S_1 be fitted at the ground floor and a switch S_2 be fitted at the first floor. The bulb is not glowing since the circuit is not complete. The bulb can now be switched on independently by either pressing switch S_1 or switch S_2.

Refer Figure 9.12, Page 189 of the textbook.

ii. If the switch S_1 (on the ground floor) is pressed, the connection ab is changed to bc, which completes the circuit and the bulb lights up.

Refer Figure 9.13, Page 189 of the textbook.

iii. On reaching the first floor and upon operating the switch S_2, the connection bc changes to ba that again breaks the circuit and the bulb is switched off.

Refer Figure 9.14, Page 189 of the textbook.

16. The earth pin of the plug is always made longer and thicker than the other pins because of the following reasons:

i. The earth pin is longer, so unlike inserting the plug, the earth connection is made first. This protects the user from getting an electric shock. If the appliance is defective, the fuse will blow off due to the earth connection.

ii. The earth pin is thicker, so that even by mistake it cannot be inserted into the live or neutral hole of the socket. It can never fit into the live or neutral holes (which are smaller).

17. A socket is a fixture in an electric circuit. The plug is inserted into the socket. A socket has three holes with the inner walls in the form of metallic cylinders.

18. **Main switch:** The main switch is used to completely cut-off the electric supply beyond the electric meter when required so as to repair any faults in the internal wiring.

Three pin plug: In a three pin plug, the top (longer and thicker) pin is for earthing, the live pin is on the right and the neutral pin is on the left.

19. Earthing of an appliance means connecting the metallic body of an electrical appliance to the earth by a conducting wire to prevent electric shock.

In a house, the local earthing is made near the electric meter. Earthing is done by connecting a metal plate to a thick copper wire surrounded by hollow insulating pipe. The metal plate is carried deep (about 5 metres) into the earth, where it is surrounded by a mixture of charcoal and salt for making good earth connection. Through the insulating pipe, water is supplied to the earth periodically, since water forms a conducting medium between the plate and the ground.

Refer Figure 9.17, Page 190 of the textbook.

20. The need for earthing of an appliance is as follows:

i. Earthing of an electric appliance is done to protect the user from any accidental electric shock.

ii. Earthing also saves the appliances from being damaged in case of short circuit and overloading.

21. The earth is regarded as electric sink because the excess current flows through the earthing to the earth.

22. Safety precautions to be taken while using electricity are as follows:

i. **Wiring** → Only good quality electrical wires should be used in electrical circuits.

ii. **Fuse** → Each circuit should have a fuse of proper rating. Fuse should be connected to the live wires.

iii. **Earthing** → All electrical appliances must be properly earthed.

23. Refer Table 9.2, Page 191 of the textbook.

24. a. The power rating of an electric appliance is the electrical energy consumer per second by the appliance when connected across the voltage of the mains.

A bulb having marking of 60 W, 220 V over it, indicate that the bulb will consume 60 J of energy per second when connected across the mains supply of voltage 220 V.

b. Live wire

c. The function of main switch in a distribution board is to switch on or off the main supply.

Questions Based on ICSE Examination (Page 192)

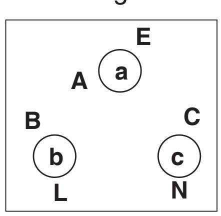
1. A fuse and an MCB.
2. The characteristic properties of fuse wire are:
   - i. It has low melting point.
   - ii. It has high resistivity.
3. A copper wire cannot be used as a fuse wire because
   - i. It has high melting point and
   - ii. It has low resistance.
4. Copper wire cannot be used as a fuse wire since meting point of copper is higher and resistance is very low and current can flow through it without melting it, and without breaking the circuit.
5. As power = voltage × current

   So, $\text{current} = \dfrac{\text{power}}{\text{voltage}}$

   $= \dfrac{5000}{200} = 25 \text{ A}$

   But the fuse is rated 8 A; hence, it cannot be used.
6. The two safety devices connected to the live wire of a domestic electrical circuit are:
   - i. **Fuse:** It prevents the electrical appliances from getting damaged during short circuit or overloading.
   - ii. **MCB:** It protects household wiring from overloading or short circuit.
7. An electric switch should not be touched with wet hands.
8. In Fig. **a.** 1. earth (E)
   2. neutral (N)
   3. live (L)

   In Fig. **b.** 4. earth (E)
   5. neutral (N)
   6. live (L)
9. According to the old convention of colour coding, the green wire is connected to the metallic body of an appliance. However, according to the new convention, the wire connected to the metallic body of an appliance may be either green or yellow.
10.



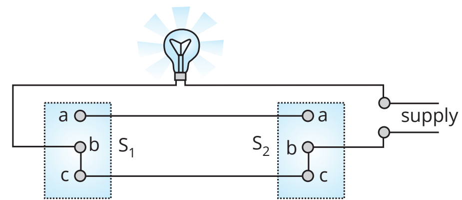
   - **a.** Brown = live wire
   - **b.** Green = Earth wire
   - **c.** Light blue = Neutral wire

   - **a.** Brown is live wire, so it will go in terminal C of the socket,
   - **b.** Green is earth wire, so it will go in terminal A of the socket.
   - **c.** Light blue is neutral wire, so it will go in terminal B.

EXERCISES

Questions Based on ICSE Examination (Page 193)

1.



On pressing switch S_1, the bulb glows since the circuit is complete

2. The household wiring is done in parallel because:
   - i. Each circuit operates separately.
   - ii. Each appliance draws the current as needed.
   - iii. Each circuit will have some potential difference.
3. A fuse is a safety device which consists of a short piece of metal on metal alloy which melts and breaks the circuit if the current exceeds a safe value.
4. **a.** Electric fuse

   b. Heating effect of electricity
5. **Bulb:** $P = 150 \text{ W}$

   $V = 220 \text{ V}$

   $$R_B = \frac{V^2}{P} = \frac{220 \times 220}{150}$$

   $R_B = 322.67\,\Omega$

   Heater: $P = 1500 \text{ W}$

   $V = 220 \text{ V}$

   $$R_H = \frac{V^2}{P} = \frac{220 \times 220}{1500} = 32.267\,\Omega$$

   $$\frac{R_B}{R_H} = \frac{10}{1}$$

   $R_B : R_H = 10 : 1$
6. The fuse wire rated at 20 A will be more thick than the fuse wire rated as 5 A because resistance of fuse wire rated at 20 A will have low resistance and resistance is inversely proportional to the area of cross section.
7. Connecting the metallic body of an electric appliance to the earth by a conducting wire to

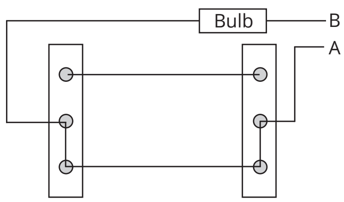
prevent electric shock is called earthing of an appliance.

8. The preventive measure of earthing can protect a person from electric shock.

9. In case the live wire gets damaged and the live wire comes in contact with the metallic body of the appliance then the current will flow to the earth through the earth connection and the potential difference of the metallic body would not be raised. Thus, earthing protects the user from electrical shock.

10. Nichrome wire is preferred for an electric heater to a copper wire because nichrome wire has high resistance and high melting point.

11. a.



b. Wire A is the live wire and wire B is the neutral wire.

12. Two circumstances under which an electrical gadget can give an electric shock to its user are:

i. Poor insulation of users.

ii. Touching electrical appliances with wet hands.

13. a. The phase wire is also known as the live wire.

b. The wire connected to the top terminal of a three-pin socket is the earth wire.

14.

$P = 3000$ W

$V = 240$ V

$t = 1.5$ h

Rate = ₹ 3.50/unit

$$E(\text{kWh}) = \frac{P(W) \times t\ (\text{h})}{1000} = \frac{3000 \times 1.5}{1000}$$

$= 4.5$ kWh

Cost @ ₹ 3.50 per unit = ₹ 3.5 × 4.5 = ₹ 15.75

15. 20 Bulbs — 1 Fan — 1 Heater

$P_1 = 20 \times 60 = 1200$ W — $P_2 = 120$ W — $P_3 = 750$ W

$T_1 = T_2 = T_3 = 8$ h

$P = 1200 + 120 + 750 = 2070$ W

$$E = \frac{2070 \times 8}{1000} = 16.56 \text{ kWh}$$

Cost @ ₹ 3.50/unit

Daily expenditure = ₹ 3.50 × 16.56 = ₹ 57.96

Additional Numericals (Page 194)

1.

$I = 4$ A

$V = 220$ V

$t = 5 \times 60$ s $= 300$ s

$E = VIt = 220 \times 4 \times 300$ J $= 2{,}64{,}000$ J

2.

$I = 5$ A

$R = 100\ \Omega$

$t = 10 \times 60$ s

$E = I^2Rt = 5 \times 5 \times 100 \times 600$

$= 1500000$ J $= 1500$ kJ

3.

$R = 5\ \Omega$

$V = 220$ V

$t = 5$ min $= 5 \times 60$ s $= 300$ s

$$E = \frac{V^2}{R} \times t = \frac{220 \times 220}{5} \times 300 \text{ J}$$

$= 2904000$ J $= 2904$ kJ

4.

$P = 200$ W

$V = 220$ V

$$I = \frac{P}{V} = \frac{200}{220} = 0.91 \text{ A}$$

5.

$P = 1500$ W

$V = 220$ V

$$R = \frac{V^2}{P} = \frac{220 \times 220}{1500} = 32.27\ \Omega$$

6.

$I = 6$ A

$V = 20$ V

$t = 5$ min $= 5 \times 60 = 300$ s

$E = VIt$

$= 20 \times 6 \times 300$

$= 36000$ J $= 36$ kJ

7.

$V = 220$ V

$R = 110\ \Omega$

$t = ?$

$M = 1$ kg

$\theta = \theta_2 - \theta_1 = 86 - 20 = 66$ °C

$C = 4200$ J/kg °C

$$\frac{V^2}{R} t = MC\theta$$

$$t = \frac{MC\theta \times R}{V^2} = \frac{1 \times 4200 \times 66 \times 110}{220 \times 220}$$

$t = 630$ s

$t = 10$ min 30 s

8. $P = 5.5$ kW = 5500 W

$V = 220$ V

a. $I = \frac{P}{V} = \frac{5500}{220} = 25$ A

b. $R = \frac{V^2}{P} = \frac{220 \times 220}{5500} = 8.8\ \Omega$

c. $t = 5$ h

$E = \frac{P \times t}{1000} = \frac{5500 \times 5}{1000}$

$= 27.5$ kWh

d. Cost @ ₹ 3/unit

Cost = 27.5 × ₹ 3 = ₹ 82.50

9. 8 Bulbs $P = 60$ W × 8 = 480 W

$t = 10$ h

$E_1 = \frac{480 \times 10}{1000} = 4.8$ kWh

Heater $P = 1000$ W

$t = 2$ h

$E_2 = \frac{1000 \times 2}{1000} = 2$ kWh

$E = E_1 + E_2 = 4.8 + 2 = 6.8$ kWh

In one month (30 days)

$E = 6.8 \times 30 = 204$ kWh

Cost @ ₹ 2.40 per unit

Cost = 204 × 2.40 = ₹ 489.60

10. $P = 5$ kW = 5000 W

$V = 240$ V

$t = 5$ h

Cost = ₹ 2.40 per unit

$E = \frac{5000 \times 5}{1000} = 25$ kWh

Cost = ₹ 2.40 × 25 = ₹ 60

11. $P = 5000$ W (5 kW)

$t = 2$ h

Cost = ₹ 3/unit

$E = \frac{5000 \times 2}{1000} = 10$ kWh

Cost = ₹ 10 × 3 = ₹ 30

12. 3 Tubes $P = 60 \times 3 = 180$ W

1 Fan $P = 150$ W

1 Heater $P = 1250$ W

Total Power $P = 180 + 150 + 1250 = 1580$ W

$t = 5$ h

$E = \frac{1580 \times 5}{1000} = 7.9$ kWh

Consumption in 1 month (30 days) = 7.9 × 30

= 237 W

Cost = ₹ 3 per unit

Cost = ₹ 3 × 237 = ₹ 711

13. $V = 220$ V

$P = 60$ W

$R = \frac{V^2}{P} = \frac{220^2}{60} = 806.7\ \Omega$

14. $V = 220$ V

$P = 60$ W

a. $R = \frac{V^2}{P} = \frac{220 \times 220}{60} = 806.7\ \Omega$

b. $I = \frac{P}{V} = \frac{60}{220} = 0.27$ A

CHAPTER – 10

ELECTROMAGNETISM

CHECK YOUR PROGRESS 1 (PAGES 201–204)

A. **1.** c **2.** b **3.** b **4.** d **5.** d
6. c **7.** c **8.** a

B. **1.** The term magnetic effect of current means that an electric current (i.e. flow of electric charge) produces magnetic effect in the space around the current-carrying conductor.

2. Experiment to demonstrate the magnetic effect of current:

Oersted's experiment showed that a current-carrying wire produces a magnetic field around it.

i. Take a thin insulated copper wire and fix it in such a way that the portion AB of the wire is in the north–south direction. The two ends of the wire are connected to a battery through a switch. A magnetic compass is kept directly below the wire AB. When no current is flowing in the wire AB, the magnetic needle is parallel to the wire AB and points in the usual north–south direction. There is no deflection in the magnetic needle (Refer Figure 10.1(a), Page 195 of the textbook).

ii. On pressing the switch, the electric current passes through the wire AB. It is found that the magnetic needle is deflected from its north–south position (Refer Figure 10.1(b), Page 195 of the textbook).

iii. On increasing the current in the wire AB, the deflection of the needle is increased and vice versa (Refer Figure 10.1(c), Page 195 of the textbook).

iv. On reversing the direction of current by reversing the polarity of the battery, the deflection of the needle is found to be in the opposite direction (Refer Figure 10.1(d), Page 195 of the textbook).

Conclusion:

Hence, we conclude from the above experiment (or Oersted's experiment) that:

i. A current-carrying conductor produces a magnetic field.

ii. The larger the value of the current in the conductor, stronger is the magnetic field and vice versa.

3. The region around a current-carrying conductor where the magnetic effect due to it can be experienced is called the magnetic field of that conductor.

The path which a north pole would follow is called a magnetic line of force.

4. Magnetic field due to a straight current-carrying conductor

i. Take a sheet of stiff but smooth cardboard and pierce a hole through its centre.

ii. Place the cardboard horizontally and pass a conducting wire vertically through the hole.

iii. Connect the ends of the wire to an ammeter A, a battery B, rheostat and a key as shown in Figure 10.2, Page 196 of the textbook.

iv. Sprinkle some iron filings on the cardboard. Switch on the key and allow the current to pass through the conducting wire. Gently tap the cardboard.

v. It is observed that the iron filings arrange themselves in concentric circles around the wire as shown in Figure 10.2(a), Page 196 of the textbook.

vi. If a small compass needle is placed on the cardboard near the wire, the direction in which the north pole of the needle points gives the direction of the magnetic field at that point.

5. Refer Figure 10.2(a), Page 196 of the textbook.

a. The number of lines of force increases.

b. The number of lines of force increases.

c. The direction of the lines of force is anticlockwise.

d. It gets deflected.

6. Properties of magnetic lines of force around the straight conductor:

i. The magnetic lines of force are in the form of concentric circles around the straight conducting wire.

ii. The plane of the magnetic lines of force is perpendicular or normal to the straight conductor.

iii. If the direction of the current in the wire is reversed, the direction of the lines of force is also reversed.

- When the direction of current is downwards, then the direction of the lines of force is clockwise.
- When the direction of current is reversed, i.e. upwards, then the direction of the lines of force is anticlockwise.

iv. On increasing the strength of current in the conducting wire, the number of lines of force around it increases, spaces between the lines of force decrease (i.e. lines of force become closer).

In other words, the strength of the magnetic field (B) is directly proportional to the current (I) passing through the conductor, i.e. $B \propto I$.

v. It is also observed that the strength of the magnetic field (B) is inversely proportional to the distance (r) from the conductor, i.e. $B \propto \frac{1}{r}$, i.e. with an increase in the distance from the conductor, the strength of magnetic field decreases. As a result, as we go away from the conductor, the spacing between the lines of force increases.

7. a. Clockwise

b. Anticlockwise

8. The direction of magnetic field around the current-carrying conductor can be determined by the following rules:

i. Right hand thumb rule

ii. Maxwell's corkscrew rule

iii. Ampere's swimming rule

9. Refer Figure 10.7 on Page 198 of the textbook.

10. Properties of magnetic lines of force due to current in a circular coil:

i. The magnetic lines of force are nearly circular near the wire.

ii. The lines of force are in the same direction, i.e. in the upward direction within the space enclosed by the wire.

iii. Near the centre of loop, the magnetic field lines are nearly parallel and the magnetic field may be assumed to be practically uniform.

iv. At the centre of the coil, the plane of magnetic lines of force is perpendicular to the plane of the circular coil.

v. The magnetic lines of force become straight and parallel at the middle point of the coil and the magnetic field may be assumed to be practically uniform in that region.

vi. The strength of the magnetic field (B) produced by a current-carrying circular coil increases

- if the strength of the current (I) in the coil is increased, i.e. $B \propto I$.
- if the number of turns (n) in the coil is increased, i.e. $B \propto n$.

vii. The magnetic field (B) increases if the radius of the circular coil is decreased, i.e. $B \propto \frac{1}{r}$. In other words, for the same current, a smaller coil will produce stronger magnetic field.

11. a. The strength of the magnetic field increases.

b. The strength of the magnetic field increases.

c. The strength of the magnetic field decreases.

12. The strength of magnetic field of an electromagnet depends on:

i. The number of turns of wire wound around the coil, and.

ii. The amount of current flowing through the wire.

13. a. At point Q South pole will get induced and at point R north pole will get induced.

b. Electromagnetic induction is the phenomenon due to which the current is induced in the coils.

c. Lenz law.

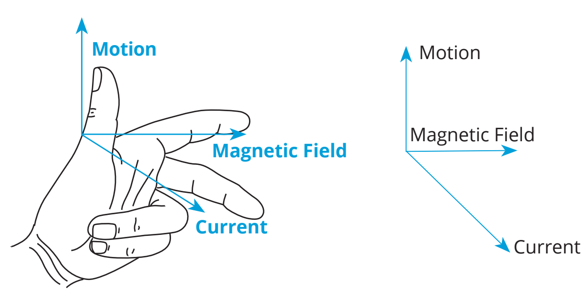
14. a. i. Force depends upon length of the wire and current flowing in the wire.

ii. Force is directly proportional to the length of the wire.

iii. Force is also directly proportional to the current flowing in the wire.

b. Fleming's left hand rule: when a current carrying conductor is placed in an external magnetic field the conductors experiences a force perpendicular to both the field and the current flow's direction.

It is used to find the direction of the force acting on the current carrying conductor placed in a magnetic field.



15. a. As the anticlock flow of current will occur at A, north pole will be produced at A: and as clockwise flow of current will occur at B, the south pole will be produced at B.

b. In order to increase the strength of the magnetic field in this coil, one can increase the number of turns on the coil and/or increase the current flow and/or place an iron core inside the hollow cardboard cylindrical tube.

c. If we place a soft iron bar at the centre of the hollow cardboard and replace the DC source with an AC source then there will be no attraction of small iron pins towards itself when the current is flowing through the coil. This is because AC will not create any magnetic effect though it is a flow of free charged particles.

16. According to the Clock rule:

i. If the current at a face facing us is in clockwise direction, that face of the coil behaves like south pole. [Refer Figure 10.8(a), Page 198 of the textbook].

ii. If the current at a face facing us is in anticlockwise direction, that face of the coil behaves like north pole [Refer Figure 10.8(b), Page 198 of the textbook].

17. Uses of electromagnets:

i. Electromagnets are used in the construction of a large number of electrical devices like electric bells, loudspeakers, electric motors, electric fans and telephone instruments, etc.

ii. Electromagnets are used to lift and transport heavy loads like big machines, steel girders and scrap iron objects for loading and unloading purposes. Unloading of goods is done by switching off the current in the electromagnet.

iii. Electromagnets are used to separate magnetic substances like iron and steel from the non-magnetic heap of metal scrap.

iv. They are used for removing pieces of iron accidentally getting into wounds or removing steel splinter from the eye.

Questions Based on ICSE Examination (Page 202)

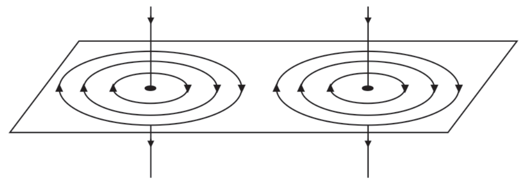
1. The needle of compass gets deflected from its north–south position because a current carrying conductor produces a magnetic field.

2. a. Refer Figure 10.2(b), Page 196 of the textbook.

b. Right-hand thumb rule.

3. **Right-hand thumb rule:** If a current-carrying conductor is imagined to be held in the right hand such that the thumb points in the direction of current, then the tips of the fingers encircling the conductor will give the direction of the magnetic lines of force.

4.



5. Refer Figure 10.7, Page 198 of the textbook.

6. a. North-pole

b. An electromagnet produces a strong magnetic field whereas magnetic field of a permanent magnet is not so strong.

7. A solenoid carrying current behaves like a bar magnet as its two ends act as the two poles of a magnet.

8. a. A solenoid carrying current behaves like a bar magnet, hence, when it is suspended freely, it comes to rest in the north–south direction.

b. North–South

9. a. North pole

b. The strength of the electromagnet can be increased by increasing the number of turns in the coil.

10. Solenoid

11. i. By increasing the number of turns in the coil.

ii. By increasing the strength of the current.

12. The device is called electromagnet. It is used to separate magnetic substances like iron and steel from the non-magnetic heap of metal scrap.

13. a. South pole

b. South pole

c. Into the plane.

14. The magnetic field of an electromagnet can be increased in the following two ways:

i. by increasing the number of turns of the coil.

ii. by increasing the strength of the current through the coil.

15. The core of an electromagnet is made of iron because it makes the magnetic field stronger and gets demagnetised as seen as the current is switched off.

16. Advantages of electromagnet over a permanent magnet are:

i. Electromagnets can get demagnetised.

ii. Electromagnets produce a stronger magnetic field.

17. **a.** At A, current flows in the clockwise direction in the coil. Hence, by the clock rule, polarity induced at A is the south pole. At B, current flows in the anti-clockwise direction in the coil. Hence, by the clock rule, polarity induced at B is the north pole.

b. By increasing the current, the strength of the magnetic field intensity can be increased.

c. If the direction of current is reversed, then polarity at A is the North Pole and polarity at B is the South Pole.

18. **a.** South pole.

b. By increasing the magnitude of current flowing through the coil.

19. **a.** In the given circuit, current is flowing in part to west direction, and the direction of needle is in south which shows there is deflection in needle. Hence, current is flowing in this direction and the switch S_1 is closed.

b. Generally, compass needle always points towards geographical north direction but in the given circuit it shows south direction. Hence, we can say that the current is flowing in the circuit and the switch S_1 is closed.

c. The purpose of placing the magnetic needle is to find whether the current is flowing in the circuit or not.

Check Your Progress 2 (Page 208)

A. **1.** b **2.** b **3.** c **4.** a **5.** b **6.** a

B. **1.** The total force experienced by a moving charged particle when both electric and magnetic fields are present are called Lorentz force.

2. The direction of the force acting on a current carrying conductor placed in a magnetic field is perpendicular to the direction of the current as well as perpendicular to the direction of the magnetic field.

3. The direction of force on a current-carrying conductor (i.e. the direction of movement of the conductor) placed in a magnetic field can be reversed by

i. reversing the direction of current flowing through the conductor.

ii. reversing the direction of magnetic field.

4. Due to interaction between two forces acting on it.

5. **i.** The force (F) is directly proportional to the current (I) flowing in the conductor, i.e. $F \propto I$.

ii. The force (F) is directly proportional to the strength of the magnetic field (B) i.e. $F \propto B$.

iii. The force (F) is directly proportional to the length of the conductor (l), i.e. $F \propto l$.

iv. The force (F) is directly proportional to the sine of the angle between the direction of current in the wire and the direction of the magnetic field, i.e. $F \propto \sin\theta$.

6. **a.** A current carrying conductor will experience maximum force when it is placed at right angle to the direction of the magnetic field.

b. A current carrying conductor will experience no force when it is placed parallel to the direction of the magnetic field.

7. The unit of magnetic field is N/Am.

8. Electric motor is a device which converts electrical energy into mechanical energy. It is based on the principle that when a current carrying conductor is placed in a magnetic field it experiences a force.

Construction:

i. Armature – Refer Page 206 of the textbook.

ii. Horseshoe magnet – Refer Page 206 of the textbook.

iii. Commutator – Refer Page 206 of the textbook.

iv. Battery – Refer Page 206 of the textbook.

v. Brushes – Refer Page 206 of the textbook.

Working of a DC motor

Figure 10.16(a), Refer Page 207 of the textbook.

Figure 10.16(b), Refer Page 207 of the textbook.

Points 1–8, Refer Page 207 of the textbook.

Questions Based on ICSE Examination (Page 208)

1. Refer Experiment 5, Page 204 of the textbook.

2. **According to Fleming's left hand rule:** Stretch the forefinger, central finger and the thumb of your left hand mutually perpendicular to each other. If the forefinger indicates the direction of magnetic field and the central finger, the direction of current, then the thumb gives the direction of the force acting on the conductor.

Refer Figure 10.13, Page 205 of the textbook.

3. Electric motor is a device which converts electrical energy into mechanical energy. It is based on the principle that when a current carrying conductor is placed in a magnetic field it experiences a force.
4. Refer Figure 10.15, Page 206 of the textbook.
5. The speed of rotation of the coil of a DC motor is increased by
   i. increasing the current in the coil.
   ii. increasing the number of turns of the coil.
   iii. increasing the area of cross-section of the coil.
6. In a DC motor, electrical energy is converted into mechanical energy.
7. Uses of a DC motor are:
   i. to run machinery in factories.
   ii. to run transports.
8. a. Commutators are two split rings which are used to reverse the direction of current flowing through the coil every time the coil just passes the vertical position during a rotation.
   b. Brushes are connected to the battery to supply current.
9. a. 0° b. 90°

Check Your Progress 3 (Page 217)

A. 1. d 2. a 3. b 4. b

B. 1. An electric current could be produced in a circuit by changing magnetic field. This phenomenon is called electromagnetic induction. The current produced in the conductor is called induced current and the electromotive force produced is called the induced e.m.f.
2. Refer Experiment 6, Page 209 of the textbook.
3. a. The induced current stays as long as there is a relative motion between the coil and the bar magnet.
   b. The direction of deflection in the galvanometer is reversed if
      i. the direction of motion of the bar magnet is reversed.
      ii. the polarity of the bar magnet is in motion.
4. The strength of the induced current depends upon the following factors:
   i. **Strength of the magnetic field:** The strength of the induced current increases with the strength of the magnetic field.
   ii. **Number of turns of wire in the coil:** Larger the number of turns in the coil, stronger is the induced current.
   iii. **Relative speed between the coil and the magnet:** Higher the relative speed between the coil and the magnet, stronger is the induced current.
5. **Faraday's laws of electromagnetic induction:**

   First law: "When the magnetic flux linking a conductor or coil changes, an e.m.f. is induced in it, an e.m.f. lasts so long as the change in the magnetic flux linking the coil continues."

   Second law: The magnitude of the e.m.f. induced in a conductor or coil is directly proportional to the rate of change of magnetic flux linked with the coil.
6. The direction of induced e.m.f. (or induced current) is such that it always tends to oppose the cause that is responsible for its existence.
7. Transformer is a device used to convert low alternating voltage at higher current into high alternating voltage at lower current and vice versa.
8. It is based on the principle of mutual induction.
9. A transformer consists of two windings, the primary and the secondary, wound on a common laminated soft iron core.

   Laminated core: The core is made up of soft iron that has a high magnetic permeability. The core is laminated to reduce the eddy current loss in the transformer.

   Primary coil: A coil of insulated copper wire wound on one arm of the laminated core. It is connected to an AC source.

   Secondary coil: A coil of insulated copper wire wound on another arm of the laminated core and its ends connected to the load.
10. **Working of a transformer:**
    i. When an alternating source of e.m.f. (E_P) is connected to the primary coil, an alternating current (I_P) flows through it.
    ii. Due to the flow of alternating current (I_P) in the primary coil, an alternating magnetic field is produced in the core of the transformer.
    iii. The laminated soft iron core links the whole of changing magnetic flux produced in the primary coil with the secondary coil.
    iv. The changing magnetic flux induces an alternating e.m.f. (E_S) in the secondary coil.

    For an ideal transformer:

$$\text{Output power} = \text{Input power}$$

$$\text{Then, Output power} = E_S I_S$$

$$\text{Input power} = E_P I_P$$

$$\therefore \quad E_S I_S = E_P I_P$$

$$\text{or} \quad \frac{E_S}{E_P} = \frac{I_P}{I_S}$$

$$\therefore \quad \frac{E_S}{E_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$$

$$= K \text{ (turns ratio)}$$

11. **Transformation ratio:** The magnitude of induced e.m.f. is directly proportional to the ratio of number of turns in the secondary coil (N_S) to the number of turns in the primary coil (N_P).

12. Two factors on which the magnitude of induced e.m.f. produced in a secondary coil depends are:

i. Transformation ratio.

ii. Magnitude of applied e.m.f.

13. **a.** An e.m.f. and hence current is induced in the coil.

b. Faraday's law of electromagnetic induction.

c. The coil behaves like north pole.

d. The coil generates an anticlockwise current in itself as seen from the magnet.

14. **a.** Step-up transformer.

b. Transformation ratio is less than 1 in step-down transformer.

c. More current flows in the secondary coil in the step-down transformer.

d. Thicker wire is used in the primary coil in the step-up transformer.

e. Thinner wire is used in the primary coil in step-down transformer.

f. Primary coil is heavily insulated in the step-down transformer.

15. Since more current flows in the primary coil, a lot of energy is lost on account of heat produced in the coil that is given by the expression I^2Rt. To reduce this energy loss, we decrease the resistance 'R' which is possible by making the primary coil thicker.

16. Primary coil is heavily insulated to prevent any short circuit due to high e.m.f. applied to it.

17. Three uses of step-up transformer are:

i. They are used in electric grids to save electrical energy during power transmission through overhead wires.

ii. Used for the production of X-rays in X-ray tubes.

iii. Used for protecting sensitive devices such as television, refrigerator, etc.

18. Three uses of step-down transformer are:

i. Used at power sub-stations to step-down the voltage before its distribution to the consumers.

ii. Used in electric bells, radio-sets, transistors, etc.

iii. Used for protecting sensitive electrical devices like TV, etc.

Questions Based on ICSE Examination (Page 218)

1. Two factors on which the magnitude of induced e.m.f. depends are:

i. Change in magnetic flux.

ii. Time in which magnetic flux changes.

2. **Fleming's Right-hand Rule:** According to this rule, stretch out the forefinger, central finger and thumb of your right hand so that they are at right angles to one another. If the forefinger points in the direction of magnetic field, thumb in the direction of motion of the conductor, then the central figure will point in the direction of the induced current.

3. **a.** Q to P **b.** Lenz's Law

4. Principle on which AC generator works is electromagnetic induction, i.e. when a coil is rotated in a uniform magnetic field, an e.m.f. is is induced in it.

5. Refer Figure 10.24 on Page 212 of the textbook.

6. Mechanical energy into electrical energy.

7. It is used to produce alternating current which is used to transport electricity to households.

8. Refer Table 10.3, Page 214 of the textbook (Any two out of the three differences).

9. Similarities between a DC motor and AC generator are:

i. In both AC generator and DC motor, a coil rotates in a magnetic field set-up between the poles of a magnet.

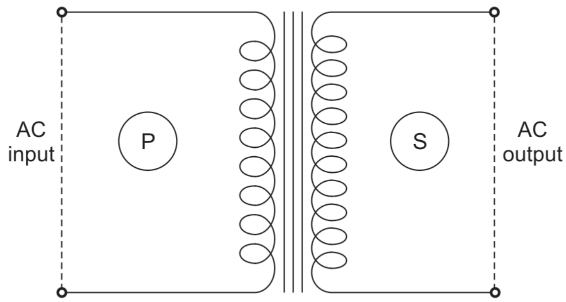
ii. There is a transformation of energy from one form to another in both AC generator and DC motor.

10. An advantage of AC over DC is that AC at any desired voltage can be obtained using transformers.

11. a. Step-up transformer

b. It is based on the principle of mutual induction, i.e. whenever the current through a coil changes, an e.m.f. is induced in the neighbouring coil.

12.



Step-up Transformer

13.

Step-up transformer	Step-down transformer
Used to change a low voltage alternating e.m.f. to a high voltage alternating e.m.f.	Used to change a high voltage alternating e.m.f. to a low voltage alternating e.m.f.
Transformation ratio > 1.	Transformation ratio < 1.
More current flows in primary coil.	More current flows in secondary coil.
Secondary coil is heavily insulated.	Secondary coil is less insulated.

14. The two factors on which magnitude of an induced e.m.f. in the secondary coil depends are:

i. Transformation ratio

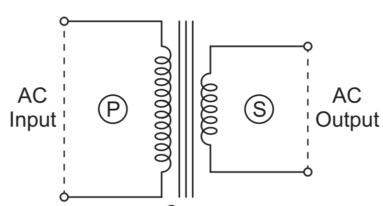
ii. Magnitude of applied e.m.f.

15. Characteristics in a step-up transformer of the following are:

i. **Primary coil:**
- Thicker wire is used in primary coil.
- It is less insulated.

ii. **Secondary coil:**
- Thinner wire is used in secondary coil.
- It is heavily insulated.

16. a. On page 216 under the column of step-down transformer.



b. Principle on which step-down transformer is based is the principle of mutual induction, i.e. whenever the current through a coil changes, an e.m.f. is induced in the neighbouring coil.

c. A step-down transformer is used to change a high voltage alternating e.m.f. to a low voltage alternating e.m.f.

17. Causes of energy loss in a transformer:

i. Eddy currents developed in the core.

ii. Hysteresis loss because of repeated magnetisation and demagnetisation of the iron core.

18. Transformer works on alternating current (AC).

EXERCISES

Questions Based on ICSE Examination (Page 220)

1. a. Refer Figure 10.11 on Page 199 of the textbook.

b. Refer Figure 10.11 on Page 199 of the textbook.

c. Magnetic field can be increased by

i. increasing number of terms of the coil.

ii. increasing the strength of the current through the coil.

2. Two ways by which e.m.f. of an AC generator can be increased are:

i. increasing number of turns in the coil.

ii. increasing the rate of change of magnetic flux.

3. a. The galvanometer shows deflection because of the flow of the current due to movement of the magnet towards and away from the magnet.

b. Current flows in the anticlockwise direction.

c. The galvanometer shows a deflection towards the left side.

d. No deflection because there is no relative motion between the coil and the magnet.

4. $x < y$ as coil B has more number of turns of wire. Larger the number of turns in the coil, stronger will be the induced current and hence greater will be the deflection.

5. Advantages of an electromagnet over a bar magnet are:

i. The strength of the magnetic field of an electromagnet can be easily changed by changing the strength of current in the coil.

ii. Polarity of electromagnet can be changed by reversing the direction of the current in the solenoid.

6. Refer Figure 10.11 on Page 199 of the textbook.

The pattern of magnetic lines of force of a current carrying solenoid is similar to that of a bar magnet.

7. The polarity of the faces of the coil depends on the direction of current and is obtained by a rule known as clock rule.

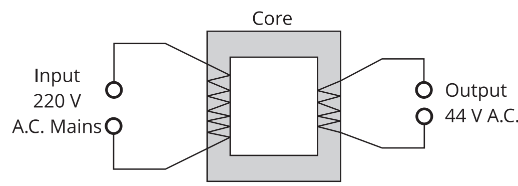
According to this rule:

i. If the current at a face facing us is in clockwise direction, the face of the coil behaves like south pole.

ii. If the current at a face facing us is in anticlockwise direction, then face of the coil behaves like north pole.

8. a. The core is made of soft iron.

b.



CHAPTER – 11

CALORIMETRY AND LATENT HEAT

Check Your Progress 1 (Page 230)

A. **1.** d **2.** c **3.** c **4.** c **5.** c
6. d **7.** c **8** d **9.** a **10** c
11. c **12.** b

B. **1.** According to the kinetic molecular theory, heat is a form of energy called thermal energy possessed by the body on account of the random motion of its molecules.

2. **a.** When we supply a certain quantity of heat energy to a body, the kinetic energy of its molecules increases and they move with a greater speed. This results in the increase of average kinetic energy of the molecules and hence, the temperature of the body rises.

b. When we remove certain quantity of heat energy from a body, the kinetic energy of its molecules decreases and they move with a lesser speed. This results in the decrease of average kinetic energy of the molecules and hence, the temperature of the body falls.

3. The principle of calorimetry is that when two bodies at different temperatures are brought in contact, the quantity of heat lost by hot body is equal to heat gained by the cold body provided there is no change of state and no heat is lost to/gained from the surroundings.

4. Heat

5. One calorie of heat is the quantity of heat required to raise the temperature of one gram of pure water from 14.5 °C to 15.5 °C.

1 calorie = 4.186 joules = 4.2 J (nearly)

6. Refer Table 11.1, Page 222 of the textbook.

7. The specific heat capacity of water is 4180 J $kg^{-1} K^{-1}$. This conveys that 4180 joules of heat energy is required to raise the temperature of 1 kg of water by 1 kelvin.

8. Heat capacity = Mass × Specific heat

9. **a.** Refer Table 11.3, Page 224 of the textbook.

b. Heat capacity = Mass × Specific heat capacity

10. Farmers always water their fields in the evening when the weather forecast is frost. The specific heat capacity of water is very high. For every degree drop in its temperature, it releases 4200 joules of heat. This cooling water liberates large amount of heat energy which does not allow the temperature of the field to fall below 0 °C. Hence, the crops are saved from the ill effect of the frost.

11. During daytime, sun shines equally on the land as well as the sea. The specific heat capacity of water is about 5 times more than that of sand.

Thus, the temperature of land rises rapidly as compared to sea. The air above the land becomes hot and light and hence, rises up. This results in lowering of pressure over the land. To make up for this drop in pressure, the cool air from sea starts blowing towards the land thereby setting up the sea breeze.

During night, the land as well as the sea radiate out heat energy. Due to high specific heat of water, land cools faster than the sea water. Therefore, the temperature of sea water is more than that of land. The air above the water being wet and light, rises up. This results in lowering of pressure over the water. To make up this drop in pressure, the cool air from the land starts blowing towards the sea thereby setting up the land breeze.

12. The property which makes water an effective coolant is high specific heat capacity of water.

13. Water is used as a coolant in car radiators. The water absorbs large amount of heat from the car engine but the radiator itself does not get heated up as it is filled with water which has a very high specific heat capacity.

14. Fomentation means heating the swollen parts of body at a moderate temperature of about 50 °C as it brings lot of relief. Due to high specific heat capacity, water can store large quantities of heat energy for a longer time period in the water bottle.

15. When a person is suffering from very high fever, sometimes a wet cloth or handkerchief is applied on his forehead.

Due to high specific heat capacity of water it absorbs a large amount of heat from the head and lowers the body temperature. Thus, the brain is protected from damage.

16. **a.** The calorimeter is made of thin sheet of copper because the specific heat capacity of copper is low and by making it thin, the thermal capacity of the calorimeter becomes still low so that it takes a negligible amount of heat from its contents so that the temperature of the contents remains stabled.

b. The inner and outer surfaces of the calorimeter are polished to reduce the loss of heat due to radiation.

c. The space between the calorimeter and the insulating jacket is filled with same poor conductor (e.g. air, cotton) to avoid loss of heat by conduction.

d. The calorimeter is covered with a lid to avoid loss of heat by convection.

17. Refer Figure 11.2, Page 227 of the textbook.

18. **Heat lost by hot body A:**

Mass of the hot body A = m_1

Specific heat of the hot body A = C_1

Initial temperature of the hot body A = t_1°C

Equilibrium temperature = t °C

Fall in temperature of the hot body A = $(t_1 - t)$ °C

Heat lost by the hot body = $m_1 \times C_1 \times (t_1 - t)$ °C

Heat gained by cold body B:

Mass of the cold body B = m_2

Specific heat of the cold body B = C_2

Initial temperature of the cold body B = t_2 °C

Equilibrium temperature = t °C

Rise in temperature of cold body B = $(t - t_2)$ °C

Heat gained by cold body = $m_2 \times C_2 \times (t - t_2)$ °C

Now, according to principle of calorimetry

Heat lost = Heat gained

$$m_1 \times C_1 \times (t_1 - t) = m_2 \times C_2 \times (t - t_2)$$

19. The apparatus designed by Sir Regnault consists of two parts – heater and calorimeter.

The heater consists of an air chamber surrounded by two coaxial cylinders. There is a face between the cylinders into which steam is supplied continuously. The top of the air chamber is closed by a cork while its bottom is closed by trap door. A thermometer is inserted inside the air chamber through the cork to read the temperature of the solid. The main purpose of the heater is to heat the solid uniformly.

The calorimeter is a cylindrical vessel made of thin copper sheets. The inner and outer surfaces of the calorimeter are polished. The calorimeter is kept inside a wooden jacket. The space between the calorimeter and the wooden jacket is (filled with some poor conductor) (e.g. cotton wool, etc.). The calorimeter is converted with an insulating lid having two holes, one for the stirrer and the other for thermometer.

20. Refer Experiment 1, Pages 227–228 of the textbook.

21. The procedure followed is same as Experiment 1 but instead of water, a liquid like kerosene of unknown specific heat capacity is taken and the solid used is of known specific heat capacity.

22. a. It is given that two metals A and B have specific heat capacities in the ration 2 : 3. They are supplied the same amount of heat. Assuming, the specific heat capacities of metals A and B are 2 C and 3 C respectively.

It is also given that masses are same.

Let us take the heat amount is Q and masses are m.

So, for metal A.

Amount of heat (Q) = $m \times 2\ C \times \Delta t_A$

and for metal B,

Amount of heat (Q) = $m \times 3\ C \times \Delta t_B$

Now we can write,

$$m \times 2\ C \times \Delta t_A = m \times 3C \times \Delta t_B$$

Simplifying $\Delta t_A = 1.5\ \Delta t_A$

Therefore, it can be said that metal A will show a greater rise in temperature than metal B.

b. $m_1 \times c_1 \times \Delta T = m_2 \times c_2 \times \Delta T\ m_1 \times 2x = m_2 \times 3x$

$\frac{m_1}{m_2} = \frac{3}{2}$ as we can see that the ratio of m_1 of metal A is high so metal A will have greater mass.

c. mass ratio = 3 : 5

specific heat capacity ratio = 2 : 3

ratio of temperature = $\frac{m_1 \times c_1 \times t_1}{m_2 \times c_2 \times t_2}$

$$= \frac{3 \times 2 \times t_1}{5 \times 3 \times t_2}$$

$$= \frac{6 \times t_1}{15 \times t_2}$$

$$= \frac{2 \times t_1}{5 \times t_2}$$

$$= t_1 : t_2 = 5 : 2$$

d. Specific heat capacity of metal

A = 0.26 J $g^{-1}C^{-1}$

SHC of metal A/SHC of metal B = 2 : 3

$$\frac{0.26}{x} = \frac{2}{3}$$

$0.26 \times 3/2 = x$

0.39 is specific heat of metal B.

23. Total heat absorbed by ice = Heat required to convert ice into water + Heat required to change the temperature from 0˚C to 100°C.

$$Q = Q_L + Q_s$$
$$Q = m\text{L} + mS\,\Delta T$$
$$Q = (200\text{ g})(336\text{ Jg}^{-1}) + (200\text{ g})(4.2\text{ Jg}^{-1\circ}\text{C}^{-1})(100°\text{C})$$
$$Q = 67200\text{ J} + 84000\text{ J}$$
$$Q = 151200\text{ J} = 151.200\text{ kJ}$$

Therefore,

Heat absorbed by ice will be 151.200 kilo-joules.

24. Mass of the metal piece m_1 = 80 g = 0.08 kg

Initial temperature of metal piece, t_1 = 120°C

Final temperature of the mixture, t = 40°C

Fall in temperature of the metal piece

$(t_1 - t)°$ C = (120 – 40)° C = 80°C

Heat capacity of metal piece = ? (To be calculated)

∴ Heat lost by metal piece = C_1 x $(t_1 - t)$

= C_1 X 80°C.

Mass of water = 0.2 kg (m_2)

Initial temp. of water t_2 = 30°C

Final temp. of water t = 40°C

Rise in temp. of water = $(t - t_2)$°C

= (40 – 30) = 10°C

Specific heat capacity of water,

$C_2 = 4.2\text{ Jg}^{-1\circ}\text{C}^{-1}$

∴ Heat gained by water and calorimeter

= 0.2 kg × 4.2 × 10°C

+ 0.08 × 0.4 × 10°C

= 8.72 kJ

= 8720 J

According to principle of calorimetry

Heat lost = Heat gain

$C_1 \times 80$ = 8720 J

So, $C_1 = \dfrac{8720}{80}$

= 109 Jg^{-1}

25. The specific heat capacity of water is 4000 Jkg–1°C^{-1} the region BC is 6.72 × 10^4 J.

Explanation:

Mass of water = $\dfrac{200}{1000}$ = 0.2 kg

Rate = 100 J/S = Q/t

Time = 640 s

a. $Q = 100 \times 640 = 64000$ J

$\Delta T = T_1 - T_2 = 80°\text{C} - 0°\text{C} = 80°\text{C}$

We know.

$Q = ms\Delta T$

Where m = mass

s = specific heat capacity

ΔT = change in temperature

64000 = 0.2 × s × 80

$s = \dfrac{64000}{0.2 \times 80} = 4000\text{ Jkg}^{-1\circ}\text{C}^{-1}$

b. In the region BC

Δt = 1312 – 640 = 672 s

Q_{Bc} = Rate × Δt

Q_{BC} = 100 × 672 = 67200

$Q_{BC} = 6.72 \times 10^4$ J

Hence, the specific heat capacity of water is 4000 J = 1 kg^{-1}°C^{-1}, and heat releases in the region BC is 6.72 × 10^4 J.

C. 1. Mass (m) = 20 kg

SHC (C) = 0.2 K cal/kg°C

= 200 cal/kg°C

Heat (Q) = 2 K cal = 2000 cal

$Q = mCt$

$t = \dfrac{Q}{mC} = \dfrac{2000}{20 \times 200}$

t = 0.5°C

2. Mass (m) = 100 g = 0.1 kg

t_1 = 100 °C

t_2 = 30°C

C = 480 J/kg°C

Heat lost = $mC(t_1 - t_2)$

= 0.1 × 480 × (100 – 30)

= 48 × 70 = 3360 J

3. Mass of aluminium (m) = 1.5 kg

C = 900 J/kg°C

Heat capacity = Mass × SHC

= 900 × 1.5 = 1350 J/°C

4. Raise in temperature (t) = 35°C

Heat supplied (Q) = 3500 J

Mass (m) = 600 g = 0.6 kg

$Q = mCt$

∴ SHC (C) = $\dfrac{Q}{m \times t} = \dfrac{3500}{0.6 \times 35}$

= 166.7 J/kg°C

Heat capacity $= m \times C$

$= 0.6 \times 166.7 = 100$ J/°C

5. Mass of solid (m_1) = 200 g

Temperature (t_1) = 100 °C

Mass of water (m_2) = 400 g

Temperature of water (t_2) = 25 °C

Final temperature (t) = 40 °C

Heat lost by hot body = Heat gained by cold body

$m_s \times C_s \times (t_1 - t) = m_w \times C_w \times (t - t_2)$

$200 \times C_s \times (100 - 40)$

$= 400 \times 4.2 \times (40 - 25)$

$$C_s = \frac{400 \times 4.2 \times 15}{200 \times 60}$$

$C_s = 2.1$ J/g °C

Questions Based on ICSE Examination (Page 232)

1. 'C' is the temperature in degree Celsius and to convert temperature in Kelvin (K), SI unit of temperature in °Celsius to Kelvin we can use the following formula: K = C + 273.

2. Specific heat capacity is defined as the amount of heat required to raise the temperature of unit mass of substance through 1 °C. Its unit is J/kg °C.

3. a. Heat capacity is defined as the amount of heat required to raise the temperature of a substance through 1 °C. It units is J/°C.

b. By making the base of a cooking pan thick, its thermal capacity becomes large and it imparts sufficient heat energy at a low temperature to the food for proper cooking. Further, it keeps the food warm for a long time after cooking.

4. Material A

Mass = 1 g = 0.001 kg

Change in temperature = 5 °C

Heat $= m_A \times C_A \times \Delta T_A$

$Q = 10^{-3} \times C_A \times 5$ ...(i)

Material B

Mass = 1 g = 0.001 kg

Change in temperature = 6 °C

Heat $= m_B \times C_B \times \Delta T_B$

$Q = 10^{-3} \times C_B \times 6$ ...(ii)

Equating equations (i) and (ii), we get

$10^{-3} \times C_A \times 5 = 10^{-3} \times C_B \times 6$

$$\frac{C_A}{C_B} = \frac{6}{5}$$

∴ Material A has higher specific heat capacity than B.

5. Mass of metal = 50 g = 0.05 kg

Initial temperature = 37 °C

Heat required for 337 °C = 2400 J

Final temperature = 337 °C

$H = m \times C \times (T_f - T_i)$

$2400 = 0.05 \times C \times 300$

$$C = \frac{24}{0.05 \times 3} = \frac{800}{5}$$

$= 106$ J kg^{-1} °C^{-1}

6. a. i. The outer and inner vessels of a calorimeter are highly polished to prevent the transference of heat energy by radiation.

ii. Metal B with specific heat capacity 380 J kg^{-1} °C^{-1} should be selected to make a calorimeter. By selecting this metal, the heat capacity of the calorimeter will be reduced and the amount of heat energy consumed by it from its contents to acquire their final temperature will also be negligible.

b. Heat energy imparted by water

$= \text{Mass}_{water} \times \text{Specific Heat Capacity}_{water} \times (t_1 - t_2)$

$= 150 \times 4.2 \times (32 - 5) = 17010$ J

If m g is the amount of ice used, then heat energy taken by ice to melt

$= m \times$ Latent heat capacity of ice

$= 330 \times m = 330\ m$

And heat energy taken by the melted ice to raise its temperature from 0° to 5 °C

$= m \times 4.2 \times (5 - 0) = 21\ m$

By law of conservation of energy,

Heat energy imparted by water = heat energy taken by ice and melted ice

$17010 = 330\ m + 21\ m$

$17010 = 351\ m$

∴ $m = 48.46$ g

Amount of ice required for this process is 48.46 g.

7. Specific heat capacity of a substance P = 3.8 J kg^{-1} °C^{-1}

Specific heat capacity of a substance Q = 0.4 J kg^{-1} °C^{-1}

a. Q is a good conductor of heat.

b. Since specific heat capacity is the amount of heat required to increase the temperature of unit mass of a substance by unit degree. Therefore, Q requires less heat, hence it is a good conductor of electricity.

c. P would be more useful in car radiators as it would act as a better coolant due to high specific heat capacity.

8. Hot water (A)

Mass = 200 g = 0.2 kg

Initial temperature = 80 °C

Cold water (B)

Mass = 300 g = 0.3 kg

Initial temperature = 10 °C

Let the final temperature = T °C

Heat lost by hot water = Heat gained by cold water

$$m_A \times C_A \times (T_i - T)_A = m_B \times C_B \times (T - T_i)_B$$

$$0.2 \times 4200 \times (80 - T) = 0.3 \times 4200 \times (T - 10)$$

$$16 - 0.2T = 0.3T - 3$$

$$19 = 0.5T$$

$$T = \frac{19}{0.5} \text{ °C} = 38 \text{ °C}$$

9. Let the mass of metallic blocks P and Q be denoted as m_P and m_Q.

Ratio $m_P : m_Q = 2 : 1$

Thus, $m_P = 2m_Q$

We know that

$$\Delta Q = C.m.\Delta T \quad \text{Or,} \quad C = \frac{\Delta Q}{m\Delta T}$$

$$\therefore \; C_P = \frac{\Delta Q}{m_P \Delta T} \quad \text{and } C_Q = \frac{\Delta Q}{m_Q \Delta T}$$

$$\therefore \; \frac{C_P}{C_Q} = \frac{m_Q}{m_P} = \frac{m_Q}{2m_Q} = 1 : 2$$

10. Liquid 'X' is water because water has highest specific heat capacity.

11. Mass of calorimeter (m_c) = 0.16 kg

Temperature of calorimeter (t_c) = 15 °C

Mass of water (m_w) = 0.02 kg

Temperature of water (t_w) = 70 °C

Final temperature (t) = 45 °C

SHC water (C_w) = 4200 J/kg °C

a. Heat lost by 1 kg of water for fall of 1 °C temperature

$$Q = m \times C \times t = 1 \times 4200 \times 1 = 4200 \text{ J}$$

b. Heat lost by water = $m_w C_w (t_w - t)$

$$= 0.02 \times 4200 \times (70 - 45)$$

$$= 84 \times 25 = 2100 \text{ J}$$

c. Heat gained = Heat lost

$$M_c \times C_c \times (t - t_c) = 2100$$

SHC of calorimeter, $C_c = \dfrac{2100}{0.16 \times 30}$ J/kg °C

$$C_c = 437.5 \text{ J/kg °C}$$

12. Metal (*m*)

Mass = 20 g

Temperature = 100 °C

C = 0.3 J g^{-1} °C^{-1}

Final temperature = 22 °C

Calorimetric (*C*)

Mass = 50 g

C = 0.42 J g^{-1} °C

Final temperature = 22 °C

Water (*w*)

Temperature = 20 °C

Final temperature = 22 °C

C = 4.2 J g^{-1} °C^{-1}

Heat lost by metal = Heat gained by calorimeter and water

$$m_m \times C_m \times \Delta T_m = (m_c \times C_c \times \Delta T_c) + (m_w \times C_w \times \Delta T_w)$$

$$20 \times 0.3 \times 78 = (50 \times 0.42 \times 2) + (m_w \times 4.2 \times 2)$$

$$468 = 42 + 8.4\, m_w$$

$$426 = 8.4\, m_w$$

$$m_w = 50.71 \text{ g}$$

13. a. Copper is a good conductor of heat. So, the calorimeter can measure the heat releases or absorbed easily.

b. Copper has low specific heat capacity and that's why it reaches the equilibrium temperature quickly by absorbing a small amount of heat.

Given, mass of water = 40 g

Specific heat capacity of water

= 4200 Jkg^{-1}°C^{-1}

Formula for thermal capacity is

= mass × specific heat capacity

or $m \times c = \frac{40 \times 4200}{1000}$

$= 168 \text{ J°C}^{-1}$

14. a. There is a lot of cold in the atmosphere after the hailstorm.

After the hailstorm ice absorbs the heat energy needed for melting, from the environment, lowering the surrounding temperature and making us feel cold.

b. This statement is false, because specific heat capacities also depend on mass of that substance, but here mass is not mentioned.

Metal piece:

Mass of metal piece (M_m) = 420 g

Initial temperature(t_i) = 80˚C

Final temp. (t_f) = 30˚C

temp. difference (Δt_m) = (80 – 30)˚C = 50˚C

Water:

mass(m_w) = 80 g

t_i = 20˚C

t_f = 30˚C

Δt_w = (30 – 20)˚C = 10˚C

Specific heat capacity (C_w) = 4.2 Jg^{-1} ˚C^{-1}

Calorimeter:

mass(m_c) = 84 gram

t_i = 20˚C

t_f = 30˚C

Δt_c = 30 – 20 = 10˚C

C_c = 200 J kg^{-1}˚C^{-1}

= 0.2 J.g^{-1}˚C^{-1}

As we know that,

Heat loss by metal = Heat gained by water + Heat gained by calorimeter

$\Rightarrow \quad m_c C_m \Delta t_m = M_w C_w \Delta t_w + m_c C_c \Delta t_c$

On putting values

$\Rightarrow \quad 420 \times C_m \times 50 = (80 \times 4.2 \times 10) + (84 \times 0.2 \times 10)$

$\Rightarrow \quad C_m = \frac{3360 + 168}{21000} = \frac{3528}{21000}$

$= 0.168 \text{J g}^{-1}\text{˚C}^{-1}$

$= 1.68 \text{ J kg}^{-1}\text{˚C}^{-1}$

Check Your Progress 2 (Page 239)

A. 1. a **2.** c **3.** a **4.** c **5.** b **6.** b

B. 1. Change of substance from one physical state to another at a constant temperature is called change of phase.

The condition needed for change of phase is that the temperature should remain constant.

2. Water can exist in three different physical states:

Solid (Ice)

Liquid (Water)

Gas (Water vapour)

Ice (solid) can be converted into water (liquid) and water (liquid) can be converted into vapours (steam/gaseous). On the other hand, water vapour when cooled gives water (liquid), which on further cooling gives ice (solid).

$\text{Ice} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Water} \underset{\text{Cool}}{\overset{\text{Heat}}{\rightleftharpoons}} \text{Steam (water vapours)}$

During the change of state, the temperature remains constant.

3. Melting: The process in which a solid on heating at a constant temperature, changes into liquid is called melting.

Melting point: The fixed temperature at which a solid gets converted into liquid is called the melting point of the substance.

4. Freezing: The process in which a liquid substance on cooling at a constant temperature, changes into a solid is called freezing.

Freezing point: The fixed temperature at which a liquid substance gets converted into solid is called the freezing point of the substance.

5. a. Pure water **b.** Wax

6. Vaporisation: The process in which a liquid on heating at a constant temperature changes into vapours is called vaporisation.

Boiling point: The fixed temperature at which a liquid gets converted into vapours is called boiling point.

7. Condensation: The process in which vapours on cooling at a constant temperature, change into liquid is called condensation.

Condensation point: The fixed temperature at which vapours get converted into liquid is called the condensation point of the substance.

8. Sublimation: The change of state of a solid directly into its gaseous state, on heating, without going through the liquid state (and vice versa on cooling) is called sublimation, for example, iodine, ammonium chloride.

9. **Heating curve:** The graph between the temperature of a substance being heated at constant rate against time is called the heating curve.

   The nature of heating curve depends on:

   i. The range of temperature over which the substance is heated.

   ii. Any change of state which might occur during heating.

10. Energy absorbed during the phase change is called latent heat.

11. The amount of heat required to change the state of unit mass of a substance without any change in the temperature is called the specific latent heat.

    Two kinds of latent heats are:

    i. The specific latent heat of fusion.

    ii. The specific latent heat of vaporisation.

12. Since temperature remains constant during change of phase, the average kinetic energy of the molecules of the substance will not change.

13. The quantity of heat required to convert unit mass of ice into liquid water at 0 °C (melting point) is called specific latent heat of fusion of ice.

14. **a.** The specific heat capacity of a substance changes when its state changes from solid to liquid.

    b. Specific heat of ice = 2090 J kg^{-1} $°C^{-1}$,

    Specific heat of water = 4180 J kg^{-1} $°C^{-1}$ and

    Specific heat of steam = 460 J kg^{-1} $°C^{-1}$.

15. Refer Experiment 2, Page 238 of the textbook.

16. **a.** Snow on the mountains do not melt all at once. Every kilogram of snow requires 336000 J of heat energy in order to form water at 0 °C. Due to the reduced intensity of heat energy available from the sun at high altitudes, the snow on the mountains changes into water slowly.

    b. It becomes bitterly cold as soon as snow starts melting. Every kilogram of snow requires 336000 J of heat energy in order to form water at 0 °C which it takes from the surroundings making the surroundings bitterly cold.

    c. Water bodies like lakes and ponds do not freeze suddenly in cold countries because every one kilogram of water on freezing at 0 °C releases 336000 J of heat energy to the surroundings.

    d. The weather becomes mild during a snowstorm because every one kilogram of water on freezing at 0 °C releases 336000 J of heat energy to the surroundings.

    e. Soft drinks are cooled by ice cubes than by ice water because every gram of ice absorbs 336 J of heat from the drink to melt into water at 0 °C. Thus, the cold drink loses a considerable amount of heat and can be cooled effectively.

17. **i.** Take some water in a beaker. Place a thermometer in the water and note down the temperature. Let the water be at an initial temperature of 20 °C.

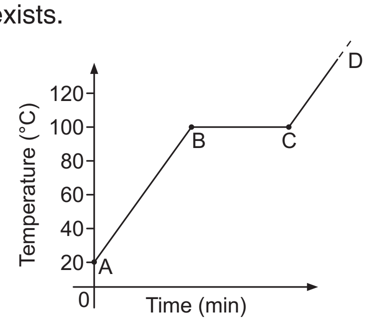
    ii. Heat this water by using a burner. It is observed that the temperature of the water increases. Record the temperature at regular intervals of one minute.

    iii. It is observed that the temperature increases until it reaches 100 °C at which the water boils to form steam but the thermometer reading remains at 100 °C showing that there is no rise in temperature during the boiling of water. The temperature remains constant at 100 °C as long as there remains some water. When all the water has boiled to form steam then the temperature begins to rise again.

    iv. The above results can be shown in the form of a 'temperature–time' graph drawn by using the readings obtained in the experiment.

    v. In this graph, the region AB indicates the gradual rise in the temperature of water. At the point B which corresponds to the temperature of 100 °C, the water begins to boil. The region BC in the given graph shows a constant temperature of 100 °C during the period when boiling of water takes place. At point C, all the water has boiled to form steam. Thus, we have only steam at point C. Now the temperature of steam starts rising as shown by the sloping line CD in the graph.

    vi. In the region AB, water exists only in its liquid form. In the region BC, water and steam co-exist. In the region CD, only steam exists.



C. 1. Mass of ice (m) = 1 kg

Temperature = 0 °C

Ice is converted into water (m) = 1 kg

Temperature = 0 °C

$\therefore$ Heat gained = mL

$L = 3.3 \times 10^5$ J/kg

$Q = 1 \times 3.3 \times 10^5$

$= 3.3 \times 10^5$ J

2. Mass of block (m_1) = 10 kg

Temperature of block (t_1) = 1000 °C

Mass of ice melted (m_2) = 4 kg

SLH of ice = 3.35×10^5 J/kg

Heat lost by block = Heat gained by ice

$$m_1C_1(t_1 - 0) = m_2L$$

$$C_1 = \frac{4 \times 3.35 \times 10^5}{10 \times 1000}$$

$$C_1 = 134 \text{ J/kg °C}$$

3. i. 1.5 kg of ice at 0 °C

↓ is converted into

1.5 kg of water at 0 °C

$$Q_1 = \text{mL} = 1.5 \times 3.35 \times 10^5 \text{ J}$$

$$= 502500 \text{ J}$$

ii. 1.5 kg of water at 0 °C

↓ is converted into

1.5 kg of water at 15 °C

$$Q_2 = mCt$$

$$= 1.5 \times 4186 \times (15 - 0)$$

$$= 94185 \text{ J}$$

Total heat required

$$Q = Q_1 + Q_2$$

$$= 502500 + 94185$$

$$= 596685 \text{ J} = 5.97 \times 10^5 \text{ J}$$

Questions Based on ICSE Examination (Page 241)

1. The heat supplied goes is used to bring about a change in the state of matter.
2. Melting point decreases.
3. Water is containing impurities which has resulted in increased boiling point of water.
4. Latent heat is absorbed.
5. Refer Figure 11.5(b), Page 235 of the textbook.
6. Kinetic energy remains same.

7. a.

$$H = m \times C \times \Delta T$$

$$1000 = m \times 500 \times 80$$

$$m = \frac{1000}{500 \times 80} \text{ kg}$$

$$= \frac{1}{40} \text{ kg} = \frac{1000}{40} \text{ g} = 25 \text{ g}$$

b.

$$1000 = m \times L_f$$

$$1000 = \frac{25}{1000} \times L_f$$

$$L_f = \frac{100 \times 10^4}{25} = 4 \times 10^4 \text{ J/kg}$$

8. Refer Figure 11.5(b), Page 235 of the textbook.

9. $m = 2$ kg

Thermal capacity = 966 J/°C

a.

$$H = C_T \times \Delta T$$

$$= 966 \times 20 = 19320 \text{ J}$$

b.

$$C = \frac{C_T}{m}$$

$$= \frac{966}{2} = 483 \text{ J/kg °C}$$

10. a. It means 50 J of heat energy is required to increase the temperature of the whole body by 1°C or 1 K.

b. It means 336000 J of heat energy is required to convert 1 kg of the substance from solid state to liquid state at its melting point without any change of temperature.

c. It means 0.4 J of heat energy is required to increase the temperature of 1 g of copper by 1 °C.

11. The weather becomes very cold after a hailstorm because the heat is absorbed from the surrounding when ice melts.

12. The temperature of surrounding falls when ice melts because heat is absorbed during the melting of ice.

13. Every 1 kg of water on freezing at 0 °C releases 336000 J of heat energy to the surroundings. Hence, water bodies like lakes and ponds in cold countries do not freeze at once.

14. Drinks are cooled by ice because every gram of ice absorbs 336 J of heat from the drink to melt into water at 0 °C. Thus, the drink loses considerable amount of heat and can be cooled effectively.

15. Ice cream, at 0 °C when melts, absorbs more heat in the form of specific latent heat of fusion (i.e. 336 J/g) which the water at 0 °C does not have and hence ice cream appears cooler than water at 0 °C.

16. Energy absorbed for melting in 4 min

$$= 100 \times 4 \times 60 = 24000 \text{ J}$$

Specific latent heat of fusion of the metal

$$= 24000/0.150 = 160 \text{ kJ/kg}$$

17. a. Kinetic energy increases.

b. Potential energy increases but kinetic energy remains same.

18. Specific heat capacity of water is much less than the specific latent heat of vaporisation of steam. Hence, it takes more time for a given mass of water to boil off rather than to reach its boiling point from 20 °C.

19. Heat required to convert 10 kg of ice at 0 °C to 10 kg of water at 0 °C.

SLH ice = 334 kJ/kg

m = 10 kg

Change of state takes place

$$Q = mL = 10 \times 334000 \text{ J} = 3340 \text{ kJ}$$

20. a. Mass of ice = 150 g

Mass of water = 30 g

t_1 = 0 °C

Final temperature = 0 °C

150 g of ice at 0 °C changes to 150 g of water at 0 °C

Heat gained = Heat required

$$Q = mL = 150 \times 336 \text{ J} = 50400 \text{ J}$$

Heat lost by steam

Mass of steam at 100 °C

Q_1 changes to mass of water at 100 °C

Q_2 changes to mass of water at 0 °C

$$\text{Heat lost} = Q = Q_1 + Q_2 = mL + mCt$$

$$= m \times 2260 + m \times 4.2 \times 100$$

$$= m(2260 + 420) = m(2680)$$

Heat gain = Heat lost

$$\therefore \quad 2680\,m = 50400$$

or $$m = \frac{50400}{2680} \text{ g}$$

$$m = 18.8 \text{ g}$$

b. Amount of water = 150 + 30 + 18.8

= 198.8 g

21.

Cold water	Hot water
Mass (m_1) = 600 g	Mass (m_2) = 300 g
SHC C_1 = 4.2 J/g °C	C_2 = 4.2 J/g °C
t_1 = t °C	t_2 = 50 °C

Final temperature (T) = (t + 15) °C

Heat gain = Heat lost

$$m_1C_1(T - t_1) = m_2C_2(t_2 - T)$$

$$600 \times 4.2 \times 15 = 300 \times 4.2 \times (50 - t - 15)$$

$$30 = 35 - t$$

$$t = 5 \text{ °C}$$

22. Mass of ice = 40 g

Temperature of ice = 0 °C

Mass of water = m g

Initial temperature = 60 °C

Final temperature = 10 °C

Heat loss = Heat absorbed

$$40 \times 10^{-3} \times 336 \times 10^3 + 40 \times 10^{-3} \times 4200 \times 10 = m \times 4200 \times 50$$

$$13{,}440 + 1680 = 210000\,m$$

$$15{,}120 = 210000\,m$$

$$m = \frac{15{,}120}{210000}$$

= 0.072 kg = 72 g

23. Mass of water = 5 g

Initial temperature = 20 °C

Final temperature = 0 °C (ice)

Heat energy released = 5 × 4.2 × 20 + 5 × 336

= 5 × 84 + 1680

= 420 + 1680

= 21000 J

24. Mass of water = 100 g

Initial temperature = 20 °C

Final temperature = –10 °C (ice)

Time = 35 min

Heat extracted = 100 × 4.2 × 20 + 100 × 336 + 100 × 2.1 × 10

= 8400 + 33600 + 2100

= 44,100 J

$$\text{Average rate of heat extraction} = \frac{44{,}100}{35 \times 60}$$

$$= 21 \text{ W}$$

25. Melting point = 40 °C

Boiling point = 160 °C

26. Mass of water = 250 g = 0.25 kg

Mass of copper vessel = 50 g = 0.05 kg

Initial temperature = 30 °C

Final temperature = 5 °C

Let the mass of ice required = m kg

Heat lost = Heat absorbed

$$m \times 336 \times 10^3 + m \times 4200 \times 5$$

$$= 0.05 \times 400 \times 25 + 0.25 \times 4200 \times 25$$

$$357 \times 10^3\, m = 500 + 26{,}250$$

$$m = \frac{26{,}750}{357 \times 10^3}$$

$$= 74.92 \text{ g}$$

27. a. Condenses at 150°C

Solidifies at 60°C

b. 150° – 60° = 90°C

c. Because ice takes heat equal to its latent heat without raising temp.

28. Mass of ice = 100 g

Initial temperature = 0 °C (ice)

Final temperature = 0 °C (water)

Heat absorbed = $m \times L$

$$= 100 \times 336 = 33600 \text{ J}$$

$$P = \frac{33600}{2 \times 60} = 280 \text{ J/s}$$

Initial temperature = 0 °C

Final temperature = 20 °C

Heat absorbed = $100 \times 4.2 \times 20$

$$= 8.4 \times 10^3 \text{ J}$$

$$\text{Time taken} = \frac{8.4 \times 10^3}{280} = 30 \text{ s}$$

29. Mass of ice = 100 g

Temperature of ice = 0 °C

Mass of liquid = 300 g

Temperature of liquid = 30 °C

Heat absorbed = Heat lost

$$100 \times 33.6 = 300 \times 2.65 \times (30 - T)$$

$$30 - T = \frac{336}{3 \times 2.65}$$

$$30 - T = 42.26$$

$$T = -12.26 \text{ °C}$$

30. Mass of water = 40 g

Temperature of water = 60 °C

Inside vessel

Mass of water = 50 g

Temperature of water = 20 °C

Final temperature = 30 °C

Heat lost = Heat absorbed

$$40 \times 4.2 \times 30 = 50 \times 4.2 \times 10 + m_v \times C_v \times 10$$

$$5040 = 2100 + \text{thermal capacity} \times 10$$

$$2940 = 10 \times C_T$$

$$C_T = 294 \text{ J/°C}$$

EXERCISES

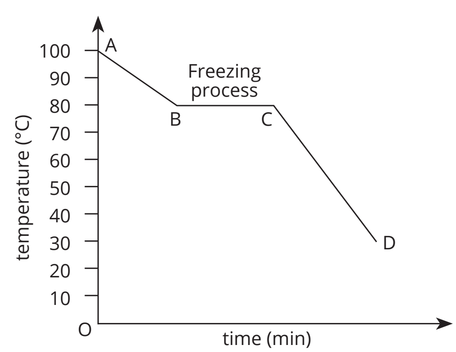
Questions Based on ICSE Examination (Page 243)

1. a. Calorimetry is the science associated with determining the changes in energy of a system by measuring the heat exchanged with the surroundings. In other words, it is the measurement of the amount of heat released or absorbed in a chemical reaction, change of state, or formation of a solution.

b. The material used for making a calorimeter is copper.

c. A calorimeter is made of thin sheet of copper because the specific heat capacity of copper is low and by making it thin, the thermal capacity of the calorimeter becomes still low so that it takes a negligible amount of heat from its contents (so that the temperature of contents remains stable).

d.



e. Given: Mass of water = 104 g

Mass of copper vessel = 42 g

Initial temperature = 30 °C

Final temperature = 10 °C

Let the mass of ice added = m g

According to the principle of calorimetry

Heat lost = Heat absorbed

$$104 \times 4.2 \times (30–10) + 42 \times 0.4 \times (30–10) = m \times 336 + m \times 4.2 \times (10–0)$$

$$m = (436.8 + 16.8) \times \frac{20}{378}$$

$$m = \frac{9072}{378} = 24 \text{ g}$$

2. a. 160 °C

b. Substance in a liquid state changes to solid state.

c. Specific latent heat of vaporisation of the substance is greater than specific latent heat of fusion of the substance.

3. a. Due to the high specific heat capacity, water can store large quantities of heat energy for a longer time period in the hot water bottles.

b. We know that we need to supply about 340 joule of heat per g, to convert ice at 0°C. It follows that ice-cream, at 0°C, will draw more heat (about 340 joule more per gram) from our body than water at 0°C. It therefore, feels colder than water at 0°C.

c. Due to high specific heat capacity water can absorb large quantities of heat, thus making the roads and surrounding cooler.

d. Due to high specific heat capacity of water, it can absorb great quantities of heat. Hence, the temperature falls sharply after a shower.

e. The specific heat capacity of stone is less than that of water. Thus, the time required for stone to get heated in the same duration of time is less than that of water. So, the stone lying in the sun gets heated up much more than water lying for the same duration of time.

f. Water has high specific heat capacity. It absorbs great quantities of heat. Thus, it is best for quenching thirst.

g. In cold countries, the water within fruits and vegetables freezes and hence damages them. To avoid such damage water tubs are kept. Water gives 4200 J of heat energy for every 1 kg for 1 °C fall in temperature. Hence, there is no damage to fruits and vegetables.

4. Refer Figure 11.5(b), Page 235 of the textbook.

5. Substance B is a good conductor of heat as the amount of heat required to raise the temperature of substance A is much more than that required for substance B.

6. Mass of calorimeter = 5 g

Mass of water = 50 g

Initial temperature = 30 °C

Mass of ice = 5 g

Final temperature = 20 °C

a. Total quantity of water at 20 °C

= 50 g + 5 g = 55 g

b. Heat released by calorimeter = $5 \times 0.4 \times 10$

= 20 J

Heat released by water = $50 \times 4.2 \times 10$

= 2100 J

Total heat released by water and calorimeter

= 2100 J + 20 J = 2120 J

c. Heat gained by ice = $5 \times L_{ice} + 5 \times 20 \times 4.2$

= $5 \times L_{ice}$ + 420 J

d. $5 \times L_{ice}$ + 420 J = 2120 J

$$5 \times L_{ice} = 2120 – 420$$

$$L_{ice} = \frac{1700}{5} = 340 \text{ J/g}$$

7. a. 4200 J

b. Heat released by water = $0.04 \times 4200 \times 25$

= 4200 J

c. Specific capacity of calorimeter

$$= \frac{4200}{0.32 \times 30} \text{ J/kg /°C}$$

= 437.5 J//kg /°C

8. Heat gained by water = $80 \times 4.2 \times 3$

Specific heat capacity of the solid

$$= \frac{80 \times 4.2 \times 3}{50 \times 80} \text{ J g–1 °C}^{-1}$$

= 0.252 J g^{-1} °C^{-1}

9. $15 \times L_{ice} + 15 \times 4.2 \times 50 = 8190$

$$15 \times L_{ice} + 3150 = 8190$$

$$15 \times L_{ice} = 5040$$

$$L_{ice} = \frac{5040}{15} = 336 \text{ J g}^{-1}$$

10. a. i. Slope AB denotes specific heat of a solid, while CD denotes specific heat of a liquid.

ii. t_1 is the melting point of the substance, while t_2 is the boiling point of the substance.

b. We have Specific heat capacity of water = 4.2 $Jg^{-1}K^{-1}$

Specific latent heat of fusion of ice = 336 Jg^{-1} Let the final temperature of water be T.

Heat energy gained by ice

$= m_{ice} \times (L + C_P T)$

$= 60 \times (336 + 4.2 \times T)$ …(1)

where m_{ice} is the mass of ice, L is the latent heat of fusion of ice and C_p is the specific heat of water. Heat energy lost by water = $m_w \times C_p \times (50 - T)$

$= 140 \times 4.2 \times (50 - T)$ …(2)

where m_w is the mass of water. By conservation of energy, Heat energy gained by ice is equal to the heat energy lost by water. So, from equations (1) and (2) we have

$140 \times 4.2 \times (50 - T) = 60 \times (336 + 4.2 \times T)$
$14T = 154$

Therefore $T = 11$ °C the final temperature of water

Additional Numericals (Page 244)

1. Heat required = 150 g × 4.2 × 65 J

= 40950 J = 40.95 kJ

2. Rise in temperature = $\frac{1000}{50}$ = 20 °C

3. Heat capacity = 1.5 × 390 J $°C^{-1}$

= 585 J $°C^{-1}$

4. Heat capacity = $\frac{7800 \text{ J}}{20 \text{ °C}}$ = 390 J $°C^{-1}$

5. Heat supplied by the immersion heat

= 1200 × 10 × 60

= 720000 J

a. Heat capacity of the liquid

$= \frac{720000 \text{ J}}{72 \text{ °C}}$ = 10,000 J $°C^{-1}$

b. Specific heat capacity = $\frac{10000 \text{ J °C}^{-1}}{4 \text{ kg}}$

= 2500 J kg^{-1} $°C^{-1}$

6. Let the final temperature be t.

$600 \times 4.2 \times (100 - t) = 300 \times 4.2 \times (t - 20)$

$2 (100 - t) = (t - 20)$

$200 - 2t = t - 20$

$3t = 220$

$t = \frac{220}{3}$ = 73.33 °C

7. Let the final temperature be t °C

$400 \times 0.42 \times (100 - t) = 100 \times 4.2 \times (t - 20)$

$0.4 \times (100 - t) = t - 20$

$40 - 0.4\, t = t - 20$

$1.4\, t = 60$

$t = \frac{60}{1.4}$ = 42.86 °C

8. $1.5 \times L \times 70 = 0.5 \times 4200 \times 10$

$L = \frac{0.5 \times 4200 \times 10}{1.5 \times 70}$ J kg^{-1} $°C^{-1}$

= 200 J kg^{-1} $°C^{-1}$

9. Heat required = 0.5 × 3.35 × 10^5 J

= 1.675 × 10^5 J

10. Mass of ice that can be melted

$= \frac{13400 \text{ J}}{3.35 \times 10^5 \text{ J/kg}}$

= 4000 × 10^{-5} kg = 40 g

11. Heat required = 1.5 × 3.35 × 10^5 J + 1.5 × 4180 × 20 J

= 5.025 × 10^5 J + 1.254 × 10^5 J

= 6.279 × 10^5 J

12. Heat required = 2 × 3.35 × 10^5 J + 2 × 4180 × 15 J

= 6.7 × 10^5 J + 1.254 × 10^5 J

= 7.954 × 10^5 J

CHAPTER – 12

RADIOACTIVITY AND NUCLEAR ENERGY

Check Your Progress 1 (Page 258)

A. **1.** b **2.** d **3.** c **4.** d **5.** b

6. c **7.** c **8.** b **9.** c

B. **1.** The three sub-particles of an atom are electrons, protons and neutrons.

The distinction between electron, proton and neutron on the basis of mass and charges is

	Electron	**Proton**	**Neutron**
Mass	9.1×10^{-31} kg	1.67×10^{-27} kg	1.6×10^{-27} kg
Charge	– vely charged	+ vely charged	Neutral

2. The size of the nucleus is extremely small (diameter = 10^{-15} m) as compared to the size of an atom (diameter = 10^{-10} m). So, most of the space in an atom is empty.

3. The atom is electrically neutral because the number of electrons is always equal to the number of protons.

4. The negatively charged particles called electrons revolve around the nucleus in circular orbits called energy levels or shells. The centripetal force required for the revolution of electrons around the nucleus is provided by the Coulombian force of attraction between the nucleus and the electrons.

5. The distribution of electrons in the various shells of an atom is known as electronic configuration and takes place in such a way so as to achieve maximum stability for the atom.

6. The attractive force in the nucleus exceeds in magnitude of the repulsive force which binds the protons and the neutrons inside the nucleus, i.e. the attractive nuclear force between the proton–proton and neutron–neutron and also neutrons and protons is stronger than the Coulombian repulsive forces.

7. The characteristics of isotopes are

i. The physical properties of the isotopes of an element are different because isotopes have different number of neutrons in their nuclei.

ii. The chemical properties of the isotopes of an element are identical because all isotopes have same number of electrons.

8. The chemical property of an element is determined by its valence electrons. Since in an isotope, the number of electrons are equal, therefore, all the isotopes of an element have identical chemical properties.

9. Atoms of different elements having same mass number (*A*) but different atomic numbers (*Z*) are called isobars, for example, ${}^{14}_{6}C$ and ${}^{14}_{7}N$.

10. Isobars have different atomic numbers, hence isobars have different number of electrons or valence electrons which result in different chemical properties.

11. The phenomenon of spontaneous emissions of radiations by heavy elements is called radioactivity, for example, radium (${}^{226}_{88}Ra$), polonium (${}^{210}_{84}Po$), uranium (${}^{238}_{92}U$).

12. Since radioactivity is unaffected by temperature, pressure and other physical or chemical conditions, we conclude that radioactivity is a nuclear property.

13. Small amount of radium is placed in a block of lead with a small hole. When the radiations coming out of the hole were subjected to electric field it was observed that the radiations split into three parts.

i. One part bent towards the negative plate, showing that they are positively charged α-particles.

ii. The second part bent towards the positive plate, showing that they are negatively charged β-particles.

iii. The third part went undeflected. This constituted γ-rays. They are electrically neutral electromagnetic waves of very short wavelength.

14. When the radiations coming out of the radioactive substance is subjected to an electric field the α-particles bend towards the negative plate by a small amount showing that they are heavy and positively charged particles (${}^{4}_{2}He$).

15. A part of rays coming out of the radioactive substance is when subjected to electric field bends towards the positive plate by a large amount showing that they are light and negatively charged particles (${}^{0}_{-1}C$).

16. A part of rays coming out of the radioactive substance goes undeviated. These are the electrically neutral γ-rays and are electromagnetic waves with small wavelengths.

17. α-particles are positively charged, β-particles are negatively charged and γ-radiations are electrically neutral.

Refer any four properties from Table 12.3, Page 252 of the textbook.

18.

	Speeds
α-particle	$(1.4 - 2.2) \times 10^7$ m/s
β-particle	2.97×10^8 m/s
γ-radiation	3×10^8 m/s

19. Elements having atomic number beyond 82, have nuclei which generally have too many neutrons as compared to the protons on too many protons as compared to the neutrons in the nucleus. Hence, the nuclear force of attraction is less than the electrostatic force of repulsion which makes the nuclei of the atom unstable.

20. a. ${}^{238}_{92}U \xrightarrow{\text{a decay}}$ fi ${}^{234}_{90}Th + {}^{4}_{2}He$

b. ${}^{218}_{84}Po \xrightarrow{\text{a decay}}$ fi ${}^{214}_{82}Pb + {}^{4}_{2}He$

c. ${}^{A}_{Z}X \xrightarrow{\text{a decay}}$ fi ${}^{A-4}_{Z-2}Y + {}^{4}_{2}He$

21. ${}^{A}_{Z}X$ fi ${}^{P}_{Q}Y + {}^{4}_{2}He_{\text{a-particle}}$

$\therefore \quad Q = Z - 2 \qquad P = A - 4$

22. The phenomenon of emission of electrons from a radioactive nucleus is called β-decay.

During a β-emission atomic number increases by one and mass number remains unchanged.

23. a. ${}^{A}_{Z}X \xrightarrow{\text{b decay}}$ fi ${}_{Z+1}^{A}Y + {}^{0}_{-1}e$

b. ${}^{14}_{6}C \xrightarrow{\text{b decay}}$ fi ${}^{14}_{7}N + {}^{0}_{-1}e$

24. a. $222_{86}Rn \rightarrow {}^{218}{}_{84}Po + {}^{4}2\alpha$

b. This alpha particle radiation is less deflected. This shows that they are heavy charged particles.

25. ${}^{A}_{Z}X$ fi ${}^{P}_{Q}Y + {}^{0}_{-1}e$ (b-particle)

$Q = Z + 1 \qquad P = A$

26. ${}^{198}_{82}X$ fi ${}^{194}_{80}Y + {}^{4}_{2}He$ (a-particle)

${}^{194}_{80}M$ fi ${}^{194}_{81}Y + {}^{0}_{-1}e$ (b-particle)

$\therefore \quad b = 81,\ a = 194$

27. The phenomenon of emission of gamma rays (photons) from a radioactive nucleus is called gamma decay. There is no change in atomic number and mass number during a gamma decay.

28. a. ${}^{A}_{Z}X^{*}$ fi ${}^{A}_{Z}X$ + g **b.** ${}^{12}_{6}C^{*} \longrightarrow {}^{12}_{6}C + \gamma$

29. Three uses of radioactive isotopes in medicines are:

i. Radioactive cobalt $\left({}^{60}_{27}Co\right)$ is used to remove brain tumors and some types of cancer.

ii. Radioactive phosphorus is used for the treatment of bone disease.

iii. Radioactive sodium is used to diagnose restricted circulation of blood.

30. Three uses of radioactive isotopes in agriculture are:

i. Radioactive tracers are used to study the growth of plants with respect to the type of chemical manure used.

ii. Radioactive radiations are used to eliminate pests.

iii. Radioactive isotopes are used to develop new and improved variety of plants by forced mutation.

31. a. Radioactive isotopes are used as fuel for generating electricity in the atomic power stations.

b. They are used to investigate the wear and tear in complex machines.

Harmful effects of radiations at

a. Somatic level: It causes irreversible damage to the somatic cells, thereby causing illness like leukemia, cancer, total blindness, etc.

b. Genetic level: This causes mutation in the chromosomes leading to various genetic disorders, leading to blindness, physical handicap, etc.

32. People working in places like nuclear power plants and dealing with radioactive material are constantly exposed to harmful radiations. Such people should take the following safety precautions:

i. They should put on lead lined aprons, lead gloves and use long lead tongs for handling radioactive material.

ii. They should wear specially constructed film badges.

iii. Radioactive substances should be stored in thick lead containers.

33. People working in a nuclear power plant wear a special lead lined apron because lead absorbs the harmful radiations striking its walls.

34. The radiation from all the sources whether they are a part of earth's radioactive substances or caused by man, like nuclear testing or use of nuclear weapons to which the man is exposed all times is called background radiations.

These radiations come from all radioactive substances and also from nova and supernova activities taking place in the universe.

35. The methods to reduce radioactive pollution are:

- **i.** Manufacture and use of nuclear weapons should be banned.
- **ii.** Limiting the emission of radioactive pollutants.
- **iii.** Recycling the used nuclear fuel by processing.
- **iv.** Radioactive wastes should be disposed after proper treatment.

36. Background radiations can be kept below the maximum permissible level for human safety by banning the use of nuclear weapons, restricting nuclear explosive device testing, etc.

37. When Uranium–235 atoms are bombarded with slow moving neutrons, the heavy uranium breaks up to produce two medium weight atoms, barium–139 and krypton–94 with the emission of 3 neutrons.

$$^{235}_{92}\text{U} + ^{1}_{0}n \longrightarrow ^{139}_{56}\text{Ba} + ^{94}_{36}\text{Kr} + 3^{1}_{0}n + \text{energy}$$

38. The process in which two lighter nuclei fuse to form a stable heavier nucleus with the liberation of enormous amount of energy is called nuclear fusion. For example,

$$\underset{\text{Deuterium}}{^{2}_{1}\text{H} + ^{2}_{1}\text{H}} \xrightarrow[\text{fusion}]{\text{nuclear}} \underset{\text{Helium}}{^{3}_{2}\text{He}} + ^{1}_{0}n + \text{energy}$$

Questions Based on ICSE Examination (Page 260)

1. a. Atomic Number: The number of protons present in the nucleus of an atom is called its atomic number. It is denoted as (Z).

b. Mass Number: The mass number is defined as the sum of the number of protons and neutrons in the nucleus of an atom. It is denoted by A.

2. a. Isotopes

b. Isotopes of an element have different number of neutrons in their nuclei but same number of electrons.

3. The phenomenon of spontaneous emission of radiations by heavy elements is called radioactivity. When there are too many neutrons relative to the number of protons in the nucleus, the electrostatic force of repulsion exceeds the nuclear forces between nucleons and the nucleus becomes unstable. Such nucleus becomes when one of its neutron changes into a proton and an electron. As a result, an electron is emitted as a β-particle.

$$\underset{\text{Neutron}}{^{1}_{0}n} \xrightarrow{\beta\text{-decay}} \underset{\text{Proton}}{^{1}_{1}n} + \underset{\beta\text{-particle}}{^{0}_{-1}e}$$

4. Radioactivity of an element is not affected by the chemical change as radioactivity is a nuclear phenomenon and doesn't involve intra-nuclear electrons.

5. a. i. ${}_{92}\text{U}^{235}$ is an isotope of uranium which is easily fissionable.

ii. ${}_{92}\text{U}^{235}$ undergoes fission with low energy neutrons or thermal neutrons. But for the fission process in ${}_{92}\text{U}^{238}$, fast neutrons of energy ~1 MeV is required.

iii. A nuclear reaction when Uranium-238 emits an alpha particle to form a Thorium (Th) nucleus is given by

$${}_{92}\text{U}^{238} \rightarrow {}_{90}\text{Th}^{234} + {}_{2}\text{He}^{4}$$

b. i. Radiation B which is unaffected by the electrostatic field is gamma radiation.

ii. Radiation C is beta radiation, and it is nothing but electrons. The mass of electrons is much smaller than alpha particles (radiation A). Hence, beta radiation (radiation C) deflects more.

iii. Radiation A, which is alpha radiation, causes the least biological damage externally.

iv. β radiation (radiation C) is used for carbon dating.

6. α-particles

7. a. α-particles

b. γ-radiation

8. a. α-particles and β-particles

b. X-rays

9. Helium gas

10. $^{202}_{84}\text{X} \xrightarrow{\alpha\text{-decay}} ^{198}_{82}\text{Y} + ^{4}_{2}\text{He}$

$$^{198}_{82}\text{Y} \xrightarrow{\gamma\text{-decay}} ^{198}_{82}\text{Y} + \underset{\gamma\text{-rays}}{\gamma}$$

Mass number reduces by four and atomic number by two.

11. **a.** $^{24}_{11}Na \xrightarrow{\beta\text{-decay}} {}^{24}_{12}Mg + {}^{0}_{-1}e$

b. 24 is the mass number and 11 is the atomic number.

c. Daughter nucleus.

12. Mass number of A = 84 + 128 = 212

Thus,

i. On α emission $^{212}_{84}A \xrightarrow{\alpha\text{ emission}} {}^{208}_{82}B$

ii. On β emission, $^{208}_{82}B \xrightarrow{\beta\text{ emission}} {}^{208}_{83}C$

iii. Mass number of nucleus A is 212.

iv. In gamma emission, there is no change. Thus, composition of C remains unchanged.

13. $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{144}_{56}Ba + {}^{89}_{36}Kr + 3{}^{1}_{0}n + \text{Energy}$

14. $A \xrightarrow{\beta\text{-decay}} A_1 \xrightarrow{\alpha\text{-decay}} A_2 \xrightarrow{\alpha\text{-decay}} A_3$

Atomic number of $A_3 = 69$

Mass number of $A_3 = 172$

$^{b}_{a}A_2 \xrightarrow{\alpha\text{-decay}} {}^{172}_{69}A_3 + {}^{4}_{2}He$

$b = 172 + 4 = 176$

$a = 69 + 2 = 71$

$^{d}_{c}A_1 \xrightarrow{\alpha\text{-decay}} {}^{176}_{71}A_2$

$c = 71 + 2 = 73$

$d = 176 + 4 = 180$

$^{f}_{e}A \xrightarrow{\beta\text{-decay}} {}^{180}_{73}A_1 + {}^{-1}_{0}e$

$f = 180$

$e = 73 - 1 = 72$

Mass number of A(f) = 180

Atomic number of A(e) = 72

15. $^{226}_{88}X \longrightarrow {}^{222}_{86}Y + \alpha\text{-particle} + \text{energy}$

a. Atomic mass of Y = 222

Atomic number of Y = 86

b. When α-particles acquire 2 electrons helium gas is obtained.

c. α-particles get deflected when it passes through a magnetic field.

16. Any chemical or physical activity on a radioactive substance does not produce and change in radioactivity. Therefore, on oxidation radioactive element shows no change in radioactivity as it is a nuclear phenomenon.

17. $^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ (α-particle)

$^{234}_{90}Th \longrightarrow {}^{234}_{91}Pa + {}^{0}_{1}e$ (β-particle)

18. **a.** The process of a nuclear fission reaction takes place at extremely high temperature with the liberation of enormous amount of energy. This is why it is also called a thermonuclear reaction.

b. $^{3}_{2}He + {}^{2}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{1}H + \text{Energy}$

19.

Nuclear Fission	Nuclear Fusion
A heavy unstable nucleus breaks down into two or more lighter nuclei	Two or more lighter nuclei combine to form a heavier nucleus
Limited, expensive	Unlimited, cheap

20. Two precautions to be taken while handling radioactive substances are

i. The person dealing with radioactive substances should put on lead lined aprons, and lead gloves.

ii. They should also wear specially constructed film badges.

21. Radioactive and extremely toxin byproducts of nuclear fuel processing plants, nuclear medium and nuclear weapons industries is called nuclear waste.

Radioactive waste should be disposed after proper treatment so that radioactivity is at very low level.

22. For the same mass, the energy released in a fusion reaction is more than that released in a fission reaction. A fusionable substance is found in abundance. These substances are not radioactive and do not give any harmful radiation. Disposal of waste is a fusion reaction is not difficult.

EXERCISES

Questions Based on ICSE Examination (Page 262)

1. $^{235}_{92}X$

a. Mass number = 235

b. Atomic number = 92

c. Number of electrons = 92

d. Number of neutrons = 143

2. The properties are:

i. Becquerel rays splits into three parts on passing through electric field.

ii. It can cause biological damage.

iii. Becquerel rays consist of α-particles, β-particles and γ-radiations.

γ-rays go undeviated in presence of electric and magnetic fields.

3. The nuclear of an atom tends to be radioactive when

i. Nuclei have too many neutrons as compared to the protons or too many protons as compared to the neutrons in the nucleus of an atom.

ii. The nuclear force of attraction is less than the electrostatic force of repulsion.

4. An alpha (α) particle consists of two protons and two neutrons ($^{4}{}_{2}He$) and it is not possible for a hydrogen nucleus to emit an α-particle.

5. It ejects β-particles.

$${}^{24}_{11}Na \xrightarrow{\beta\text{-decay}} {}^{24}_{12}Mg + {}^{-1}_{0}e$$

6. Three precautions that need to be taken while handling radioactive substances are:

i. Wear lead lined apron, lead gloves and use lead tongs for handling radioactive material.

ii. Wear specially constructed film badges.

iii. Radioactive substances should be stored in thick containers made up of lead.

7. $${}^{238}_{92}X \xrightarrow{\alpha\text{-decay}} {}^{234}_{90}X_1 \xrightarrow{\beta\text{-decay}} {}^{234}_{91}X_2$$

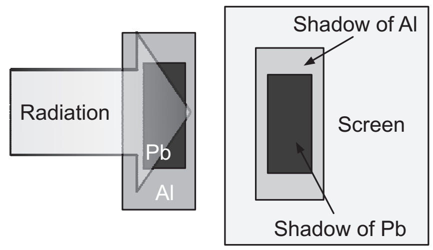
$$\xrightarrow{\beta\text{-decay}} {}^{234}_{92}X_3$$

8. $${}^{202}_{84}X \xrightarrow{\alpha} {}^{198}_{82}Z + {}^{202}_{84}He$$

$${}^{198}_{82}Z \xrightarrow{\beta} {}^{198}_{83}Y + {}^{0}_{-1}e$$

Thus $a = 83$ and $b = 198$

9.



Shadow of the Al block is fainter because Al is more transparent towards radioactive radiations compared with Pb, thus, some radiations pass through Al and produce a fainter shadow on the screen. Since very less radiation pass through Pb, thus, the shadow formed is distinct.

10. $\because$ ${}^{4}_{2}He$ is also called α- particle. Hence, it is α–radiation.

So, $${}^{235}_{92}U \longrightarrow {}^{231}_{90}Th + {}^{4}_{2}He$$

Atomic no. of uranium = 90 + 2 = 92 and, mass no. of Thorium = 235 – 4 = 231

11. **a.** Nuclear energy: The energy obtained due to loss in mass during the nuclear change is called nuclear energy.

b. As the atomic number is increased by 1 hence it is β-radiation.

c. $${}^{A}X_{Z} \longrightarrow {}^{A}Y_{Z+1} + {}^{O}e_{-1}$$

d. As mass numbers are same for both parent and daughter nucleus so we will called them Isobars.

12. **a.** γ-radiation has maximum speed because it is a neutral particle and that's why it will not affected by electric field.

b. β-particle deviates the most from its original path because these are negative particles and affected by electric field.

c. γ-particles, because these are neutral particles and do not deviate by electric field.