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ECZ GRADE 11 PHYSICS SUMMARISED NOTES FOR 5124 AND 5054.

ESKULU ZM	5/30/18	G11 PHYSICS NOTES AND EXERCISES WITH ANSWERS

Here you will find Physics notes, exam tips, practical questions and exercises with answers designed for passing ECZ exams.
Prepared by Jeffrey M for eskulu.com

Contact +260978031524

MEASUREMENT OF TEMPERATURE

- The **temperature** of a substance is a number which expresses its degree of **hotness or coldness**.

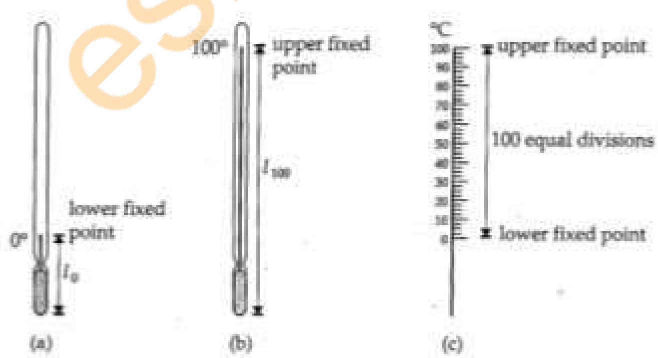
THE THERMOMETER

- Temperature is measured by a **thermometer**.
- There are different types of thermometers. Each of them makes use of a different physical property which changes continuously with temperature to show the temperature.

	Types of thermometer
1. Volume of a fixed mass of liquid	Liquid-in-glass thermometer e.g **mercury, alcohol.**
2. Electromotive force (e.m.f)	Thermocouple.
3. Resistance of a piece of metal	Resistance thermometer
4. Pressure of a fixed mass of gas at constant volume	Constant volume gas thermometer

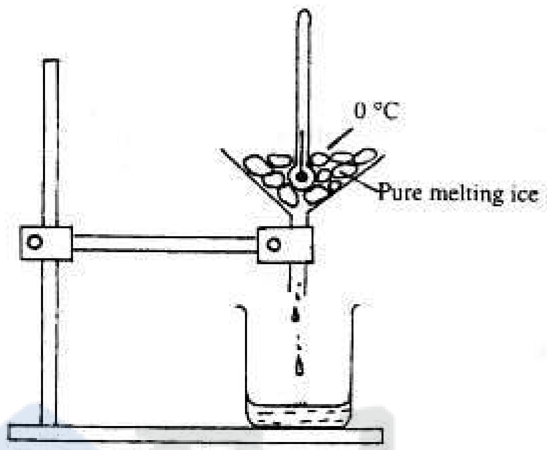
GRADUATING A THERMOMETER

The following steps must be taken;



1. To graduate a thermometer, two points are first determined. These are called **lower fixed point** and the **upper fixed point**. A fixed point is a reference temperature chosen because it is readily reproducible.
2. Determine the lower fixed point, which is the temperature of **pure melting ice**. Impurities lower the melting point.

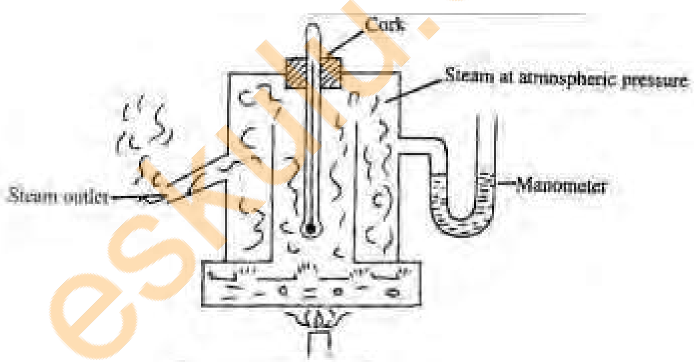
Determining the Lower Fixed Point



3. Next determine the upper fixed point, which is the temperature of **steam.**

Determining the Upper Fixed Point

The thermometer is mounted in a **hypsometer.** The double wall minimizes heat loss.



4. Divide the temperature range between the two fixed points into a number of equal parts or degrees.

THERMOMETRIC LIQUIDS

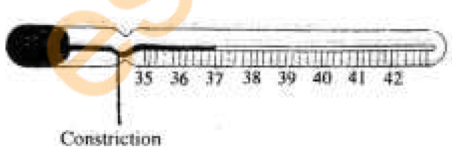
The two commonly used liquids are alcohols are **mercury** and **alcohol.**

Comparison of using mercury to alcohol:

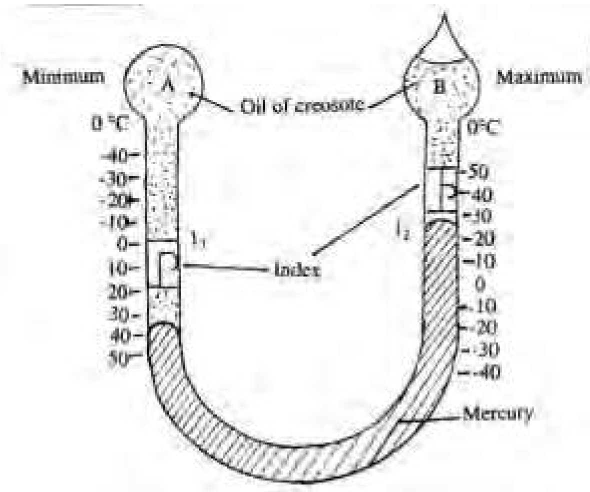
Mercury		Alcohol	
ADVANTAGES	DISADVANTAGES	ADVANTAGES	DISADVANTAGES
Boils at 357°C	**Not as cheap as alcohol**	**Cheaper**	**Boils at 78 °C**
Conducts heat rapidly – more sensitive to temperature change	**Freezes at -39 °C**	**Freezes at -115 °C – suitable for colder regions**	**Alcohol is less sensitive to temperature change**
Easy to see	**Expands less than alcohol**	**Expands more than mercury**	**Alcohol is not easy to see – needs to be coloured**
Does not cling to glass			**Alcohol vapourises easily**
Does not vaporize rapidly			**Clings to glass**

CLINICAL THERMOMETER

- Used to measure temperature of human bodies.
- The range of the thermometer is 35 **°C** to 42 **°C**.
- It is very sensitive because it has a **large bulb** and a **narrow bore.**
- It has a **constriction** to block mercury above it. The mercury below the constriction cools and contracts back into the bulb.

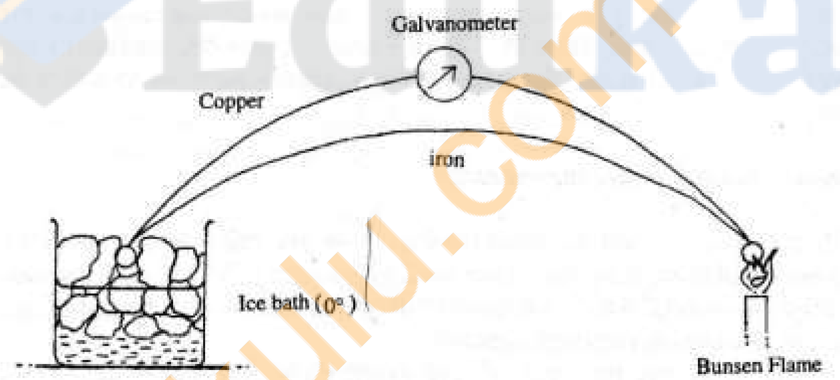


THE MAXIMUM MINIMUM THERMOMETER



- Used to record the maximum and minimum temperatures reached over a period of time.
- Consists of two bulbs.
- The scale on the side of the completely full bulb measures minimum temperatures.

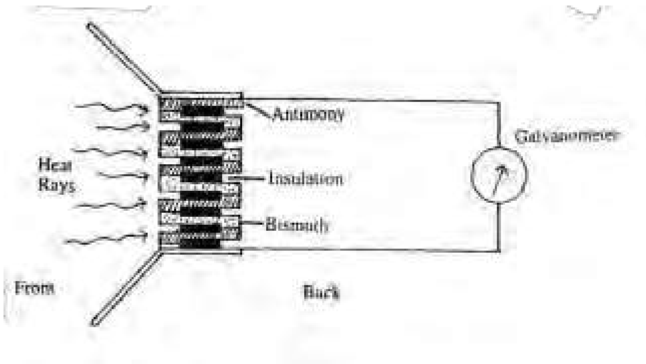
THE THERMOCOUPLE



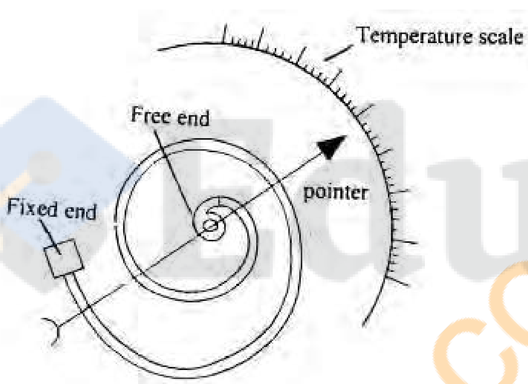
Temperatures may also be measured by variations of electric current in a thermocouple. If two wires of different materials are joined together at their ends and the two junctions are maintained at different temperatures, an electric current flows around the circuit. This is called **thermoelectric effect.**

- The magnitude of the current depends on the temperature difference between the two junctions.
- They are very sensitive and can measure high temperatures like the temperature of a Bunsen flame.
- A number of thermocouples joined together make a **thermopile.**

- Commercial thermocouples use antimony and bismuth because they give a large thermoelectric effect.
- A thermopile:



THE BIMETALLIC THERMOMETER



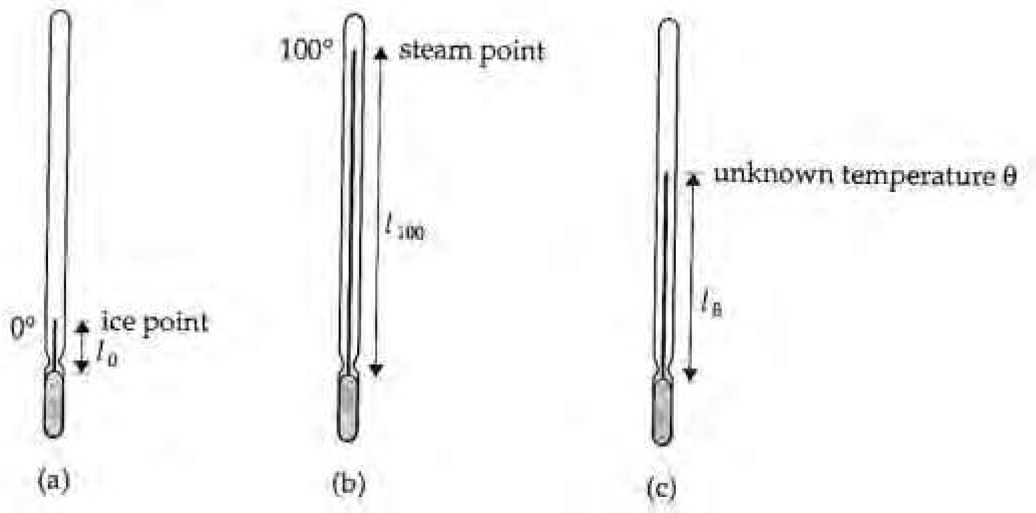
The bimetallic thermometer consists of a bimetallic strip made of a coiled spiral. One end of the spiral is free while the other is fixed. A pointer is attached to the free end and moves over a temperature scale which is predetermined.

- The thermometer works on the basis that the radius of the curvature of the spiral coiled bimetallic strip changes with the surrounding temperature. Increase in temperature makes the radius of curvature to increase. This makes the pointer move.

CALCULATION OF UNKNOWN TEMPERATURE

How to Find Unknown Temperature without a Temperature Scale?

Using **ice point (lower fixed point)** and **steam point (upper fixed point)** as reference points.



- **If the following are given:**
  - L_0 : Length of the liquid column at **ice point (0°C)**
  - L_{100}: Length of the liquid column at **steam point (100 °C)**
  - L_θ: Length of the liquid column at an unknown temperature **(θ)**

Apply the following equation:

$$\theta = \frac{l_\theta - l_0}{l_{100} - l_0} \times 100°\text{C}$$

Example

[Q] A thermometer reads 1 °C in pure melting ice and 101 °C in steam above boiling water. It is used to measure the temperature of water before and after it is heated.

What is the error when the temperature rise is calculated?

A 2 °C too low

B 1 °C too low

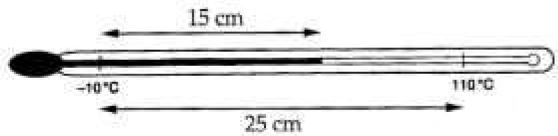
C zero

D 1 °C too high

[Ans] C Pure melting ice is 0 °C and steam above boiling water is 100 °C. From the readings given, it is found that all readings are 1 °C too high. However this error will be eliminated when the temperature difference is calculated.

Example

[Q] The diagram shows a mercury-in-glass thermometer. The distance between the –10 °C and the 110 °C markings is 25 cm.



At which temperature is the end of the mercury thread 15 cm from the –10 °C mark?

A 50 °C

B 60 °C

C 62 °C

D 72 °C

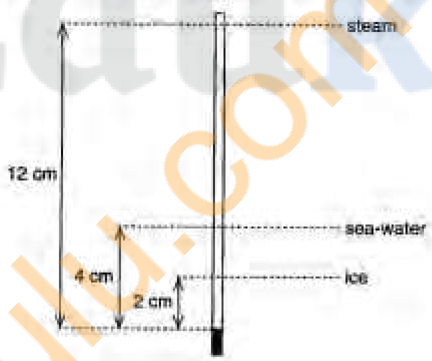
[Ans] C reading $= \left(\frac{15}{25} \times 120\right) - 10$

$= 62\,°C$

Example

[Q] A student puts the bulb of an unmarked liquid-in-glass thermometer into melting ice, then into steam above boiling water and finally into sea-water. Each time she waits until the liquid level is steady, and then marks the level.

The diagram shows the liquid levels measured from the bulb.



What is the approximate temperature of sea-water?

A 2 °C

B 20 °C

C 33 °C

D 40 °C

[Ans] B Reading $= \frac{l_\theta - l_0}{l_{100} - l_0} \times 100\,°C = \frac{4-2}{12-2} \times 100\,°C = 20\,°C$

KINETIC THEORY

States: All matter is made of **atoms** that are constantly in motion.

THREE STATES OF MATTER

Example

[Q] Which of the following correctly states the properties of solids, liquids and gases?

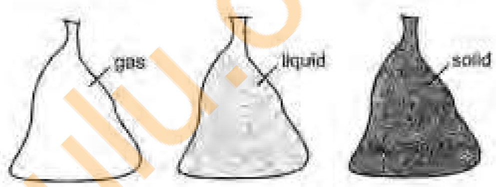
	solids	liquids	gases
A	do not flow easily	flow easily	flow easily
B	easily compressed	easily compressed	hard to compress
C	fixed shape	fixed shape	no fixed shape
D	no fixed volume	fixed volume	no fixed volume

[Ans] A Fact.

Example

[Q] A student has three sealed plastic bags. One bag is full of gas, one of liquid and one of solid.

The student squeezes each bag to see if it changes shape, and warms each bag to see if it expands.



Which bag contains gas?

A the one that changes shape easily and expands the least when heated

B the one that changes shape easily and expands the most when heated

C the one that is fixed in shape and expands the least when heated

D the one that is fixed in shape and expands the most when heated

[Ans] B A gas has no fixed shape or size and expands the most when heated.

BROWNIAN MOTION

- The existence of molecules in **continuous random motion** can be demonstrated by **Brownian motion.**

- Particles can be seen in a **random zig-zag path.**

Example

When the Brownian motion of smoke particles in air is observed with a microscope, moving points of light are seen.

These points of light are reflections from

A air particles only, moving randomly.

B smoke particles only, moving randomly.

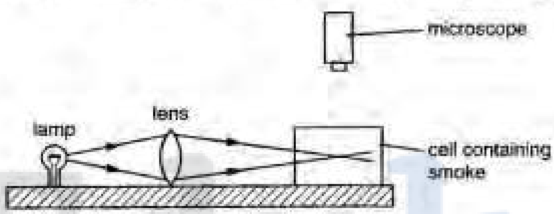
C smoke particles only, vibrating.

D both smoke and air particles, moving randomly.

Ans] **B** The air particles are too tiny to be observed and so the light spots come only from the smoke particles. The smoke particles are moving freely but not vibrating.

Example

[Q] Brownian motion of smoke particles can be studied by using the apparatus shown.



What causes the Brownian motion?

A convection currents in the air

B heat from the lamp

C random collisions between air molecules and smoke particles

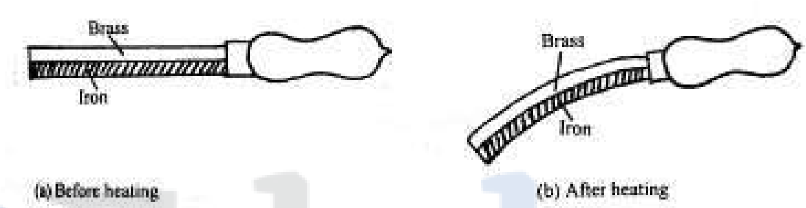
D random collisions between smoke particles and other smoke particles

Ans] **C** The zig-zag motion of the smoke particles is due to the random motion of the air molecules which collide with the smoke particles.

THERMAL EXPANSION OF SOLIDS AND LIQUIDS

THE BIMETALLIC STRIP

- This strip consists of two strips of iron and brass welded together. When temperature rises, brass expands more than iron, and so heating the bimetallic strip results in its bending towards the iron.



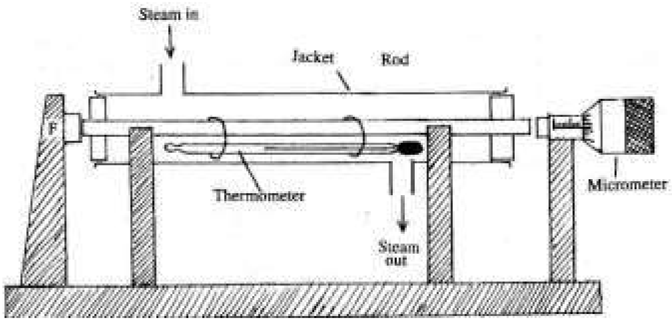
- Bimetallic strips are used in devices such as **refrigerators, pressing irons, fire alarms, direction indicators and thermostats.**
- A thermostat is a device used to maintain a steady temperature and it employs a bimetallic strip to accomplish this.

LINEAR EXPANSIVITY

- The linear expansivity of a substance is **the fraction of its original length by which a rod of the substance expands per kelvin rise in temperature.**

$$linear\ expansivity = \frac{expansion}{original\ length\ \times rise\ in\ temperature}$$

- The linear expansivity of a rod can be measured by the instrument below.



Example

A rod 50cm long expanded from 50 cm to 50.080 cm in a temperature range of 83k, find its linear expansivity. What substance could this rod be possibly made of?

Solution

$$\text{Linear expansivity} = \frac{\text{expansion}}{\text{original length X rise in temperature}}$$

$$= \frac{50.080 \text{ cm} - 50.000 \text{ cm}}{50 \times 83}$$

$$= \frac{0.080}{50 \times 83}$$

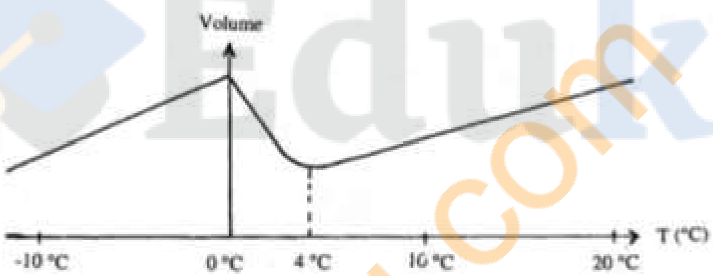
$$= 0.000\ 0193/k$$

EXPANSION OF LIQUIDS

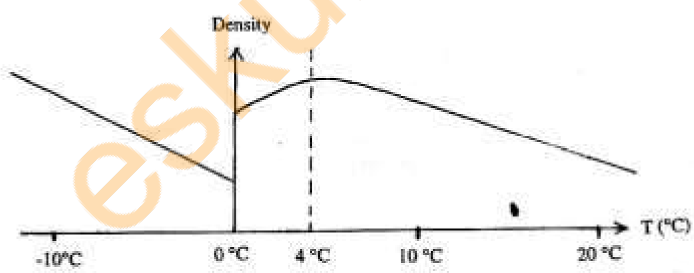
Most liquids expand when heated.

The Abnormal Expansion of Water

If water at at 0°C is heated, it gradually contracts until the temperature of 4°C. Above 4°C water expands with a rise in temperature.



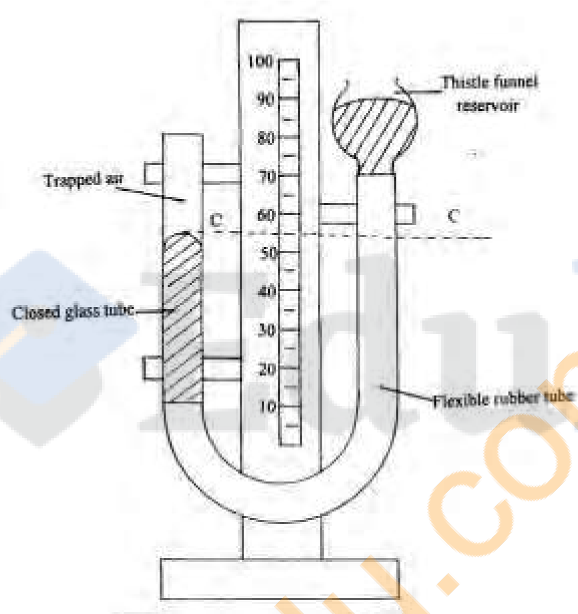
As the volume reduces between 0°C and 4°C, the density increases. Water has its maximum density at 4°C and this 1g/cm^3.



EXPANSION OF GASES

GAS VOLUME AND ITS PRESSURE AT CONSTANT TEMPERATURE

The following apparatus is usually used in the investigation of how the volume of a gas changes as the pressure exerted on it changes:



It is called Boyle's law apparatus.

- **Boyle's law states that the volume of a fixed mass of a dry gas varies inversely with the pressure, provided the temperature remains constant.**
- For a fixed mass of a dry gas at constant temperature the product of its volume and pressure is a constant.

Example

A gas occupies a volume of 150cm^3 at 25°C and pressure of 80cm of mercury. What would be the volume of the gas if the pressure were reduced to 75cm of mercury but the temperature remained constant?

Solution

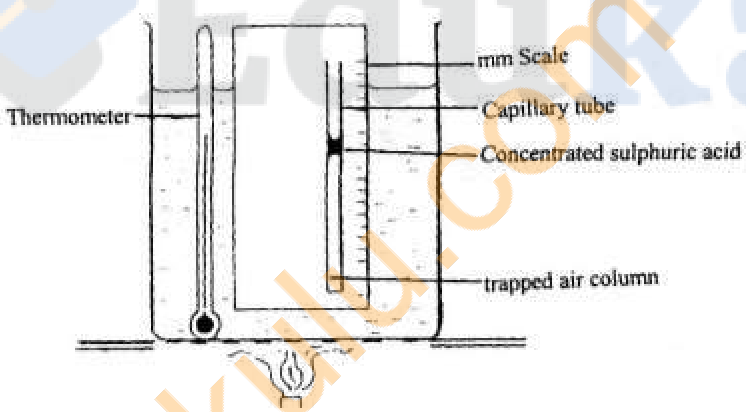
$P_1V_1 = P_2V_2$

$80 \times 150 = 75 \times V_2$

$V_2 = 160cm^3$

GAS VOLUME AND TEMPERATURE AT CONSTANT PRESSURE

- All gases expand by the same amount when heated through one degree if the pressure is constant.
- The following apparatus is used to find the relationship between the volume and temperature of a fixed mass of gas at constant pressure.



This is called Charles law apparatus.

- Charles' Law is a law stating that **the volume of an ideal gas at constant pressure is directly proportional to the absolute temperature.**
- To convert from Celsius to Kelvin scale, **just add 273.**

COMBINATIONS OF BOYLE'S AND CHARLES' LAW

Example

1. $250cm^3$ of gas is at a pressure of 70cm of mercury and a temperature of 27°C. Find it's volume when it is at a temperature of 127°C and a pressure of 35cm of mercury.

Solution

From the general gas equation

$$V_2 = \frac{P_1 V_1}{T_1} \times \frac{T_2}{P_2} = \frac{70 \times 250}{(27 + 273)} \times \frac{(127 + 273)}{35}$$

$$= 666.7cm^3$$

2. $220cm^3$ of a gas is collected at 57°C and at a pressure of 80cm of mercury. What is the volume at s.t.p. (Standard temperature and pressure)?

Solution

Standard temperature = 0°C = 273 K and standard pressure is 76cm of mercury.

$$V_2 = \frac{P_1 V_1}{T_1} \times \frac{T_2}{P_2} = \frac{80 \times 220 \times 273}{330 \times 76}$$

$$= 191.6cm^3$$

PRESSURE AND TEMPERATURE AT CONSTANT VOLUME

Pressure Law states that the pressure of a fixed mass of gas at constant volume is directly proportional to its absolute temperature.

Example

An inexpansible vessel contains a gas at a pressure of $40kN/m^2$ and a temperature of -13°C. To what temperature should the gas be heated to double the pressure?

Solution

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$T_2 = \frac{T_1 \; P_2}{P_1} = \frac{260 \times 80}{40}$$

$= 520K$

$= 247°C$

HEAT TRANSFER

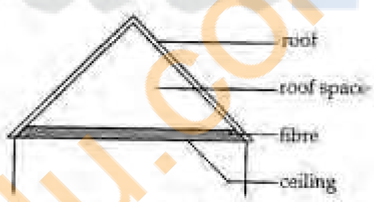
- Thermal energy is the total kinetic energy of the molecules in a body.
- Thermal energy transfer or **heat transfer** takes place **only** when there is a **difference in temperature.**
- Heat transfers from a higher temperature region to a lower temperature region.
- The three forms of heat transfer are: **conduction, convection** and **radiation.**

CONDUCTION

- **Conduction** is the process by which **heat is transmitted through a** medium **from its hotter part to its colder part until they are both at the same temperature.**

Example

[Q] Fibre is used for home insulation as shown.



How does fibre prevent heat passing easily through the ceiling?

A Fibre allows air to pass through easily.
B Fibre is highly packed.
C Fibre is warm.
D Fibre traps air.

[Ans] D Trapped air is a very good insulator.

Relative Conductivity

Relative conductivity is a measure of the degree of conductivity of a material compared to the conductivity of air.

CONVECTION

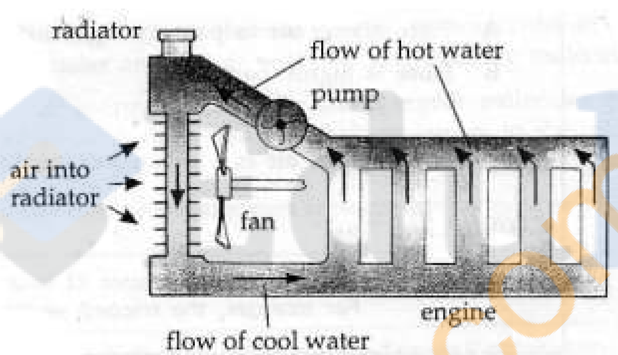
Convection is the process by which **heat is transmitted from one place to another by the movement of heated particles of a fluid (a liquid or a gas).**

Convection Current

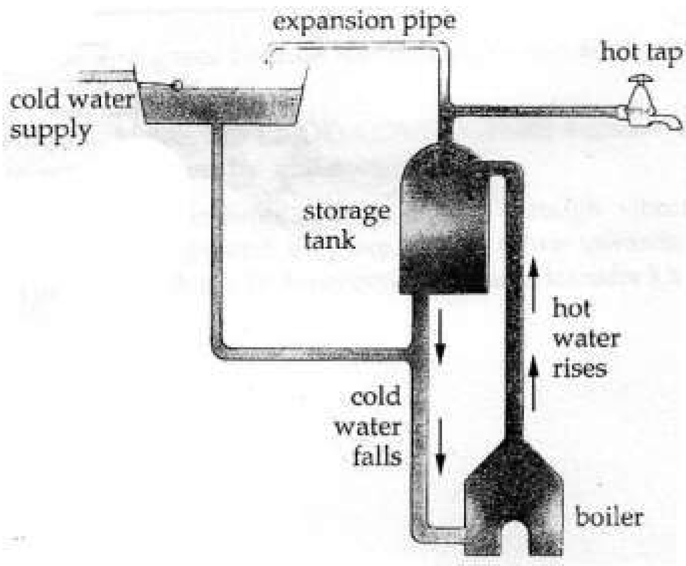
Convection currents are the **flowing of a liquid or a gas caused by a change in density, in which the whole medium moves and carries heat energy with it.**

Applications of Convection Currents

1. **Car engines** are cooled by convection currents in the water pipes. Water is a very good substance. Water is a very good substance to carry the unwanted heat away from the engine to the radiator. The radiator is a heat exchanger where the hot water gives up its energy to the air.

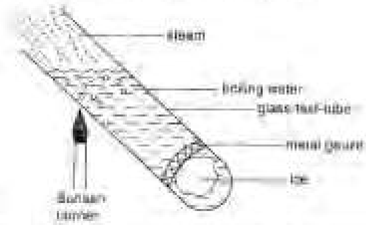


2. **Simple domestic hot-water system.** Convection currents drive the hot water up from the boiler to the storage tank while cold water flows down to the boiler.


expansion pipe
hot tap
cold water supply
storage tank
hot water rises
cold water falls
boiler

Example

[Q] An experiment is carried out as shown in the diagram.



Why does the ice take a long time to melt, even though the water at the top of the tube is boiling?

A Water is a poor conductor of heat.

B Convection cannot occur in water.

C The gauze prevents the energy reaching the ice.

D Ice is poor conductor of heat.

Example

[Q] Density changes are responsible for which methods of thermal energy transfer?

A conduction only

B convection only

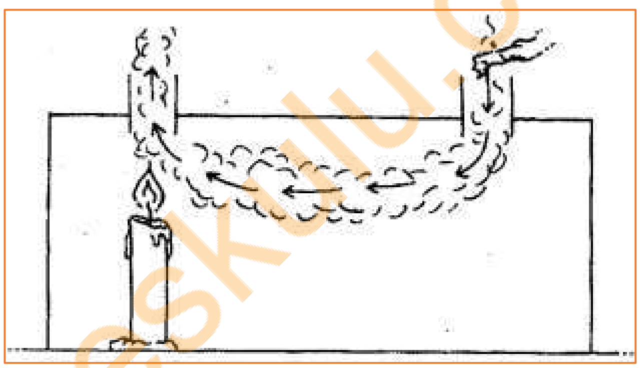
C radiation only

D conduction, convection and radiation

[Ans] B Density changes cause the bulk movement of fluid resulting in convection.

Convection in Air

Experiment:

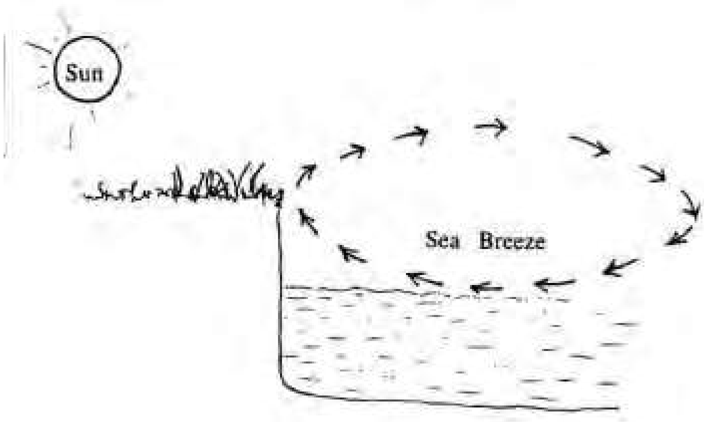


You will observe that instead of rising as usual, the smoke flows through the top of the box and emerges through the other chimney.

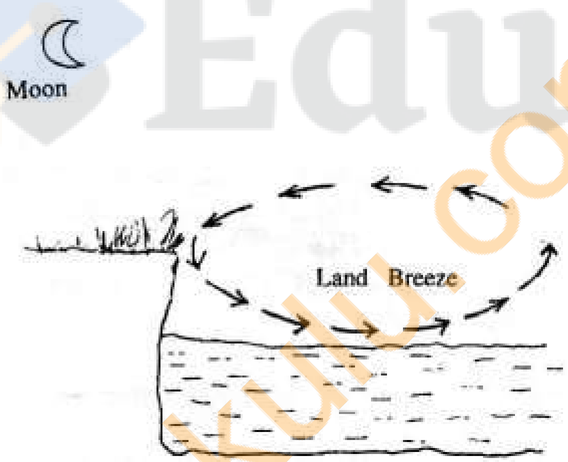
This is a result of a convection current.

Sea and Land Breeze

During the day, hot air above the land rises and is replaced by colder air from the sea. This results in a sea breeze, thus a breeze coming in off the sea.



At night the reverse occurs. The air above the sea which is warmer rises and is replaced by the air above the land which is colder. Thus a breeze blows from the land to the sea.



RADIATION

Radiation is a method of heat transfer whereby **heat energy is transmitted from a hot object to another in the form of electromagnetic waves.**

Factors Affecting Rate of Energy Transfer by Radiation

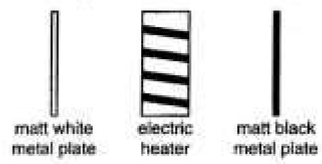
Factors:	Radiate faster	Radiate slower
Colour and texture of the surface	**dull black surface (also absorbs faster)**	**bright shiny surface (also absorbs slower)**
Surface area	**Large area**	**Small area**
Temperature	**High temperature**	**Low temperature**

Example

[Q] Two identical metal plates are painted, one matt white and the other matt black. These are placed at equal distances from a radiant heater as shown. The heater is turned on for five minutes.

Which metal plate absorbs more energy and which plate emits more energy in this time?

	absorbs more	emits more
A	black	black
B	black	white
C	white	black
D	white	white

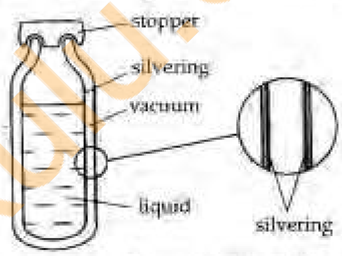


[Ans] A Black or dull surfaces are both good emitters and good absorbers of radiant energy.

VACUUM FLASK

Example

[Q] The diagram shows a vacuum flask and an enlarged view of a section through the flask wall. The main reason for the silvering is to reduce heat transfer by



A conduction only.
B radiation only.
C conduction and convection.
D convection and radiation.

[Ans] B A shiny surface is a poor absorber of radiant energy.

THERMAL PROPERTIES OF MATTER

- **Heat or thermal energy** is transferred from a higher temperature object to a lower temperature object.
- Once the energy is transferred, it becomes the **internal energy** of the lower temperature object and its temperature rises.
- This internal energy is in two forms: **kinetic energy** and **potential energy.**
- The change in temperature is due to the change in average kinetic energy of the molecules.
- The change in state (solid, liquid or gas) is due to the change in potential energy, i.e. the force between the molecules and their distances apart.
- Like all other forms of energy, internal energy is measured in **joule** (**j**)
- **In all energy transferring processes, energy is neither created nor destroyed. This is the principle of conservation of energy**

HEAT CAPACITY

The heat capacity of a body is the amount of the thermal energy that is needed to raise the temperature of the body by 1 K or 1 °C.

- SI Unit is J^oC^{-1}
- Equation:

$$E = C\Delta\theta$$

where E: Thermal energy (j); C: heat capacity;

SPECIFIC HEAT CAPACITY

The **specific heat capacity** (**c**) of a substance is the **amount of thermal energy that is needed to raise the temperature of 1 Kg of the substance by 1 °C (or 1 K).**

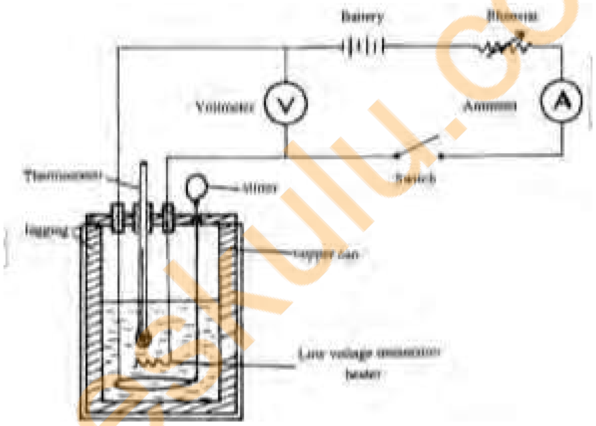
$$E = mc\Delta\theta$$

where E: Thermal energy (j); C: heat capacity; m: mass(kg);

Substances	Specific heat capacity (j Kg^{-1} $^oC^{-1}$)
Water	4200
Methylated spirit	2400
Paraffin	2200
Ice	2100
Aluminium	900
Sand	800
Iron	460
Copper	400
Mercury	140
Lead	130

FINDING SPECIFIC HEAT CAPACITY OF LIQUIDS

- Apparatus is set up as follows:



NOTE: Heat lost by heater = Heat gained

- $E = \text{Power} \times \text{Time}$
- $c = \frac{VIt}{mDT}$

Example

It takes 5 minutes for a heater rated 12V, 5A to raise the temperature of 2kg of liquid by 3°C. Calculate the specific heat capacity of the liquid.

Solution

Heat lost = Heat gained

$Vlt = mcDT$

$c = Vlt/mDT$

$$= \frac{12 \times 5 \times 30}{2 \times 3}$$

= 3 000J/Kg°C

1 kg of a metal at 100 °C is placed into two kilograms of water at 2°C and the resulting temperature of the water and metal is 5°C. Find the specific heat capacity of the metal.

Solution

Heat lost by metal = Heat gained by water

$1 \times (100-5) \times c = 2 \times 4200 \times (5-2)$

c = 265.26 J/kg°C,

HEAT TRANSFER BETWEEN TWO BODIES

- When two bodies with different temperatures are in contact, they will finally have equal temperature.
- **Energy lost by the hotter body = Energy gained by the colder body**

$$m_1c_1(\theta_1 - \theta) = m_2c_2(\theta - \theta_2)$$

LATENT HEAT

Latent heat is the thermal energy absorbed or released during a change of state.

Latent Heat of Fusion

- For a solid at its melting point, the amount of thermal energy that is needed to change its state (**without changing the temperature**) is called the latent heat of fusion.
- The molecules in a solid are held by strong forces. At melting point, all energy supplied to it is completely used up for breaking the strong forces.

- Only the potential energy of the molecules has increased, not the kinetic energy. As such, the temperature at melting point remains unchanged.

Specific Latent Heat of Fusion

- The specific latent heat of fusion of a substance is the **amount of energy needed to melt 1 kg of the solid to liquid without changing the temperature.**
- SI Unit: **j/kg.**
- Equation:

$$E = mL_f$$

E: energy; m: mass; L_f : specific latent heat of fusion;

Latent Heat of Vaporization

- **For a liquid at boiling point, the amount of energy that is needed to change its state (without changing the temperature) is called the latent heat of vaporization.**
- In this process, the latent heat is used to overcome the attractions between the molecules in the liquid. It is also used to push back the surrounding air molecules in order to let the molecules in the liquid to escape, becoming a gas.

Specific Latent Heat of Vaporization

The specific latent heat of vaporization of a substance is the amount of energy needed to vaporize 1 Kg of the liquid to gas without changing the temperature.

- SI Unit: **j/Kg**
- Equation:

$$E = mL_v$$

Example

An immersion heater rated at 150 W is fitted into a large block of ice at 0 °C. The specific latent heat of fusion of the ice is 300 J/g. How long does it take to melt 10 g of the ice?

A 2 s
B 5 s
C 20 s
D 150 s

[Ans] C Assumption: no energy lost to the surroundings
energy supplied by heat = latent heat absorbed by ice

$Pt = mL_f$

$t = mL_f / P$

$= 10 \times 300 / 150$

$= 20$ s

Example

How much heat is required to convert 5Kg of ice at -10°C to steam at 100°C?

Solution

For ice, $c = 2\ 100 J kg°C$, $L = 3\ 36\ 00OJ/kg$
For water, $c = 4\ 200\ J/kg°C$
For steam, $L = 2\ 260\ 000\ J/kg$

Heat needed to raise the temperature of ice to 0°C

$$H_1 = mcDT$$
$$= 5 X 2100 X 10$$
$$= 105\ 000J$$

Heat needed to melt the ice

$$H_2 = mL$$
$$=5 X 336000$$
$$=1\ 680\ 000J$$

Heat needed to raise the temperature of water from 0°C to 100°C

$$H_3 = mcDT$$
$$= 5 X 4200 X 100$$
$$= 2\ 100\ 000J$$

Heat needed to vaporise 5kg of water

$$H_4 = mL$$
$$=5 x 2260000$$
$$=11\ 300\ 000J$$

Total amount of heat required

$$= H_1 + H_2 + H_3 + H_4$$

$$= 105\ 000 + 1\ 680\ 000 + 2\ 100\ 000 + 11\ 300\ 000$$
$$= 15\ 1850\ kJ$$

EVAPORATION

- Evaporation causes cooling since it is the more energetic molecules that escape from the surface taking heat with them from the container.
- Thus the surrounding cools down.

Applications of Cooling by Evaporation

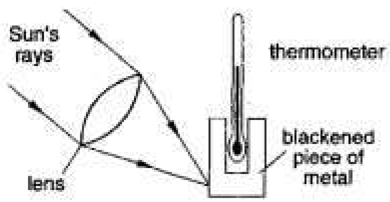
The domestic refrigerator

The cooling effect of a very volatile liquid Freon (**dichlorodiflouromethane**) forms the basis of the refrigerator.

CHALLENGING QUESTIONS – 1

Instructions: *attempt questions before looking at the answers*

1. A physics student wishes to measure the thermal energy from the Sun that falls on the surface of a lens. He sets up the experiment as shown in the figure. Sunlight is converged by a lens on to a blackened piece of metal, which absorbs all of the incident energy. The lens transmits all of the energy that falls on it.



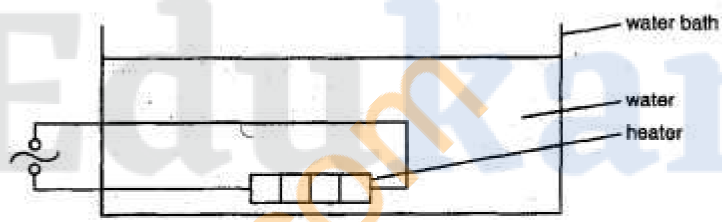
The mass of the block of metal is 0.20 kg and its specific heat capacity is 390 J/(kg K). The reading on the thermometer increases by 2.1 K in one minute.

(i) Calculate the energy received by the block of metal in one minute.

(ii) Calculate the power received by the block of metal.

(iii) What other measurement does the student need to make in order to measure the thermal power from the Sun that falls on to a 1 cm^2 area of the surface of the lens? [7]

2. A water bath is kept warm by an electric heater placed inside the water, as shown. The heater switches on when the temperature of the water is 40 °C or below, and switches off when the temperature reaches 45 °C.

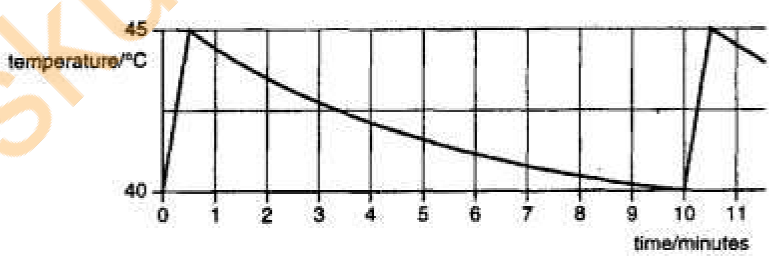


(a) Energy from the heater warms all of the water in the tank by means of convection currents.

(i) Explain in detail how convection currents are formed.

(ii) Describe an experiment that you could perform to demonstrate a convection current in a liquid or in a gas. In your account, draw a diagram showing the convection current. [6]

(b) The variation with time of the temperature of the water in the tank is shown.



The water bath contains 3.0 kg of water and the specific heat capacity of water is 4200 J/(kg °C).

(i) Show that the energy needed to warm the water from 40 °C to 45 °C is 63000 J.

(ii) Show that the power of the heater is 2100 W. You may assume that all of the energy from the heater is used to raise the temperature of the water.

(iii) In every hour, the heater is on for 3 minutes. Calculate the amount of energy in kWh used by the heater in one hour. [7]

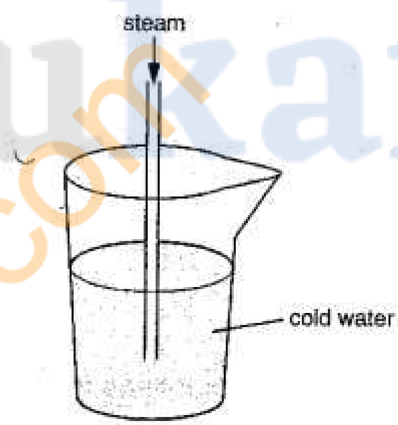
(c) Describe two ways by which the water cools down while the heater is switched off. [2]

3. A person running in a race generates, on average, 800 J of heat energy every second. Half of this heat energy is lost from the body by the evaporation of water.

(a) Explain in terms of molecules, how the loss of water by evaporation cools the body. [2]

(b) Calculate the mass of water evaporated from the body in a 2 hour race. The specific latent heat of vapourization of water is 2.25×10^6 J/kg. [3]

4. The figure below shows steam passing into a jug to warm up some cold water. In this question, you may ignore any heating of the atmosphere.



Pure steam enters at 100 °C and the jug initially contains 500 g of water at 20 °C. Eventually, the water in the jug reaches a temperature of 100 °C. The specific heat capacity of water is 4.20 J/(g °C) and the specific latent heat of vapourization of water is 2250 J/g.

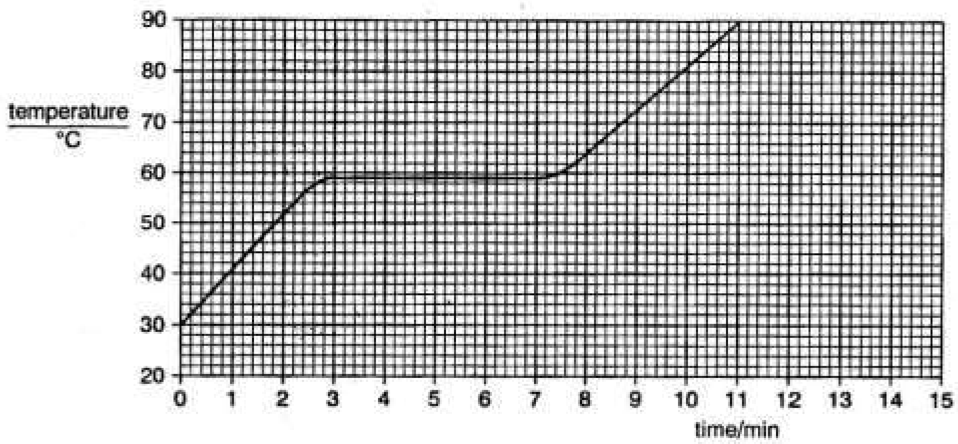
(a) State what is meant by the specific latent heat of vapourization of water. [2]

(b) Explain why the mass of water in the jug increases. [1]

(c) Calculate the energy needed to warm 500 g of water from 20 °C to 100 °C. [2]

(d) Calculate the final mass of water in the jug, when its temperature has reached 100 °C. [2]

5. A small quantity of solid wax in a test-tube is heated slowly. The figure shows the variation with time of the temperature of the wax.



(a) (i) State what is meant by the *melting point* of a substance.

(ii) Determine the melting point of the wax in the experiment. [3]

(b) In a second experiment, twice the amount of wax is used, and exactly the same amount of heat energy every second is passed into the wax as in the first experiment. The initial temperature of the wax is also 30°C.

On the figure, draw the variation with time of the temperature of the wax in this second experiment. You may assume that the heat needed to warm up the test-tube itself is negligible. [2]

SOLUTIONS

1. (a) (i) $E = mc\Delta\theta$
$= 0.20 \times 390 \times 2.1$
$= 160\ J$

(ii) $P = \frac{E}{t}$
$= \frac{163.8}{60}$
$= 2.7\ W$

(iii) cross-sectional area of the lens

ExamTip

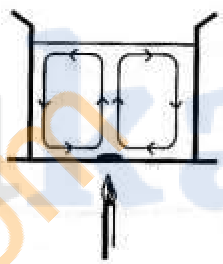
We assume that the lens does not absorb any energy from the Sun. It only transmits energy to the metal block.

Thermal power from the Sun that falls on to a 1 cm^2 area of the surface of the lens

$= \frac{\text{Thermal power}}{\text{cross-sectional area of len}}$

2. (a) (i) When the water at the bottom of the tank is heated up by the heater, the water expands and the density is decreased. The hot water rises and the cold water sinks to set up the convection current.

(ii)



A beaker is filled with some water and some crystals of potassium permanganate is placed at the centre of the bottom of the beaker. The water is then heated at the centre of the bottom. Purplish streaks can be observed moving from the bottom towards the water surface and then coming down near the rim.

(b) (i) Energy needed $= mc\Delta\theta$
$= 3.0 \times 4200 \times (45 - 40)$
$= 63000\ J$

(ii) Time taken to raise the temperature of water from 40°C to 45°C = 0.5 minute

Power $= \frac{E}{t}$
$= \frac{63000}{0.5 \times 60}$
$= 2100\ W$

(iii) Amount of energy $= \frac{2100}{1000} \times \frac{3}{60}$
$= 0.105\ kWh$

(c) Heat can be conducted to the outside of the water bath which radiates the heat away by radiation in the form of infra-red.

Evaporation may also occur near the surface of the water bath to cool down the water.

3. (a) During evaporation, the more energetic liquid molecules near the surface escape from the liquid. The less energetic molecules remain in the liquid causes the decrease in average kinetic energy and thus the temperature of the liquid drops. Heat is then drawn by the liquid from the body causing the body to cool.

(b) Energy, E = Pt = ml

$$m = \frac{Pt}{l}$$

$$= \frac{800 \times 2 \times 60 \times 60}{2.25 \times 10^6} \times \frac{1}{2}$$

$$= 1.28 \text{ kg}$$

Exam Tip

(a) Remember that the temperature of a liquid depends on the average kinetic energy of the molecules. Evaporation only occurs at the liquid surface.

(b) Evaporation is also a change of state from liquid to vapour though it happens at any temperature. The time in the equation E = Pt must be in second.

4. (a) The specific latent heat of vapourization of water is the amount of energy required to change 1 kg of water to steam at constant temperature.

(b) The steam condenses to form water.

(c) Energy needed $= mc\Delta\theta$

$$= 500 \times 4.20 \times (100 - 20)$$

$$= 168000 \text{ J}$$

(d) Final mass of water = initial mass + mass of water from steam

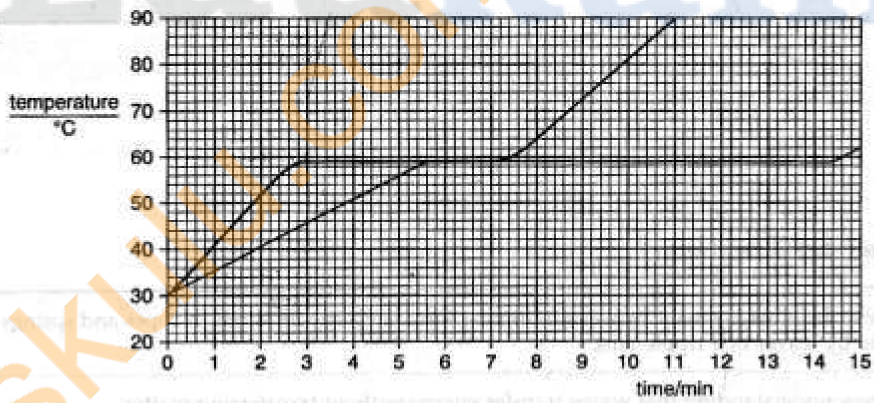
$$= 500 + \frac{168000}{2250}$$

$$= 575 \text{ g}$$

5. (a) (i) Melting point is the constant temperature at which a substance is changed from solid state to liquid state.

(ii) 59 °C

(b)



(a) The horizontal line of the graph represents melting of the solid wax. The corresponding temperature is the melting point. When change of state happens, there is no change of temperature.

(b) Since the amount of wax is doubled, the time for the wax to reach its melting point is also doubled. However, the melting point is a constant regardless of how much wax is used.

WAVE MOTION

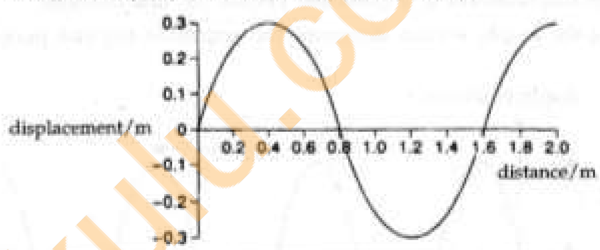
- A wave **transfers energy from one place to another.**
- NO MATTER **is transferred in the process.**

TERMS USED

1. **Wavefront:** A line joining all the crests (or troughs) of a moving wave is called the wavefront. It is an imaginary line.
2. **Wavelength (λ):** of a wave is the minimum distance at which the wave repeats itself. **The distance between two successive wavefronts is equal to one wavelength.**
3. **Amplitude:** the **maximum displacement** of a particle from its **resting position**.

Example

[Q] A long rope is stretched out on the floor. One end of the rope is then shaken. The graph shows the rope at a particular moment in time.



What is the wavelength of the wave motion?

A 0.3 m
B 0.6 m
C 0.8 m
D 1.6 m

[Ans] D Wavelength is the distance for one complete wave.

PERIOD AND FREQUENCY

- **Period (T)** is the **time taken for one complete oscillation of a point on the wave.**
- SI Unit: **Seconds (s)**

- **Frequency (f)** is the number of complete waves produced **per second**.

$$f = \frac{1}{T} \qquad f: frequency\ [in\ Hertz(Hz)]; T: period;$$

WAVE SPEED

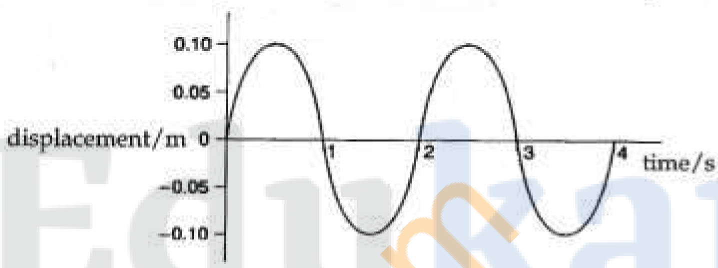
- The **speed (v)** of a wave is the **distance travelled** by the wave in **one second.**

$$\boldsymbol{v = f\lambda} \qquad where\ v: wave\ speed(\ in\ \boldsymbol{m/s}); f: frequency(in\ \boldsymbol{Hz});\ \lambda: wavelength(in\ \boldsymbol{m})$$

- SI unit of wave speed: **ms^{-1} (metre per second).**

Example

[Q] The diagram shows how displacement varies with time as a wave passes a fixed point.



What is the frequency of this wave?

A 0.25 Hz

B 0.50 Hz

C 1.0 Hz

D 2.0 Hz

[Ans] **B** frequency = 1 / period = 1 / 2 = 0.50 Hz

Example

[Q] A vibrator sends ripples across the surface of water. They run closer together as they travel further from the vibrator.

This shows that the ripples

A decrease in frequency.

B increase in frequency.

C slow down.

D speed up.

[Ans] C The frequency of the water waves always remains constant. The wavelength is then proportional to the speed of the wave.

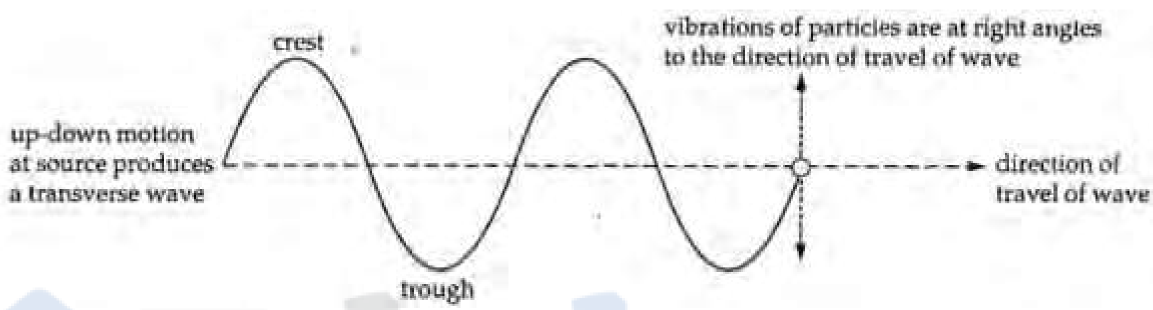
TYPES OF WAVES

There are two types of wave:

The two waves can be distinguished by their **waveforms.**

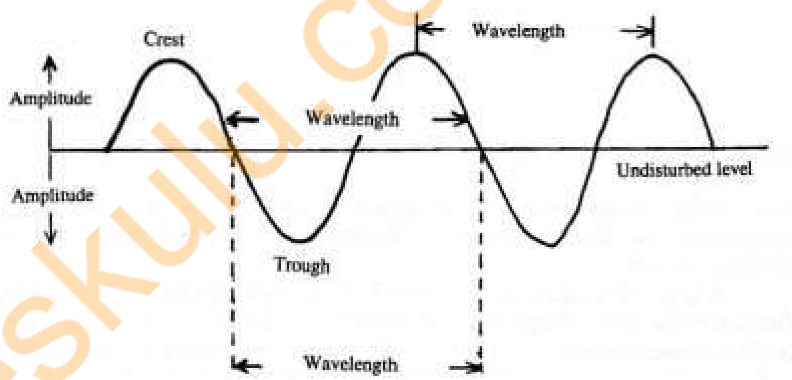
1. Transverse Waves

- The waveform of a transverse wave appears as **succession of crests and troughs,** shown in the following figure.
- The waveform appears to move at a constant speed.



A TRANSVERSE WAVE IS A WAVE IN WHICH THE OSCILLATIONS OF THE PARTICLES ARE AT RIGHT ANGLES TO THE DIRECTION OF TRAVEL.

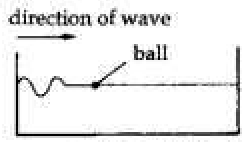
- The following are **parts of a transverse wave:**



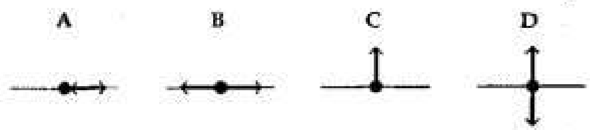
Examples: water waves, microwaves, radio waves, infra-red, visible light, ultra-violet, X-rays and ϒ-rays.

Example

[Q] The diagram shows a ball floating in a tank of water.



Which diagram shows the movement of the ball when the wave passes?



[Ans] D Water waves are transverse waves.

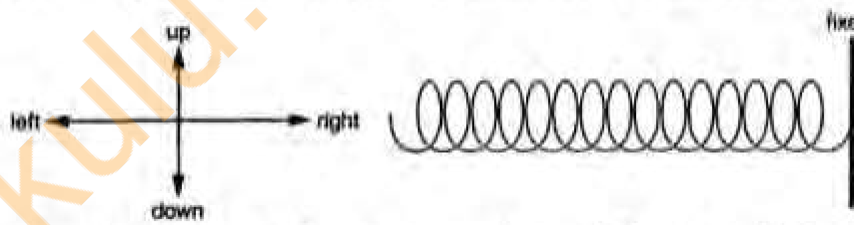
2. Longitudinal Waves

- They appear as a **succession of compressions and rarefactions.**
- An example of such waves: **sound waves.**

- **A LONGITUDINAL WAVE IS A WAVE IN WHICH THE VIBRATIONS OF THE PARTICLES ARE PARALLEL TO THE DIRECTION OF TRAVEL OF THE WAVE**.

Example

[Q] A lightly coiled spring is fixed at one end and held by hand at the other.



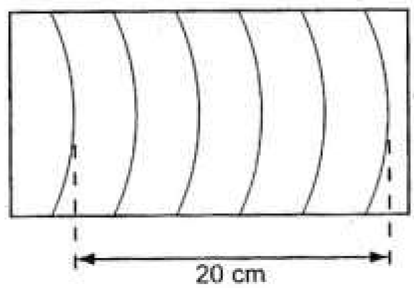
Which hand movements cause first a compression and then a rarefaction to travel along the spring?

A down then up
B up then down
C left then right
D right then left

[Ans] D A longitudinal wave is a wave such that the vibration of particles is along the direction of the wave motion.

Example

[Q] The dipper in a ripple tank vibrates at a frequency of 4.0 Hz and the resulting wave pattern is photographed. The distance between the two crests shown is 20 cm.



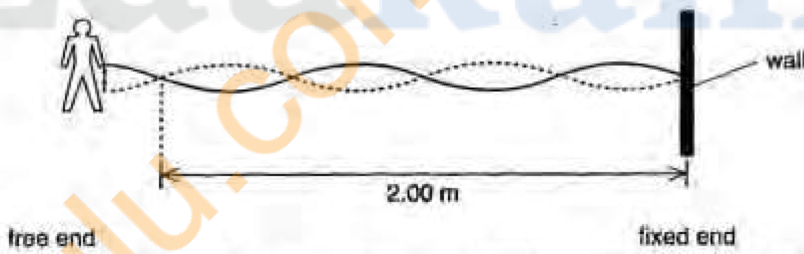
What is the speed of the wave?

A 4 cm/s
C 16 cm/s
B 5 cm/s
D 20 cm/s

[Ans] C Since the distance between two successive crests is the wavelength, $\lambda = \frac{20}{5} =$ 4 cm. Using the wave equation, speed of wave = $f\lambda$ = (4.0)(4) = 16 cm/s.

Example

[Q] The diagram shows waves set up in a rope by a student moving the free end up and down at a steady rate.



What is the wavelength of the waves shown, and what will be the wavelength when the student doubles the frequency at which the free end is moved up and down?

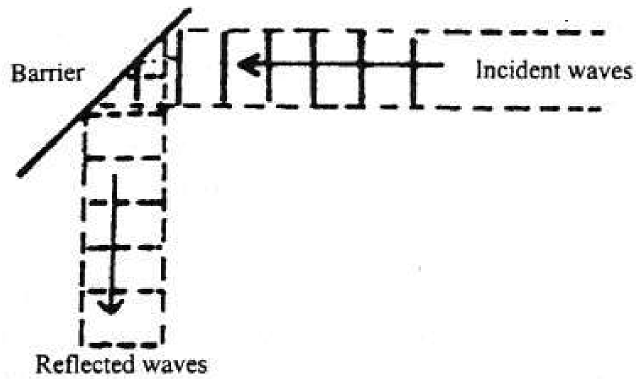
	wavelength as shown	wavelength when frequency doubled
A	0.50 m	1.00 m
B	0.50 m	0.50 m
C	1.00 m	1.00 m
D	1.00 m	0.50 m

[Ans] D There are two waves in a distance 2.00 m. Thus the wavelength is 1.00 m. The speed of wave is constant. When the frequency is doubled, wavelength must be halved to keep the wave speed constant.

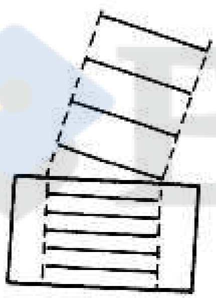
SOME BEHAVIOURS OF WAVES

- We will refer to water waves in the **simple ripple tank.**

Reflection

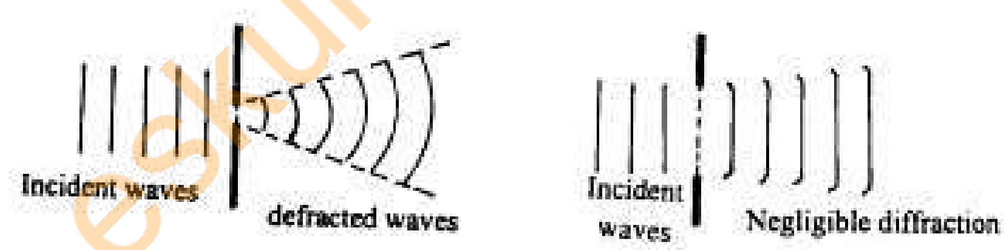


Refraction



The change in the direction of propagation caused by a change in the speed of the wave is called **refraction.**

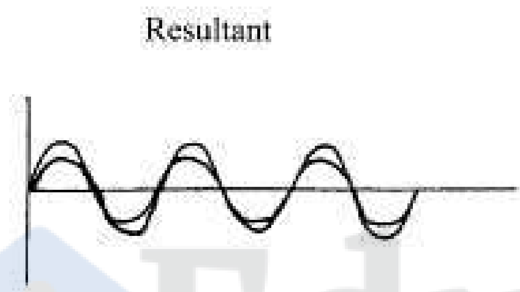
Diffraction

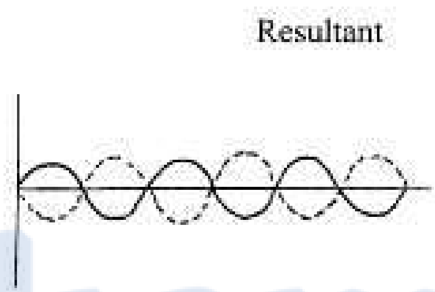


This bending of waves as they emerge from a slit is called **diffraction.**

Superposition and interference

- If a number of waves pass through a certain point at the same instant, the displacement is the resultant of the displacements of the two separate wave motions.
- This is the **principle of superposition** and applies to all kinds of waves.
- If two waves are travelling in the same direction at the **same time** and having **equal amplitudes and frequency**, while they travel in such a way that the crests of one wave meet those of the other and their troughs do the same, their displacements of the waves add up and result into a wave of **double the original amplitude**

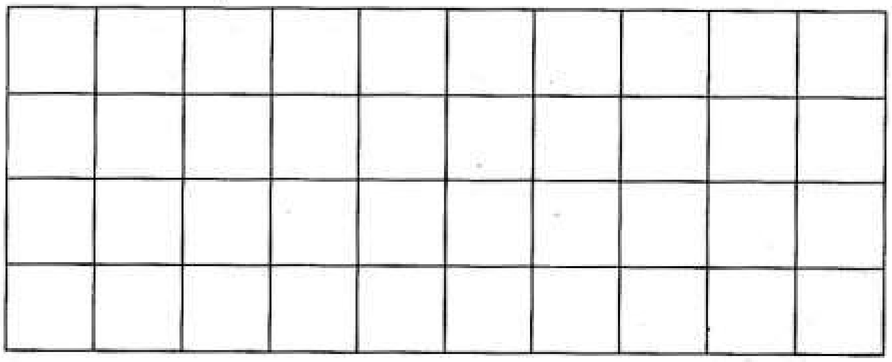




CHALLENGING QUESTIONS – 2

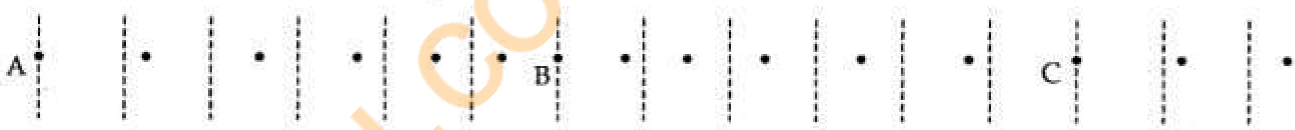
Instructions: *attempt questions before looking at the answers*

1. (a) Draw on the grid below a transverse wave at a particular instant as it travels from left to right. Your wave should be drawn full scale and should have an amplitude of 2.0 cm and a wavelength of 5.0 cm. [2]



(b) Each of the particles in a medium in which a transverse wave travels has a similar motion. Describe briefly the motion of one such particle in a medium through which a transverse wave is passing. [2]

(c) The full-scale diagram represents the positions of particles of a medium at a particular instant whilst a longitudinal wave, travelling from left to right, passes through the medium. Before the wave arrived the particles were all 1.0 cm apart, i.e. each was on one of the dotted lines in the diagram. At the instant shown, the particles A, B and C are passing through their original undisturbed positions.



By making measurements on the diagram, write down

(i) the wavelength of the wave

(ii) the amplitude of the wave motion [2]

2. Transverse waves are produced in a long rope by securing one end of the rope to a wall and then moving the other end from side to side by hand. The frequency of the waves is 2 Hz.

(a) What does the term 'transverse' mean? [1]

(b) Explain the meaning of the expression 'the frequency is 2 Hz'. [2]

(c) What determines the amplitude of the waves produced? [1]

3. (a) Fig. 3.1 is a graph of the variation of d, the displacement (y-axis), with s, the distance from the vibrator (x-axis), for ripples on the surface of water in a ripple tank.

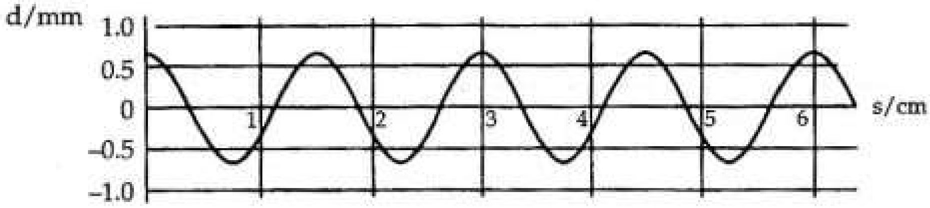


Fig. 3.1

Determine

(i) the amplitude of the ripples,

(ii) the wavelength of the ripples. [2]

(b) Fig. 3.2 is a graph of the variation with time t of the vertical displacement d of the ripple tank vibrator.

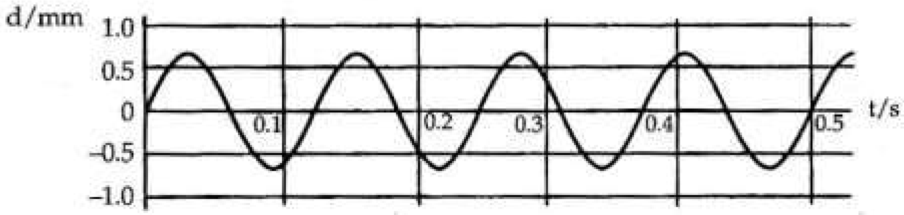


Fig. 3.2

Determine

(i) the period of oscillation of the vibrator,

(ii) the frequency of the vibrator. [3]

(c) Use your answers to (a) and (b) to determine the speed of the ripples. [3]

5. Fig. 5.1 shows a ripple tank being used to investigate waves on water.

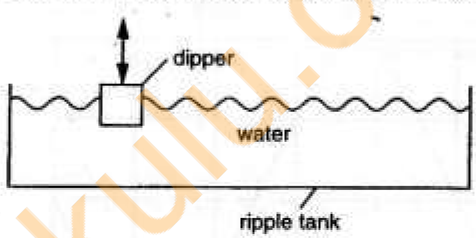


Fig. 5.1

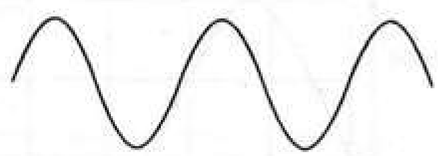


Fig. 5.2 full scale

The dipper moves up and down 20 times in one second. Fig. 5.2 shows, to full scale, a sideways view of the wave on the surface of the water at one instant.

(a) (i) Determine the wavelength of the wave in Fig. 5.2.

(ii) Calculate the speed of the water wave. State clearly the equation you use. [4]

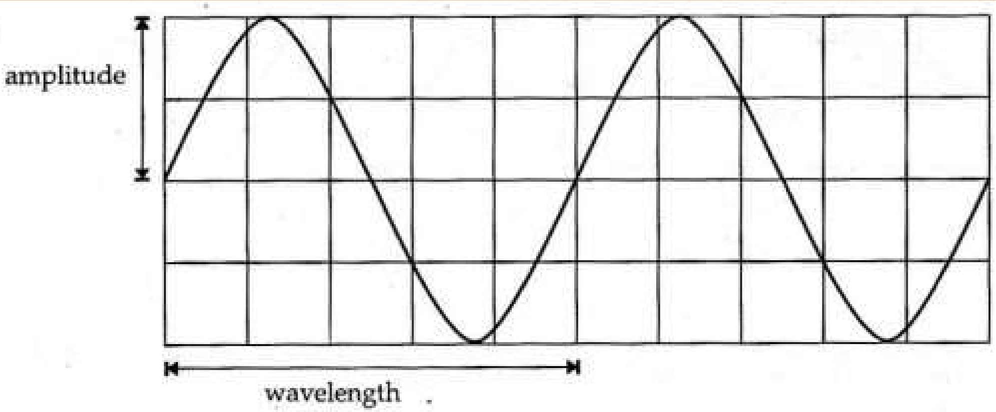
(b) The dipper is now made to move up and down 40 times in one second. The speed of the water wave is unchanged.

(i) On Fig. 5.2, draw the sideways view of the new wave.

(ii) State the value of the new wavelength of the wave. [2]

SOLUTIONS

1. (a)



(b) Each particle oscillates about a fixed position in the direction which is perpendicular to the direction in which the transverse wave is travelling.

(c) (i) 12 cm

(ii) 0.7 cm

(a) 1 square is 1 cm × 1 cm.

(c) (i) Wavelength for longitudinal wave is the distance between two consecutive rarefactions or compressions. Rarefactions occur at A and C whereas a compression occurs at B. Therefore the wavelength is the distance between A and C.

(ii) Amplitude is the greatest distance that a particle has from its resting or equilibrium position (the dotted line).

2. (a) It means that the oscillation of the particles is perpendicular to the direction of the wave motion.

(b) It means that each particle on the rope undergoes 2 complete oscillations per second.

(c) The amplitude of the source which produces the wave. It is the amplitude of the vibration of the hand which generates the wave.

It is very often in the O-Level Physics examination to ask about the meaning of transverse wave, longitudinal wave, wavelength, frequency, amplitude, period and speed of a wave. Candidates are advised to study the meaning or definition of all these terms.

3. (a) (i) 0.70 mm (ii) 1.5 cm

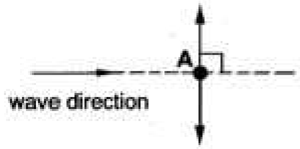
(b) (i) 0.125 s (ii) $f = \frac{1}{T} = \frac{1}{0.125} = 8.0\text{ Hz}$

(c) $v = f\lambda$

$= 8.0 \times \frac{1.5}{100}$

$= 0.12\text{ m/s}$

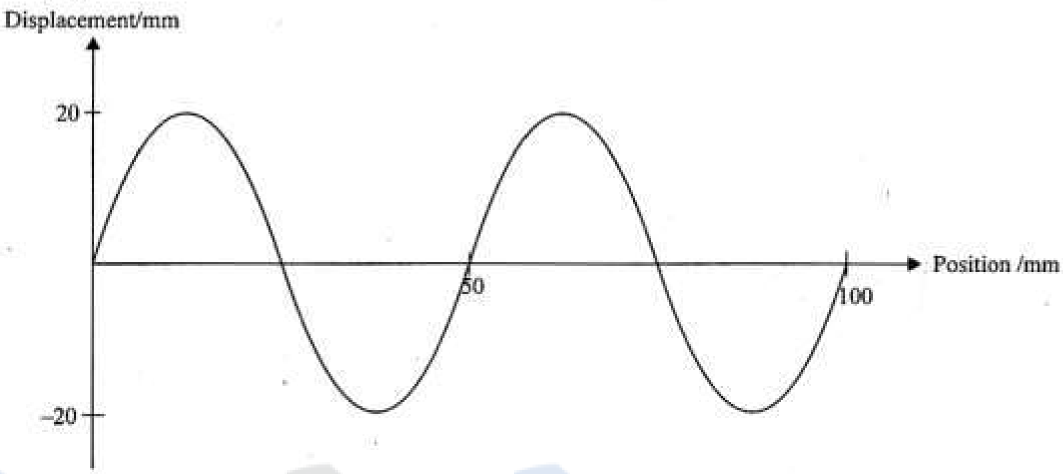
4. (a) (i)



(ii)

(b) (i) Frequency is the number of complete waves produced per second or the number of complete oscillations for each particle along the wave in one second.

(ii)



(iii) $v = f\lambda$

$= 40 \times 50 \times 10^{-3}$

$= 2.0\ m/s$

(iv) water waves, electromagnetic waves (e.g. radio waves)

(a) The diagrams drawn should show the direction of vibration of particle A compared with the wave direction.

(b) (ii) A full-scale diagram is required. Candidates need to choose a scale for displacement and position axes. Remember the number of complete wave needed.

(iv) Other possible answers are infra-red and microwaves.

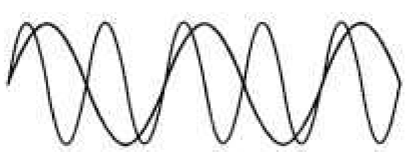
5. (a) (i) wavelength $= \frac{5.3}{2.5} = 2.12$ cm

(ii) $v = f\lambda$

$= 20 \times \frac{2.12}{100}$

$= 0.42\ m/s$

(b) (i)



(ii) wavelength = 1.06 cm

(a) (i) Candidates need to measure the total length of 2.5 wavelengths instead of just measuring the distance of 1 wavelength. To measure a longer distance will result in a more accurate answer.

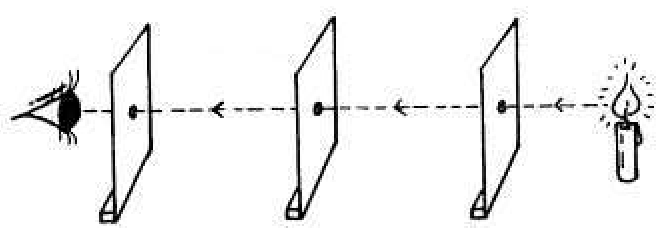
(ii) It is a good practice to include the equation used in the working. The wavelength should be expressed in m when the wave equation is applied.

(b) The speed of water wave remains unchanged as it depends on the depth of the water. If the frequency is doubled, the wavelength must be halved. However there is no change in amplitude.

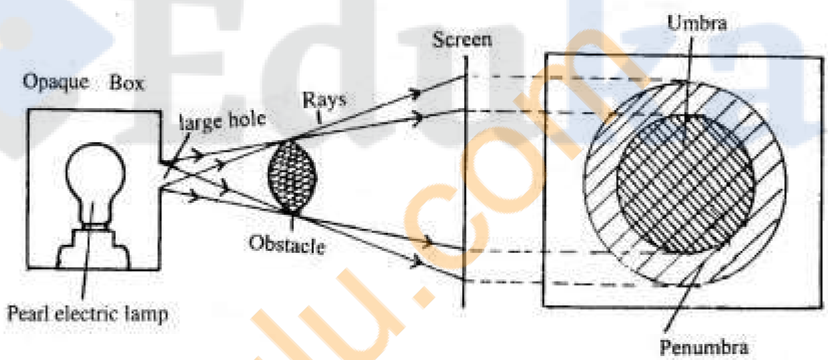
LIGHT

RECTILINEAR PROPAGATION OF LIGHT

- Light travels in a straight line. This phenomenon is called **rectilinear propagation** of light



- Rectilinear propagation of light produces sharp-edged **shadows.**



REFLECTION OF LIGHT

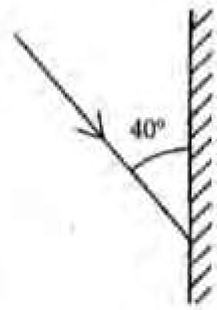
Laws of Reflection

1. **The incident ray, the reflected ray and the normal all lie in the same plane.**
2. **The angle of incidence is equal to the angle of reflection.**

Example

[Q] The diagram shows a single ray of light being directed at a plane mirror. What are the angles of incidence and reflection?

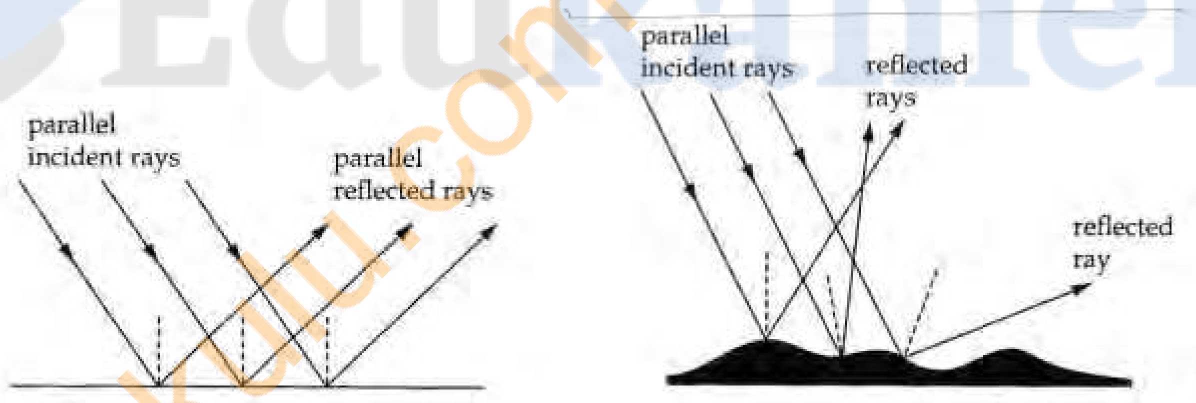
	angle of incidence	angle of reflection
A	40	40
B	40	50
C	50	40
D	50	50



[Ans] D angle of reflection = angle of incidence = 90° – 40° = 50°

Regular and Diffused Reflection

- **Regular** reflection refers to the reflection of rays coming from a **smooth plane surfaces.** All incident rays have **parallel** reflected rays in this case.
- In **diffused (irregular) reflection** the reflected rays come out in different directions as shown below. This is because of the rough surface.



(a) Regular reflection (smooth surface)

(b) Diffused reflection (rough surface)

Ray Diagrams

- An **image** is formed when an object is placed in front of a **plane mirror.**

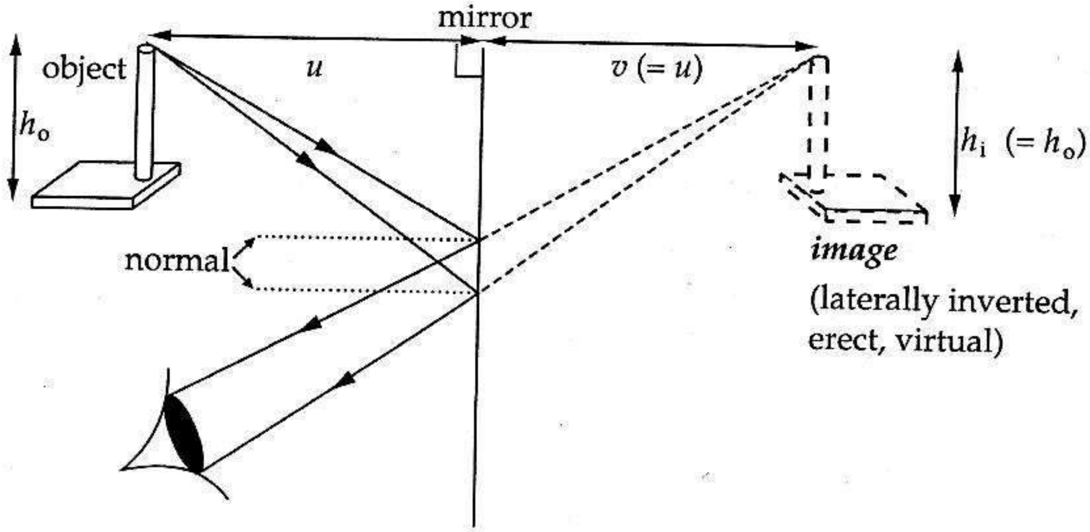


Image in a plane mirror

The image has the following properties:

1. **Same size as object ($h_i = h_o$)**
2. **Laterally inverted**
3. **Erect**
4. **Virtual**
5. **As far behind the mirror as the object is in front (v = u)**

PRACTICAL 1 – COMPARING THE SIZE OF THE OBJECT WITH ITS IMAGE

Draw a straight line on a sheet of plain paper to represent the mirror and a triangle *ABC* to represent an object. Take one point of the object after another (*A, B, C*) and locate its image *(a, b, c,)* respectively, then join the points together. The image appears as shown in Figure 7.14.

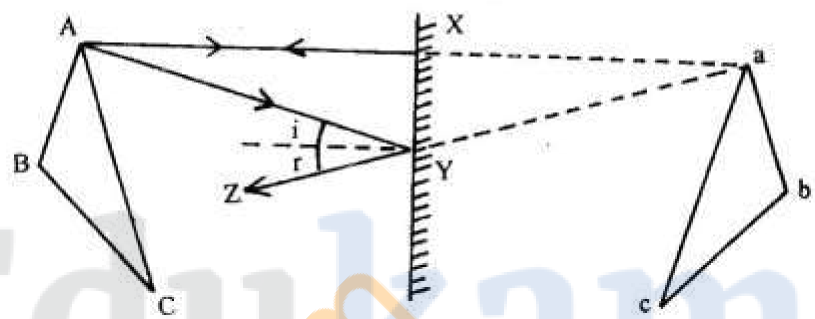


Figure 7.14 Image is same size as object

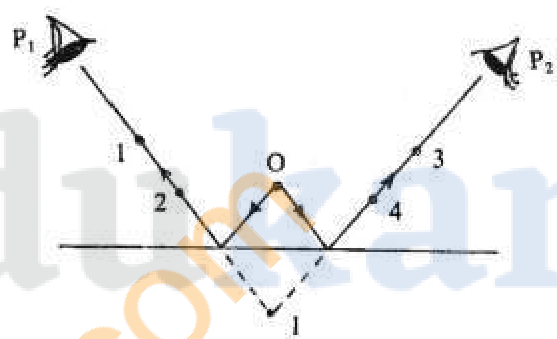
The explanation for this is as follows: the ray *AX* strikes the mirror normally and is reflected back on itself. Ray *AY* reaches the mirror at *Y* and is reflected along *YZ*, making *i* equal to *r*. Lines *AX* and *YZ*, when extended behind the mirror, intersect at '*a*', the image of *A*. Repeating the process for *B* and *C* gives the image as it appears in the diagram. The following points should be apparent about the image. It is as far behind the mirror as the object is in front. The image is of the same size as the object. It is laterally inverted and it is virtual.

PRACTICAL 2 – TO DETERMINE THE POSITION OF THE IMAGE

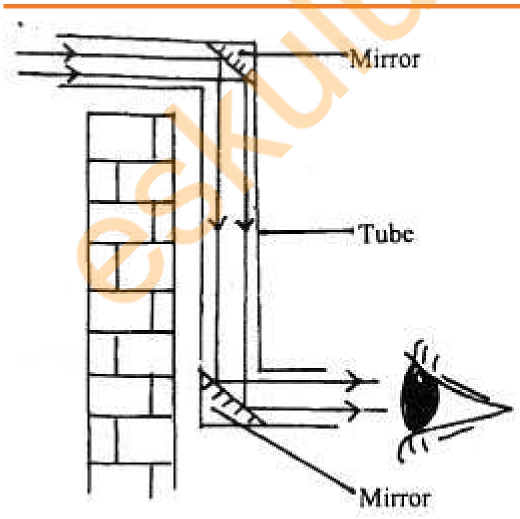
Draw a straight line on a sheet of plain paper. Stand a mirror upright with its back on the line. Stick a large pin *(O)* in front of the mirror to represent the object. View the image in the mirror from some convenient position P_1. Place two other pins 1 and 2 so that they and the image are all in a straight line.

Remove them, mark their positions, and repeat the process from another position P_2.

Remove the mirror and all the pins. Join the positions of pins 1 and 2, and the positions of 3 and 4 with solid lines touching the mirror. Extend these behind the mirror as dotted lines. Where these meet behind the mirror is the position of the image you observed from positions P_1 and P_2 Mark it as *I*. Repeat the experiment to confirm your result.



THE MIRROR PERISCOPE



This instrument uses mirrors to enable observers to see above an obstacle.

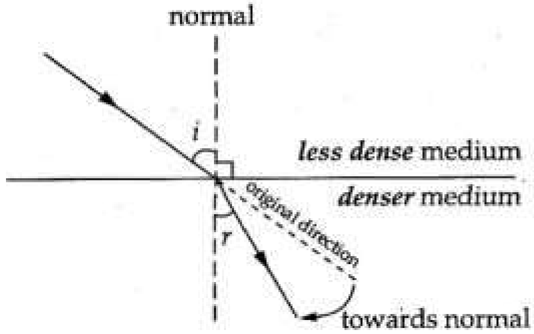
REFRACTION OF LIGHT

- Refraction refers to the bending of light **when it passes from an optically less dense medium to an optically denser medium or vice versa.**

Three Situations of Refraction

From a less dense to a denser medium: ***Speed of light becomes slower.***

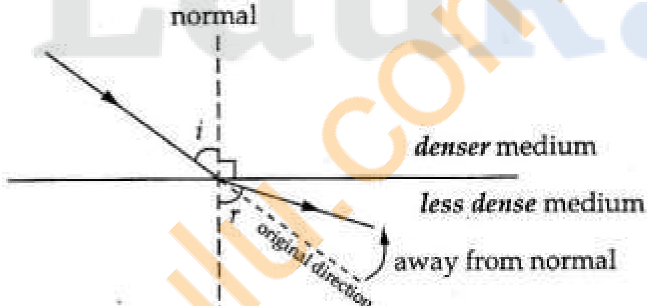
Light is ***refracted towards*** the normal ($i > r$).



Take note	In this situation, an important concept is ***refractive index.***

From a denser to a less dense medium: ***Speed of light becomes faster.***

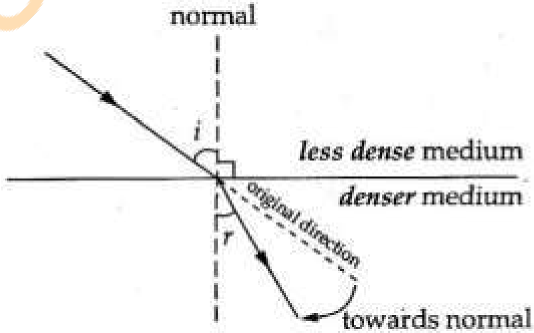
Light is ***refracted away*** from the normal ($i < r$).



Take note	In this situation, an important concept is ***total internal reflection.***

From a less dense to a denser medium: ***Speed of light becomes slower.***

Light is ***refracted towards*** the normal ($i > r$).



Take note	In this situation, an important concept is ***refractive index.***

Laws of Refraction

1. The incident ray, the refracted ray and the normal are all in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is always a constant. This is called the refractive index. (Snell's Law)
   The equation is given below.

$$\eta = \frac{\sin\theta_1}{\sin\theta_2}$$

$$\eta = \frac{\text{speed of light in vacuum (or air)}}{\text{speed of light in medium}}$$

Example

[Q] The table shows measurements taken during an experiment in which a ray of light is shone at one of the sides of a rectangular block of glass.

angle of incidence, i	26.0°	39.0°
angle of refraction, r	15.5°	22.5°
$\sin i$	0.438	0.629
$\sin r$	0.267	0.383

What is the refractive index of the glass?

A 1.50
B 1.64
C 1.68
D 1.73

[Ans] B $\eta_1 = \sin i / \sin r = 0.438 / 0.267 = 1.640$

$\eta_2 = 0.629 / 0.383 = 1.642$

$\eta_{average} = (1.640 + 1.642) / 2 = 1.64$

PRACTICAL 3 – REFRACTION THROUGH A RECTANGULAR GLASS BLOCK

Place a rectangular glass block on a plain sheet of paper on a drawing board. Mark its outline with a very sharp pencil. Remove the block temporarily and draw a normal and several long lines to represent incident rays at measured angles. Replace the block right on the outline.

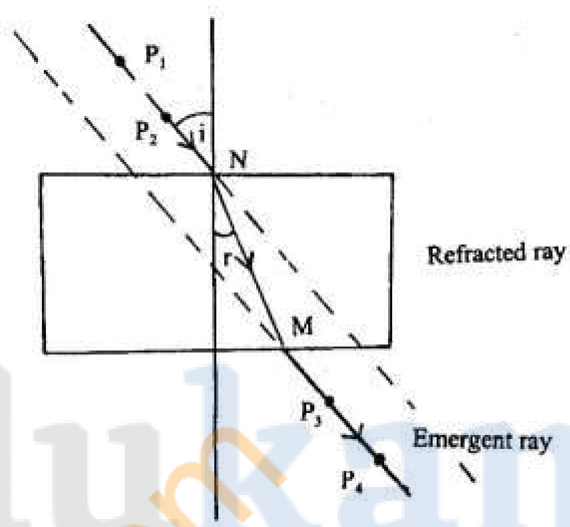


Figure 8.4 Refraction tl

Stick two optical pins P_1 and P_2 as far apart as possible along the normal to represent a ray of light incident on the block through the normal. View these pins from the opposite side of the block and stick two more pins P_3 and P_4 in the same manner so that all the four pins appear to be in one straight line.

Remove the pins, mark their positions with crosses, and repeat the procedure for all the incident angles. Each time you remove the pins, join the positions of each pair with a straight line. Line P_1P_2 represents the incident ray while P_3P_4 represents the emergent ray. To obtain the refracted ray, join point *N* with point *M*.

Measure *i* and *r*, look up their sines, and calculate the ratio for each pair of angles and complete the table below:

i	*r*	Sine *i*	Sine *r*	$\frac{\text{Sine } i}{\text{Sine } r}$

From your results you will notice that a light ray bends towards the normal when it passes from air (light medium) to glass (a dense medium), except when it passes along the normal. In the latter case there is no refraction because there is no angle of incidence *(i = 0)*. For a parallel sided block the emergent ray is parallel to the incident ray. The incident ray, the normal and the refracted ray all lie in the same plane. The ratio

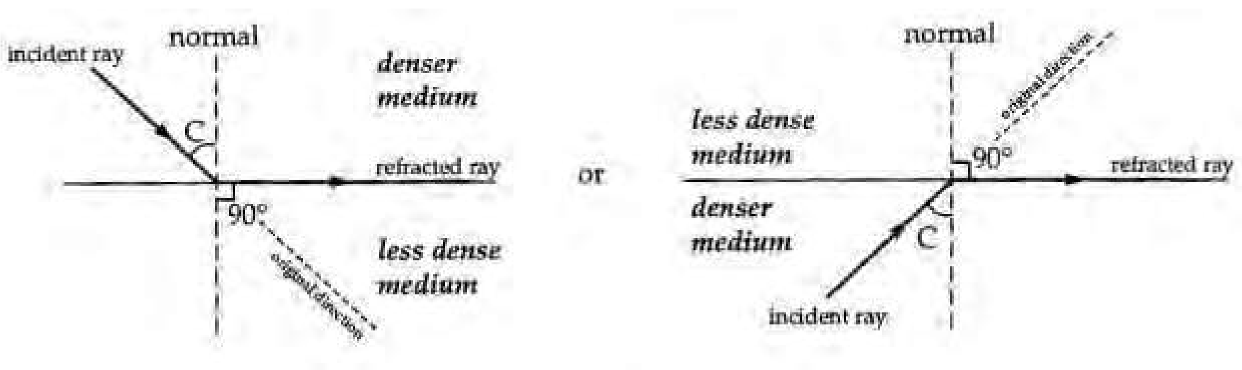
$\frac{\sin i}{\sin r}$ is constant and is therefore called the **refractive index** *(n)*. This relationship, $\frac{\sin i}{\sin r}$ = constant, discovered by Snell is called **Snell's law**. For glass the refractive index is approximately 1.5 to 1.6 depending on the kind of glass used. The refractive index of water is 1.33 and that of alcohol is 1.36. Refraction takes place because light travels at different velocities in different media. It could be shown that

$$\text{Refractive index} = \frac{\text{Velocity in air}}{\text{Velocity in medium}}$$

TOTAL INTERNAL REFLECTION

Critical Angle

- **Critical angle (C)** refers to the **angle of incidence** in the optically denser medium for which its angle of refraction in **the less dense medium is 90^{o}**.

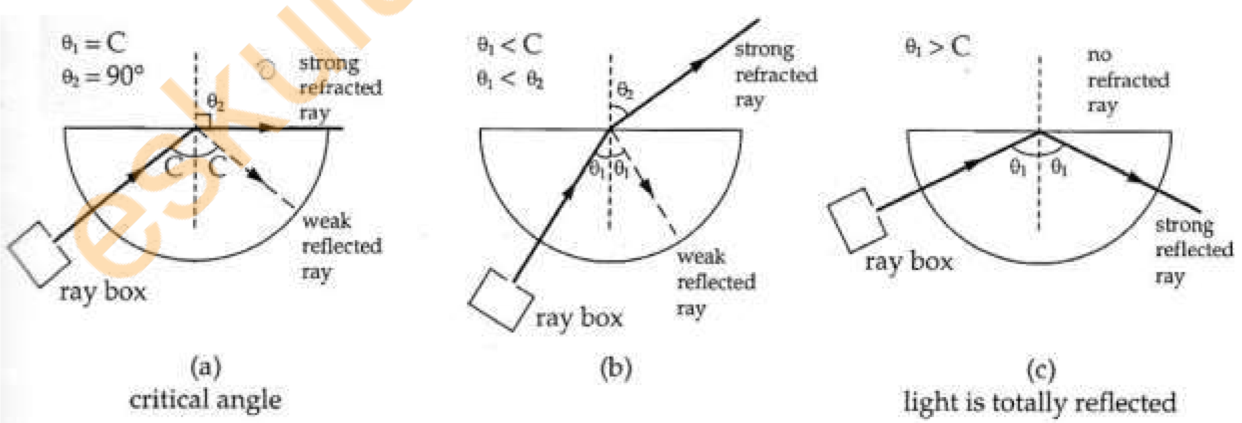


- Equation:

$$C = sin^{-1}(\frac{1}{\eta})$$

Total Internal Reflection

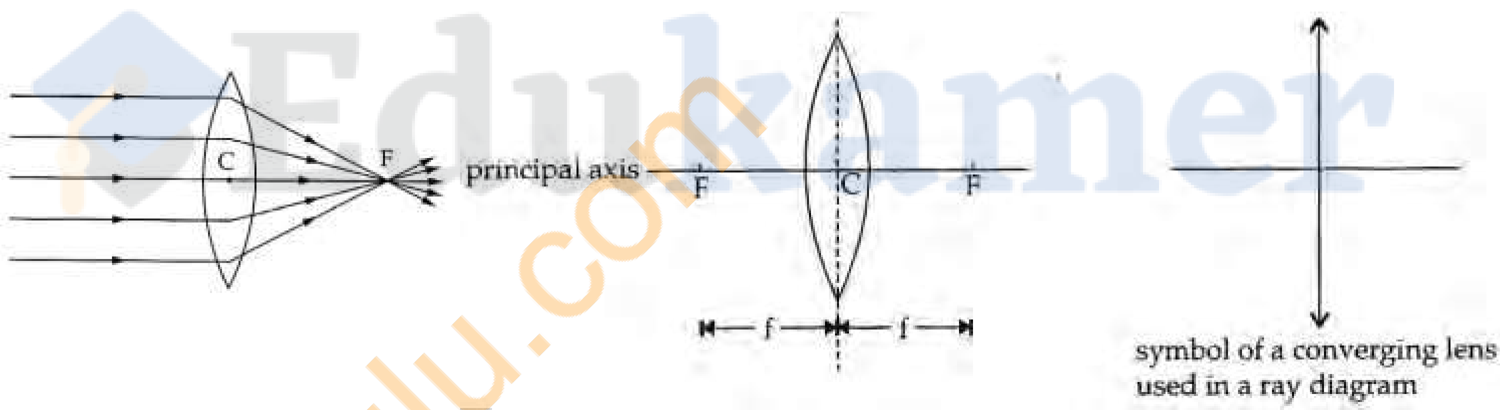
- **DEFINITION:** When light travels from an optically denser medium to an optically less dense medium and the angle of incidence is greater than the critical angle, **there is NO refracted ray,** all the light is reflected back into the optically denser medium. This is called **total internal reflection.**



LENSES

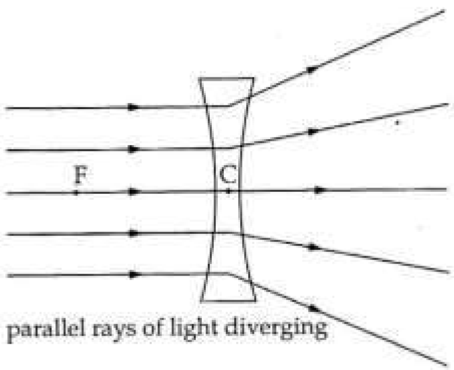
Converging Lens

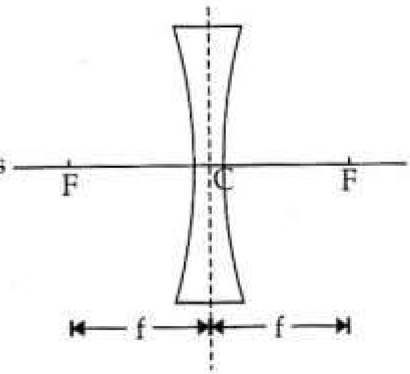
- A lens which is thicker at the center than at the edges is called a **converging (convex) lens.**
- Light rays are converged to a point (F) after passing through a converging lens
- In ray diagram:
    - '**C**' is the centre of the lens and is called the **optical centre.**
    - **'F'** is the **principal focus.**
    - **'f'** is the **focal length.**
    - A line passing through C and perpendicular to the plane of the lens, i.e the line F-C-F, is the **principal axis.**

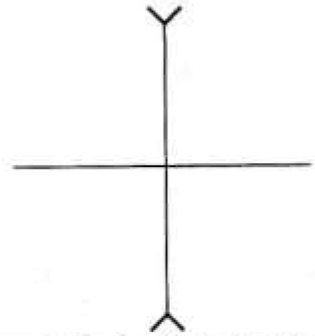


Diverging Lens

- A lens thinner at the centre than at the edges is called a **diverging (concave) lens**.
- Light rays are diverged after passing through a diverging lens.
    - '**C**' is the centre of the lens and is called the **optical centre.**
    - **'F'** is the **principal focus.**
    - **'f'** is the **focal length.**
    - The line passing through C is the **principal axis.**



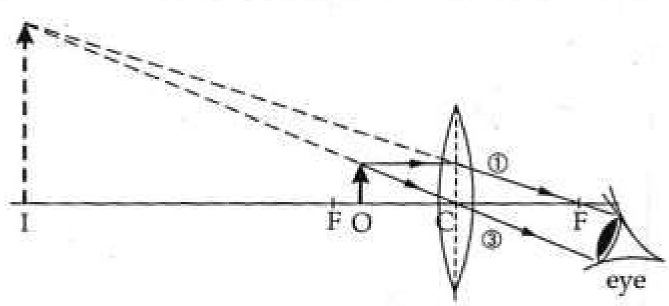
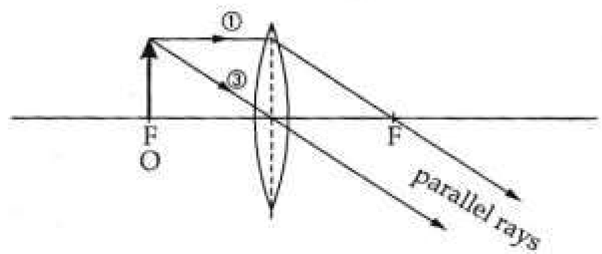


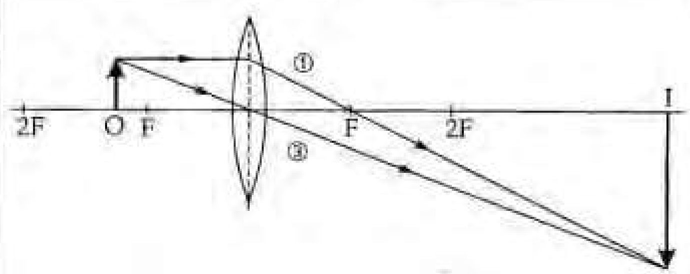
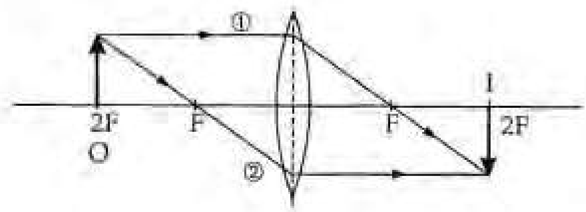
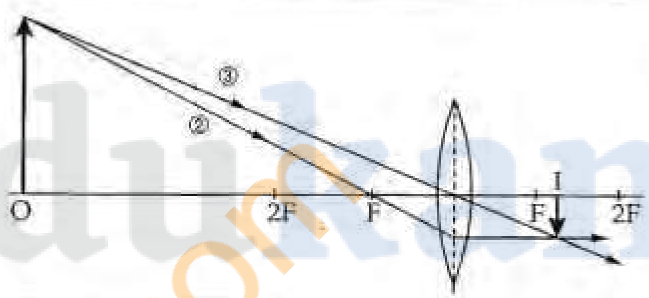
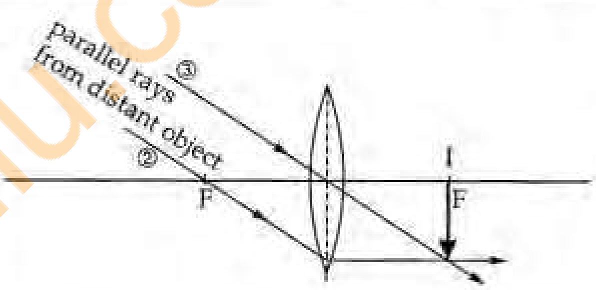


Construction of Ray Diagrams (For Converging Lens)

- Rule 1. Rays parallel to the principal axis are refracted through **'F'.**
- Rule 2. Rays passing through '**F**' are refracted parallel to the refracted through '**F**'.
- Rule 3. Rays passing through '**C**' are undeviated.

The **image** formed depends on the position of the **object.**

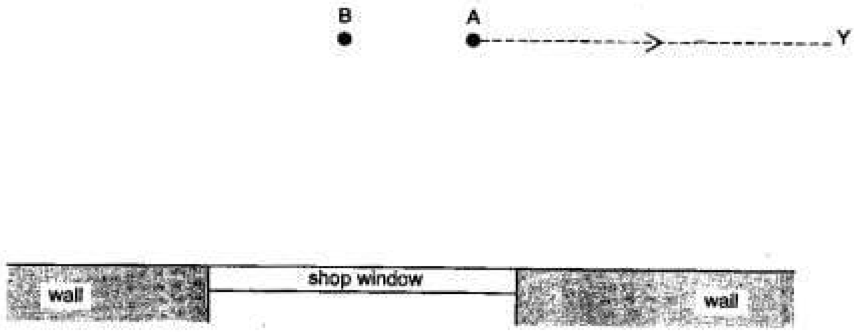
Positions of object	Ray diagrams	Nature of image
(a) O between F and C e.g. magnifying glass, spectacles correction for long-sightedness		❶ virtual ❷ erect ❸ magnified ❹ on same side of lens as O and further away
(b) O at F e.g. produces a parallel beam of light as in a spot light with lamp at O		❶ at infinity

(c)	O between F and 2F e.g. projector, microscope objective lens		❶ real ❷ inverted ❸ magnified ❹ on opposite side of lens to O, beyond 2F
(d)	O at 2F e.g. camera making equal size copies		❶ real ❷ inverted ❸ same size as O ❹ on opposite side of lens to O, at 2F (symmetrical diagram)
(e)	O beyond 2F e.g. camera, eyes		❶ real ❷ inverted ❸ diminished ❹ on opposite side of lens to O, between F and 2F (diagram in (c) reversed)
(f)	O at infinity e.g. objective lens of a telescope		❶ real ❷ inverted ❸ diminished ❹ on opposite side of lens to O, at F (diagram in (b) reversed)

CHALLENGING QUESTIONS – 3

Instructions: *attempt questions before looking at the answers*

1. A person standing at point A sees the reflection in a shop window of a person standing at point B.



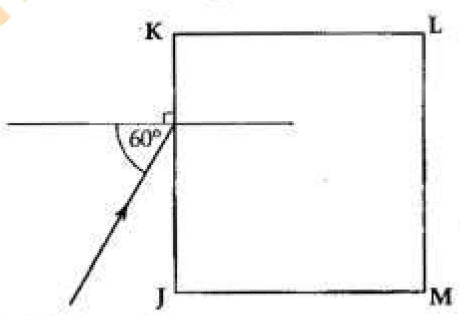
(a) Draw a ray of light to show how, by reflection, the person at A sees the persons at B. [1]

(b) Mark, with a letter I, the position of the image of B formed by reflection in the shop window. [2]

(c) (i) The person at A moves further away from B towards Y in the direction of the arrow shown. Mark with a letter X the furthest position along AY to which the person can move so that the two people will still be able to see each other by reflection in the shop window.

(ii) Explain how you decided on the position of X. [2]

2. Figure shows a square block of glass JKLM with a ray of light incident on side JK at an angle of incidence of 60°. The refractive index of the glass is 1.50.

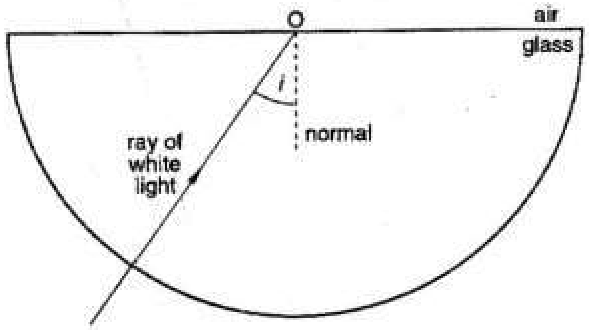


(a) Calculate the angle of refraction of the ray. [2]

(b) Calculate the critical angle for a ray of light in this glass. [2]

(c) Explain why the ray cannot emerge from side KL but will emerge from side LM. [3]

3. Figure shows the passage of a ray of white light into a semicircular glass block. The ray meets the straight side of the block at O, the centre of the semi-circle. The angle *i* is less than the critical angle.



(a) As the light meets the straight side of the block, part of the light is reflected and the rest of the light is refracted.

(i) Draw rays which show the reflection and refraction of the light at O.

(ii) Explain why a spectrum may be seen in the light that is refracted.

(iii) Explain why the reflected light stays white. [5]

(b) The angle of incidence *i* at O is increased until total internal reflection occurs.

(i) State what is meant by **total internal reflection**.

(ii) Draw a diagram to show how a light pipe (optic fibre) makes use of total internal reflection. [2]

4. Fig. 4.1 shows words seen through a lens. Fig. 4.2 shows the same words without the lens.

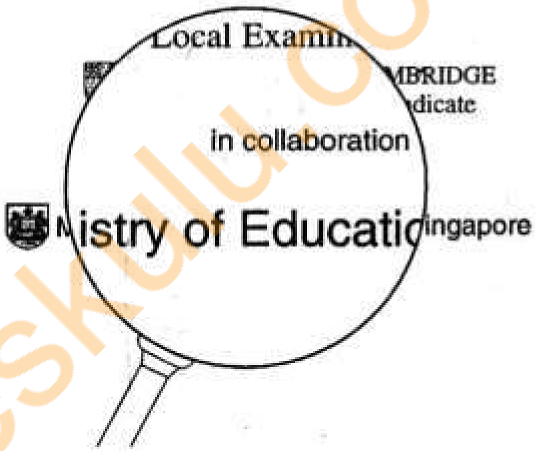


Fig. 4.1

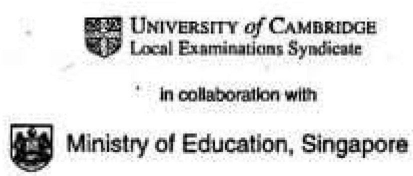


Fig. 4.2

(a) State two properties of the image formed by the lens. [2]

(b) On Fig. 4.3, sketch a ray diagram to show how the image in Fig. 4.1 was formed by the lens. Mark clearly the focal length of the lens and the image formed. [3]

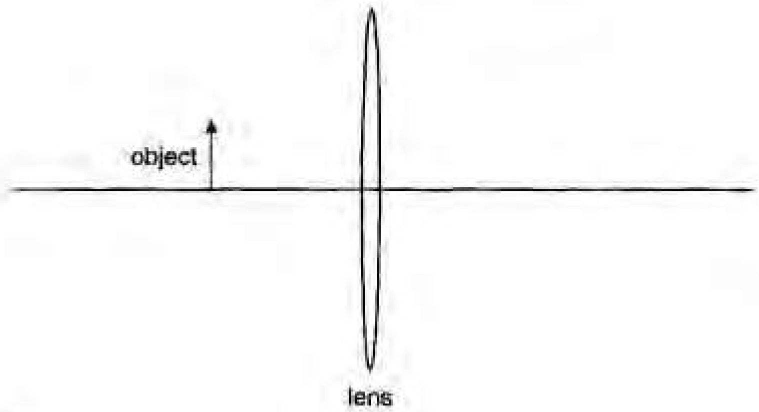
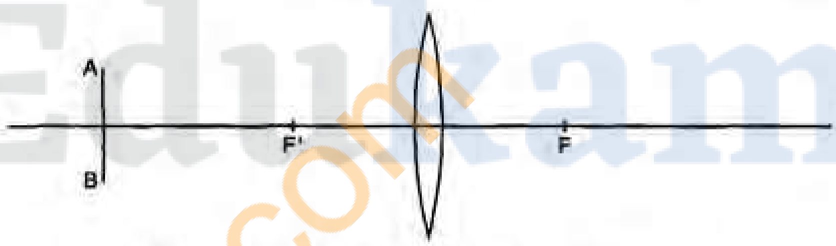


Fig. 4.3

5. Figure shows an object AB near a thin converging lens. The principal foci of the lens are at F and F'.



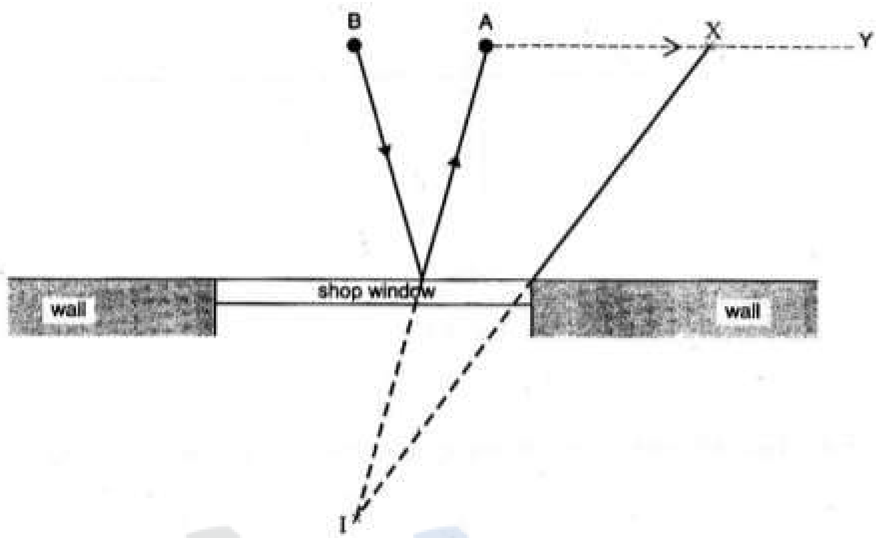
(a) Draw rays to find the positions of the images of the points A and B. [3]

(b) The image of the object AB is real. State two other characteristics of the image. [2]

(c) State the name of an optical device that uses a lens to form a real image of an object. [1]

SOLUTIONS

1. (a), (b), (c)(i)



(c) (ii) The light ray from B must be incident on the extreme right edge of the mirror such that the light ray can be received by A at point X.

It is recommended to locate the image of B first and then draw the reflected ray from image of B to A.

The multiple reflection inside the glass can be ignored.

2. (a) refractive index of glass $= \frac{\sin i}{\sin r}$

$$\sin r = \frac{\sin 60°}{1.5} = 0.577$$

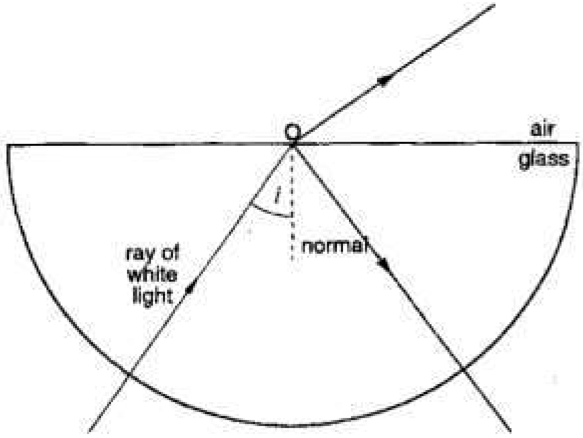
angle of refraction = 35.2°

(b) $\sin C = \frac{1}{\eta} = \frac{1}{1.5}$

$C = 41.8°$

(c) At KL, the angle of incidence is greater than critical angle. Therefore total internal reflection occurs. The light ray is reflected and travels to LM. At LM, the angle of incidence is smaller than the critical angle and the light ray emerges.

3. (a) (i)

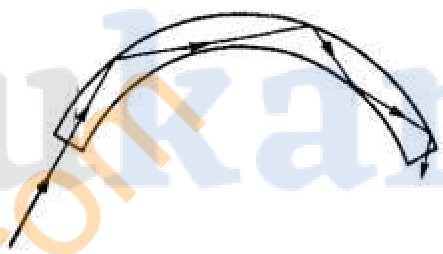


(ii) The seven colours are refracted into air with different angles of refraction. The white light is dispersed and so a spectrum is seen.

(iii) The seven colours are reflected with the same angle of reflection and they combine again to form a white light.

(b) (i) When light ray travels from an optically denser medium to an optically less dense medium and the incident angle is greater than the critical angle, the light ray is reflected back into the denser medium. This is called total internal reflection.

(ii)



Exam Tip

(a) (i) The reflected ray is weaker than the refracted ray. Angle of reflection is equal to the angle of incidence *i*.

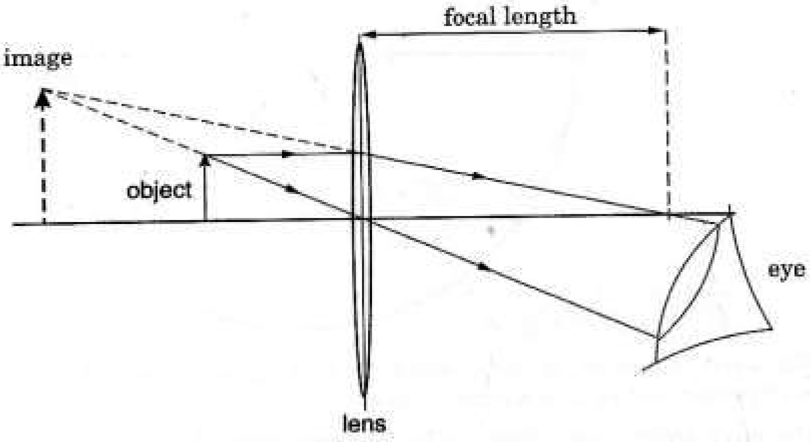
(ii) The seven colours undergo different changes in speed when they emerges into air.

(iii) The seven colours travel with the same speed when they are in the same medium.

(b) (ii) When the light ray travels along the optic fibre, it undergoes total internal reflection. The angle of incidence at the wall should be greater than the critical angle. Candidates should take note of this point when they draw the diagram.

4. (a) 1. Magnified
2. Virtual

(b)

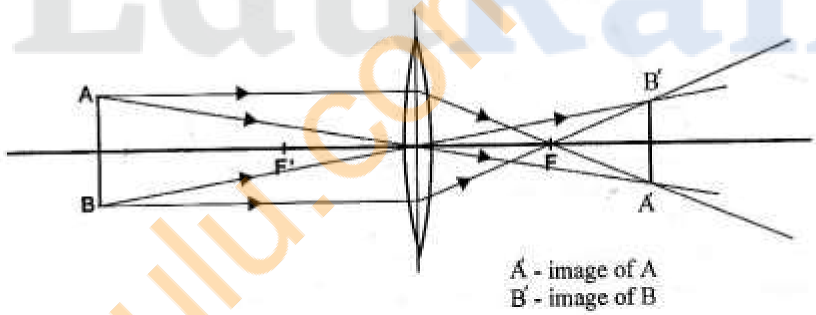


ExamTip

(a) From the figure shown in the question, it is obvious that the image formed by the lens is magnified. The lens is hence a converging lens. The image formed is virtual, magnified and upright.

(b) Candidates are reminded to use dotted line for virtual light rays and image. Focal length should also be indicated clearly in the ray diagram. Another important point is that the light rays should be given a direction.

5. (a)



(b) Diminished and inverted

(c) Camera

ExamTip

(a) Two light rays are required for both points A and B. Arrows are expected to indicate the direction of light ray.

(c) Other possible answers are eye and projector, but projector will produce a magnified image.

ELECTROMAGNETIC SPECTRUM

Electromagnetic spectrum consists of seven kinds of waves.

Radio waves.

Microwaves.

Infra-red radiation (IR).

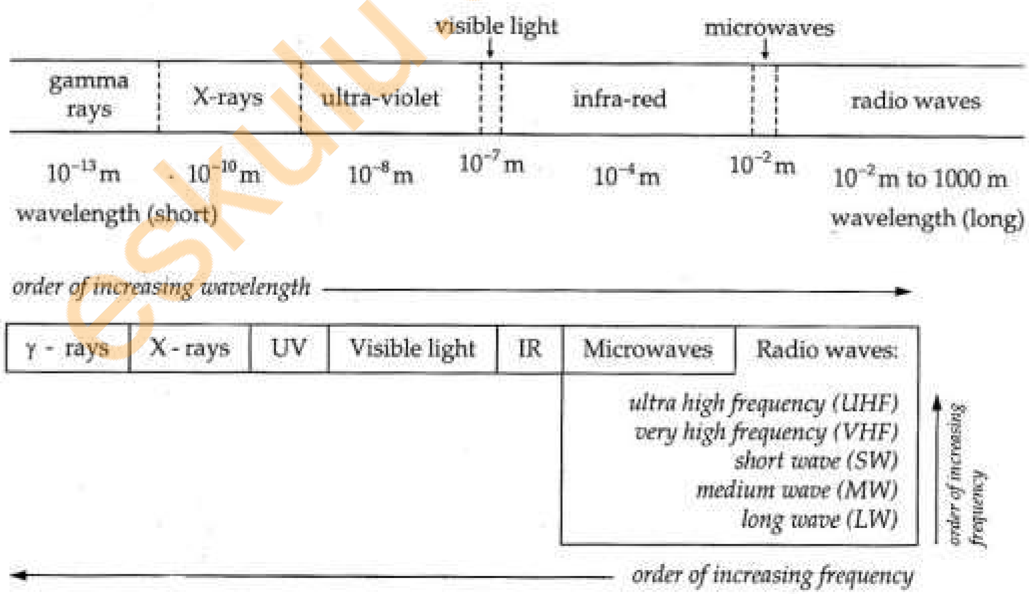
Visible light.

Ultra-violet radiation (UV).

X-rays.

Gamma (ϒ) rays.

A. The following shows the ascending order of wavelength and frequency of electromagnetic waves. **The shorter the wavelength, the higher the frequency.**



Example

[Q] Which row shows parts of the electromagnetic spectrum in order of increasing frequency?

A	radio waves	X-rays	visible light
B	radio waves	visible light	X-rays
C	X-rays	radio waves	visible light
D	X-rays	visible light	radio waves

[Ans] **B** Fact.

Properties of Electromagnetic Waves

1. They are all transverse waves.
2. They transfer energy from one place to another.
3. They all show wave properties such as reflection and refraction.
4. They can all travel through a vacuum.
5. They all travel at 3×10^8 ms^{-1} in a vacuum.
6. The equation **v = fλ** applies to all of them.

Applications of Electromagnetic Waves

Electromagnetic waves:	Wavelength	Source(s)	Applications or effect
Gamma rays (γ -rays)	10^{-13} m *(shortest)*	☐ radioactive nuclei	☐ radiotherapy
X-rays	10^{-10} m	☐ X-ray tube	☐ medical diagnosis ☐ diagnosis of flaws in machines
Ultra-violet radiation (UV)	10^{-8} m	☐ the sun ☐ mercury lamp ☐ halogen lamp	☐ causing sun-tan ☐ causing skin cancer ☐ stimulating the production of vitamin D in skin ☐ sterilization
Visible light (violet to red)	10^{-7} m	☐ the sun ☐ lamp	☐ enhance vision ☐ optical fibre
Infra-red radiation (IR)	10^{-4} m	☐ warm or hot objects	☐ furnace for car paint ☐ remote control for TV, Hi-Fi, etc
Microwaves	10^{-2} m	☐ man-made transmitter	☐ microwave oven ☐ radar ☐ telecommunication
Radio waves	10^{-2} m to 10^{3} m *(longest)*	☐ man-made transmitter	☐ broadcasting of radio or TV programmes ☐ telecommunication

CHALLENGING QUESTIONS – 4

Instructions: *attempt questions before looking at the answers*

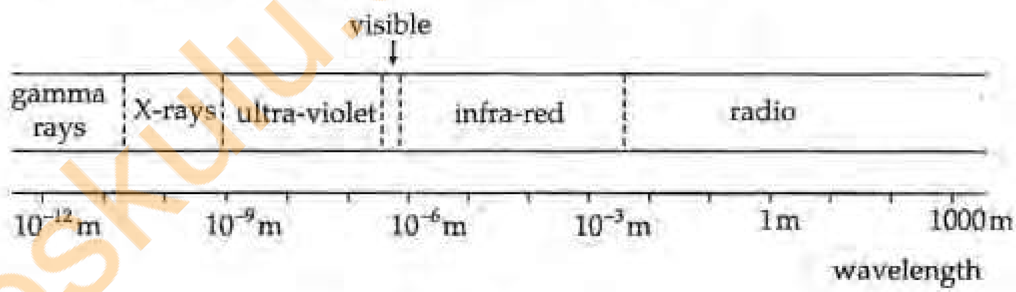
1. In each of (a) to (d) below, which part of the electromagnetic spectrum has the properties described.
   (a) Its wavelengths are longer than those of visible light it can pass through fog but is absorbed by glass.
   (b) Its wavelengths are longer than those of visible light; it can be reflected by layers in the upper atmosphere.
   (c) Its wavelengths are shorter than those of visible light; it passes readily through glass but is strongly absorbed by a lead screen several centimetres thick.
   (d) Its wavelengths are shorter than those of visible light; it is absorbed by glass; it can produce fluorescence.

2. (a) Complete the gaps in the diagram of the electromagnetic spectrum.

RADIO					GAMMA

   (b) Very short wavelength radio waves can be used to determine the distance of the Moon from the Earth, by measuring the time taken for radio-waves to travel from the Earth to the Moon and back again. Calculate the delay between the transmission and reception of the signal when the Moon is 3.9×10^8 m from the Earth. (Speed of electromagnetic waves = 3.0×10^8 m/s.) [5]

3. The chart shows the main parts of the electromagnetic spectrum.



   (a) All of the different types of electromagnetic waves in the chart may be reflected. State three other properties common to all electromagnetic waves. [3]
   (b) Microwaves travel at a speed of 3.0×10^8 m/s in a vacuum and have a frequency of 1.5×10^{10} Hz.
      (i) Calculate the wavelength of these microwaves.
      (ii) On the chart, mark a line to represent the position of these microwaves in the electromagnetic spectrum. [5]

1. (a) Infra-red
   (b) Radio waves
   (c) Gamma rays
   (d) Ultra-violet

Candidates should know the electromagnetic spectrum in order of increasing wavelength (or frequency) and the nature and application of each kind of electromagnetic waves.

2. (a)

RADIO	INFRARED	VISIBLE LIGHT	ULTRA - VIOLET	X - RAYS	GAMMA

   (b) Distance travelled by the signal = $3.9 \times 10^8 \times 2$ m = 7.8×10^8 m

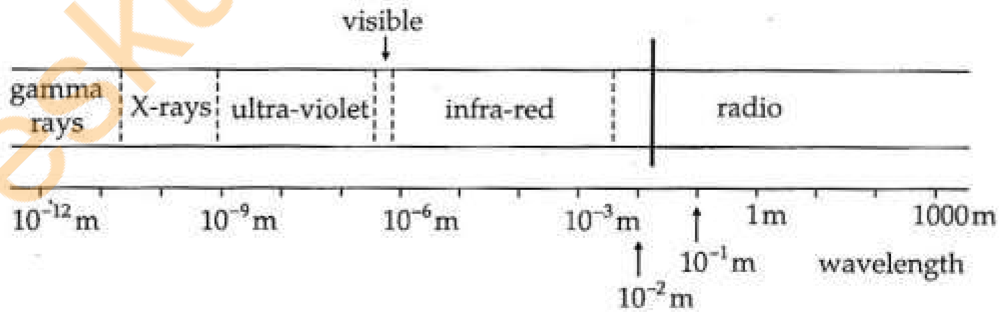
   The delay, $t = \dfrac{7.8 \times 10^8}{3.0 \times 10^8} = 2.6$ s

(b) Since the signal travels from the Earth to the Moon and back again, the distance travelled is two times the distance between the Earth and the Moon.

3. (a) 1. They are transverse waves.
   2. They travel at a speed of 3.0×10^8 m/s in a vacuum.
   3. They are neutral and undeflected by electric and magnetic field.

   (b) (i) $\lambda = \dfrac{v}{f} = \dfrac{3.0 \times 10^8}{1.5 \times 10^{10}} = 2.0 \times 10^{-2}$ m

   (ii)



SOUND

PRODUCTION OF SOUND

Sound is caused by vibration.

- Sound needs a medium (gas, liquid or solid) for transmission.
- Unlike electromagnetic waves, sound waves **cannot** propagate through a vacuum (because there are no molecules to pass on the vibrations).
- Air is the main medium for us to hear sound.

The speed of sound has the following **Equation**:

$$v = f\lambda$$

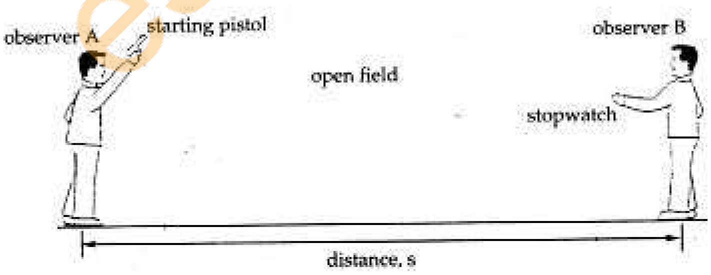
- Sound travels faster in denser media, so it travels faster in liquids than in gases and fastest in solids.
- Sound travels faster in higher temperature.

ECHOES

Sound waves can be reflected. These reflections are called **echoes**.

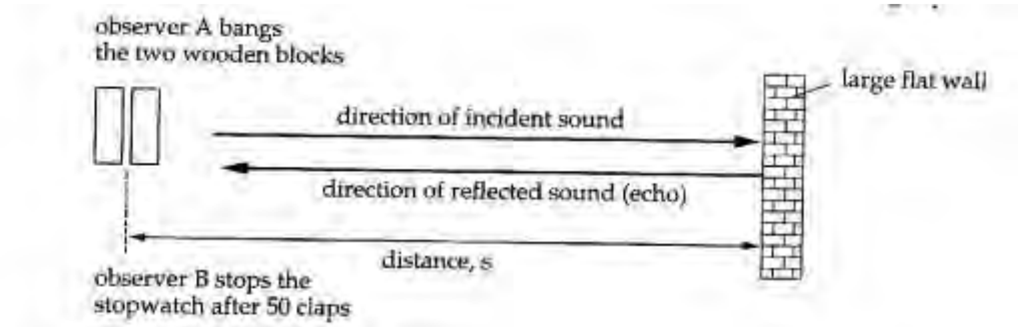
- Echoes can be used to calculate **the distance between two objects** and **the speed of sound.**
- To **calculate the speed of sound** in air we use 2 methods:

Direct Method



$$v = \frac{s}{t} \qquad where\ \ v = speed; s = distance; t = time\ interval;$$

Indirect Method



$$v = \frac{2 \times s}{t} \qquad where\ \ v = speed; s = distance; t = time\ interval$$

Example

1. The range of frequencies which the human ear can hear is from about 20 *Hz* to 20 000*Hz*. What wavelengths correspond to these frequencies in air? Take v = 330m/s.

Solution

(a) $l = \frac{n}{|}$

$= 330/20$

$= 16.5\text{m}$

(b) $l = \frac{n}{|}$

$= \frac{330}{20\ 000}$

$= 0.0165\text{m}$

2. An echo sounder produces a high-pitched sound whose echo is picked up by a hydrophone after 3s. Given that the velocity of sound is 1410m/s in water, how deep is the water at this point?

Solution

2 X Distance = $V \times t$

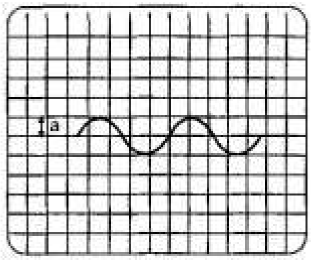
Distance (depth) = $\frac{1410 \times 3}{2}$

= 2115m

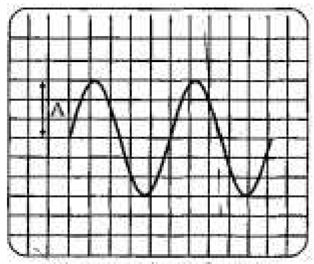
LOUDNESS AND PITCH

Loudness

- The **loudness (**how soft or loud**)** of a sound depends on the **amplitude** of the sound wave.
- Larger amplitude => more energy => **louder volume**



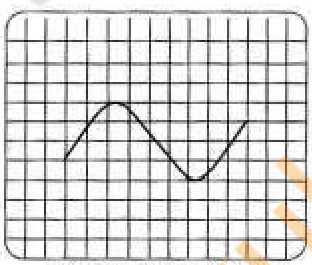
soft note
(a)



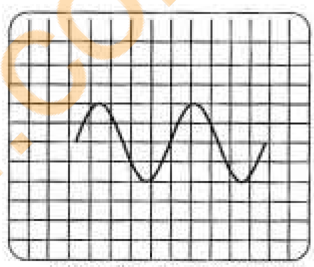
same note but LOUDER
(b)

Pitch

- The **pitch** (how low or high) of a sound depends on the **frequency of the sound wave.**
- A sound wave of **higher frequency** (shorter wavelength) produces a **higher note.**



low pitch (low frequency)
long wavelength
(a)



high pitch (high frequency)
short wavelength
(b)

ULTRASOUND

- Ultrasound refers to sounds with frequencies **greater than** 20 000 Hz.
- Ultrasound is used for: **examining an unborn baby, detecting flaws in metal joints, cleaning jewellery, for sonar instruments.**

CHALLENGING QUESTIONS – 5

Instructions: *attempt questions before looking at answers*

1. When a sound passes through the air, it affects the pressure of the air and the motions of the molecules of the air. Describe briefly how each is affected.
   (a) the pressure [2]
   (b) the motions of the molecules [2]

2. The lines in Fig. 1 represent the positions of equally spaced 'row' of molecules of air before a sound wave passes through the air. The lines in Fig. 2 represent the positions of the same 'row' at one particular instant as the sound wave passes. The wave is moving from left to right.

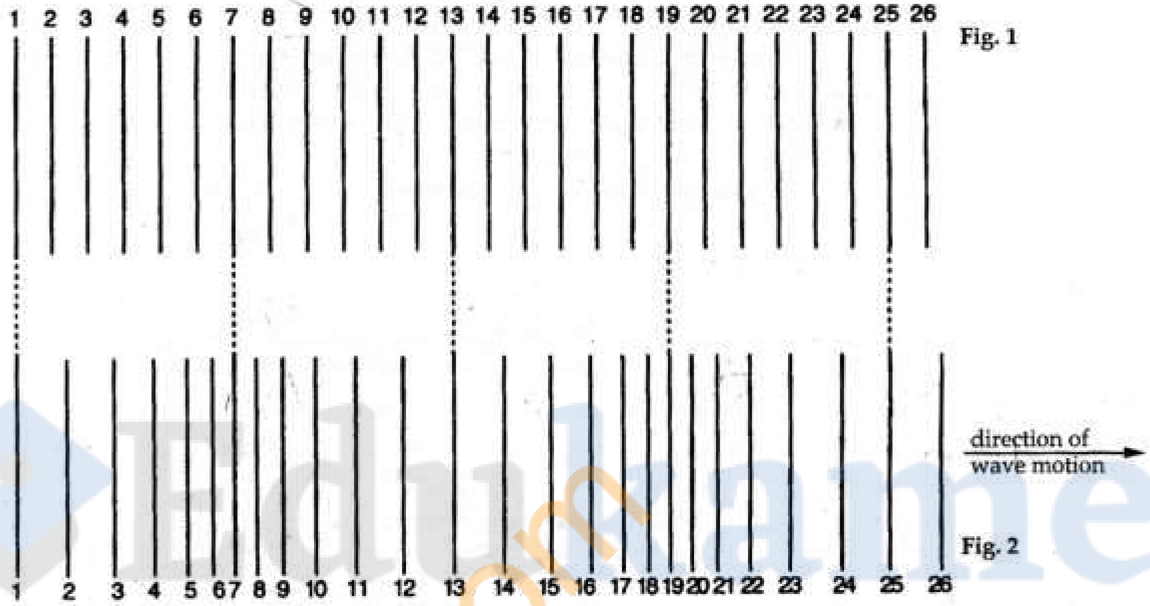
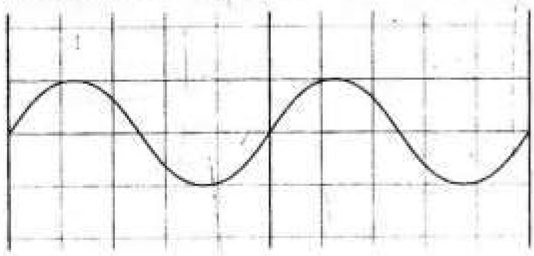


Fig. 1

Fig. 2

   (a) State the number of three 'rows' in Fig. 2 which, as well as being next to one another, are
      (i) in a region of compression,
      (ii) in a region of rarefaction. [2]
   (b) Figs. 1 and 2 are drawn to full scale. Estimate the wavelength of the wave. [1]
   (c) The speed of sound in air is 340 m/s. Estimate the frequency of the wave. [3]

3. The figure shows a cathode-ray oscilloscope trace for a sound wave produced by a loudspeaker.



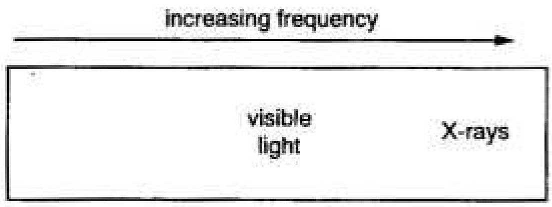
(a) Draw the trace for a louder sound of the same pitch. [2]

(b) It takes 1/50 th of a second (0.02 s) for the whole trace to be produced.

(i) Show that the frequency of the sound produced by the loudspeaker is 100 Hz.

(ii) Determine the wavelength in air of the sound produced by the loudspeaker. (The speed of sound in air is 330 m/s) [3]

4. Ultrasound and X-rays are both used to provide information about structures inside the human body. Ultrasound is sound having a frequency above the highest audible frequency that humans can hear. X-rays are a region of the electromagnetic spectrum with a higher frequency that visible light.



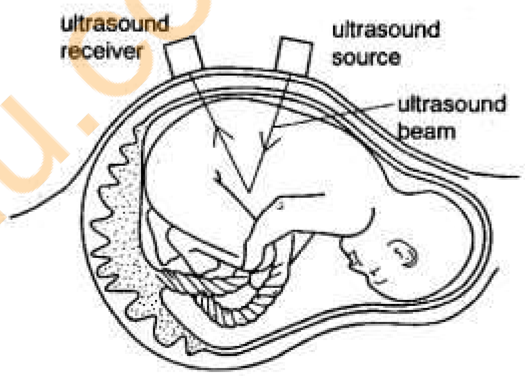
(a) (i) Name three regions of the electromagnetic spectrum other than X-rays and visible light.

(ii) Copy the above figure and on it show the position of the three regions of the electromagnetic spectrum that you have chosen in (i).

(iii) Write one or two sentences about each region of the spectrum that you have chosen, describing how the electromagnetic waves are used or how they affect people.

(iv) State one property that all parts of the electromagnetic spectrum have in common. [8]

(b) The figure below shows ultrasound being used to study an unborn baby.



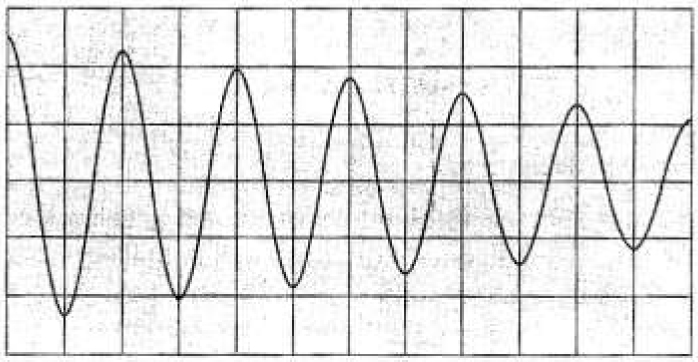
(i) Explain how the vibrations of the source produce waves of ultrasound and suggest how these waves are transmitted through the body tissue to the receiver.

(ii) Ultrasound used in medicine has a frequency which is about 100 times higher than the maximum frequency that can be heard by humans.

Estimate the frequency that might be used for ultrasound in medicine, and calculate its wavelength in the human body. The speed of ultrasound in the human body is 1500 m/s. [7]

5. (a) Sound is a longitudinal wave. Explain, with the aid of a diagram, what is meant by this statement. [4]

(b) (i) The figure shows the waveform produced on an oscilloscope screen by a sound.



State how you can tell from the waveform that

1. the loudness of the sound is decreasing,
2. the frequency of the sound is constant.

(ii) The separate waveforms of two whistles of different frequencies are obtained on the oscilloscope screen at the same time. Draw the two waveforms you would expect to see. Label the waveform that has the higher frequency. [4]

SOLUTIONS

1. (a) At each point of the air where the sound wave passes, the pressure at that point changes continuously between a high pressure (greater than normal atmospheric pressure) and a low pressure (lower than normal atmospheric pressure).

   (b) At each point of the air where the sound wave passes, the air molecules at that point oscillate about a fixed point in a direction parallel to the direction of motion of the sound wave.

(a) The high pressure region is compression and the low pressure region is rarefaction.

(b) For longitudinal wave, the direction of vibration (oscillation) is parallel to the motion of the wave.

2. (a) (i) 6 7 8

   (ii) 12 13 14

   (b) Wavelength = 6.0 cm

   (c) frequency, $f = \frac{v}{\lambda} = \frac{340}{6.0 \times 10^{-2}} = 5.7 \times 10^3$ Hz

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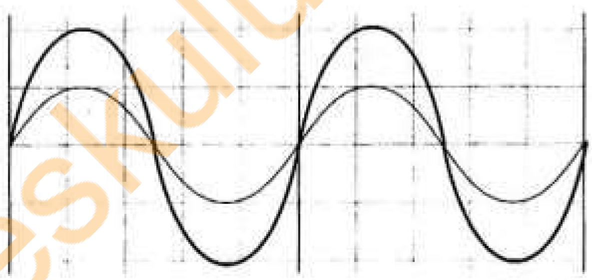
(a) (i) For compression, the particles are closest to each other. Another possible answer: 18 19 20

(ii) For rarefaction, the particles are furthest apart from each other. Another possible answer: 24 25 26

(b) Wavelength of a longitudinal wave is the distance between two successive compressions or rarefactions.

(c) The unit of wavelength is in metre.

3. (a)



   (b) (i) Period = (0.5)(0.02) = 0.01 s

   $f = \frac{1}{T} = \frac{1}{0.01} = 100$ Hz

   (ii) $\lambda = \frac{v}{f} = \frac{330}{100} = 3.3$ m

4. (a) (i) Radio wave, Infra-red, Ultra-violet

(ii) increasing frequency →

radio waves	infra-red	visible light	ultra-violet	X-rays

(iii) Radio wave – used for transmission of radio and TV signals

Infra-red – used for transmission of heat energy and remote controls of electrical appliances.

Ultra-violet – causes fluorescence which is used to detect counterfeit notes, causes skin burn and skin cancer

(iv) They travel at the same speed 3.0×10^8 m/s in vacuum.

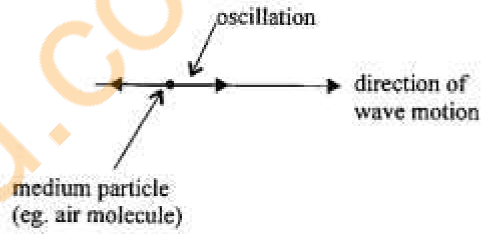
(b) (i) As the source vibrates, it produces waves of ultrasound which comprise alternate series of compressions and rarefactions travelling into the body. The ultrasound waves are reflected by various tissues in the body and the reflected waves are picked up by the receiver.

(ii) Frequency of ultrasound, $f = 100 \times 20000 = 2.0 \times 10^6$ Hz

$$\lambda = \frac{v}{f} = \frac{1500}{2.0 \times 10^6} = 7.5 \times 10^{-4} \text{ m}$$

(b) (i) When ultrasound waves pass through two media, eg body tissue and bones, the waves are reflected. The reflected waves can be analysed by a CRO to produce a 'picture'. For example, we can use ultrasound scanning to study an unborn baby.

5. (a)

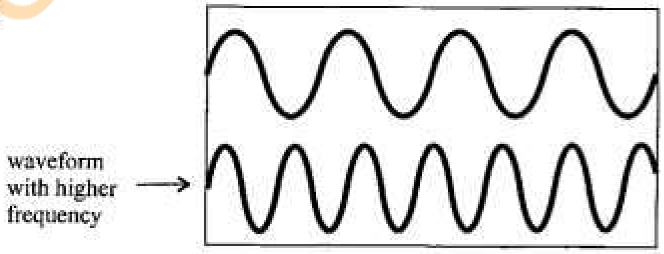


For a longitudinal wave, the oscillations of the medium particles are parallel to the direction of the wave motion.

(c) (i) 1. The amplitude of the sound wave is decreasing.

2. The period is constant.

(ii)

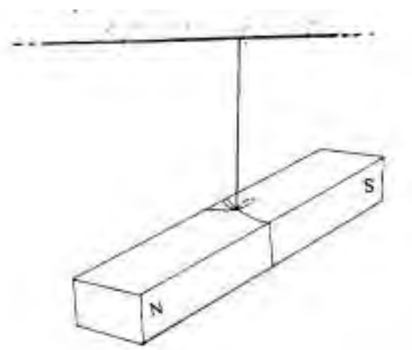


MAGNETISM

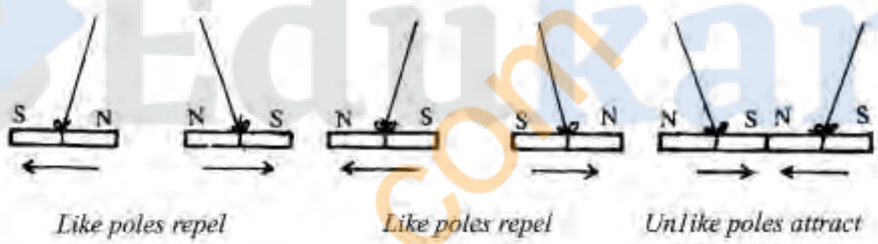
PROPERTIES OF MAGNETS

Magnetic Poles

- A **magnet** has north and south poles.
- A magnet suspended from a string so that it is free to rotate always comes to rest with its axis along an approximate north-south direction. One pole points south and the other north.



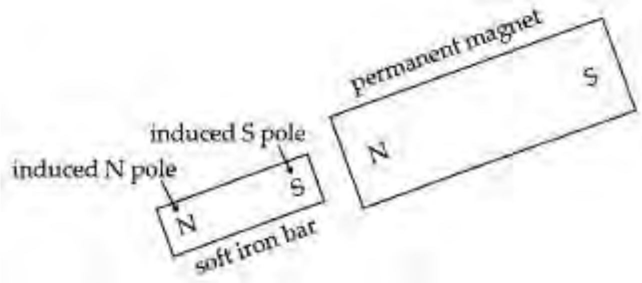
Attraction and Repulsion



1ST LAW OF MAGNETISM: "Like poles repel while unlike poles attract."

Induced Magnetism

- A permanent magnet can retain its magnetism for a long time.
- It is also able to temporarily pass its magnetism effects to a magnetic material so that the latter gains the ability to attract other magnetic materials.
- **Magnetic induction** is the **process of inducing magnetism in an unmagnetised magnetic material.**



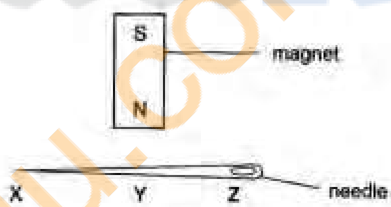
- There is an **induced magnetism** (temporary magnetism) in the soft iron bar.
- The end nearer to the north pole **becomes a south pole** and the other end **becomes the north pole.**

Magnetic Materials

- **Soft magnetic materials** lose their magnetism easily e.g Iron, stalloy, mumetal etc. **Hard magnetic materials** are those that retain their magnetism. They are used in making powerful magnets. E.g steel, alnico, alcomax etc.

Example

[Q] The diagram shows a magnet being used to pick up a steel needle. The north pole of the magnet is close to the centre Y of the needle.



What are the poles induced in the needle at X, Y and Z?

	pole induced at X	pole induced at Y	pole induced at Z
A	N	N	N
B	N	S	N
C	S	N	S
D	S	S	S

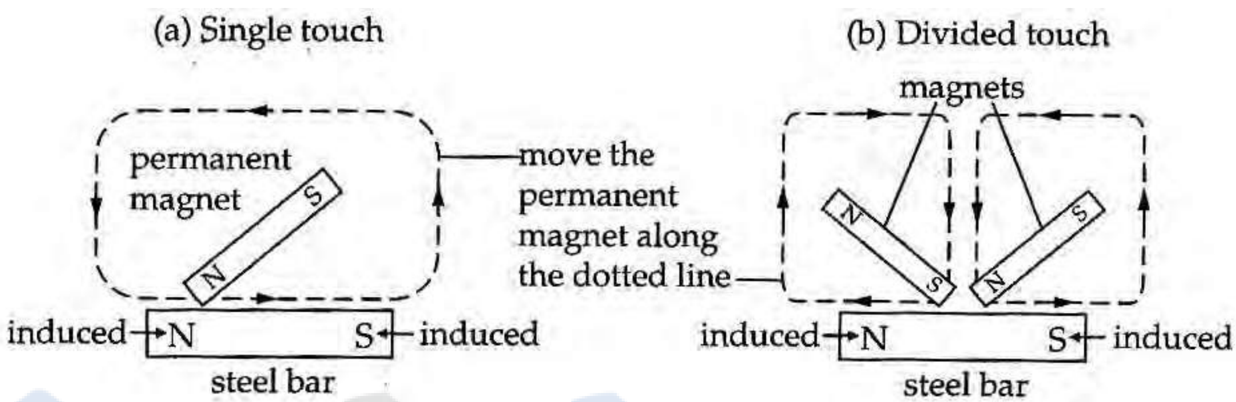
[Ans] B Fact.

Since Y is closest to N-pole, the S-pole is induced at Y. Hence opposite (N-poles) are produced at X and Z that are the furthest away.

METHODS OF MAGNETISM AND DEMAGNETISM

- A magnetic material can become a permanent magnet by using stroking and electrical methods.

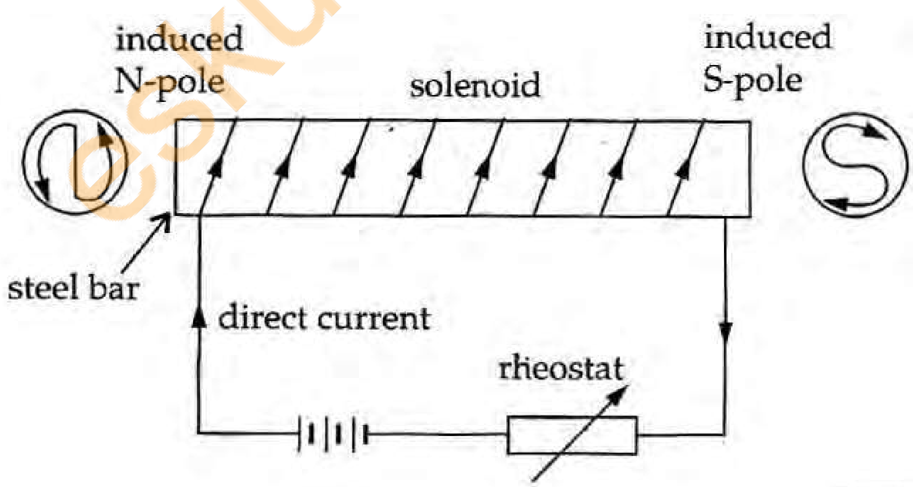
Stroking



Electrical Method

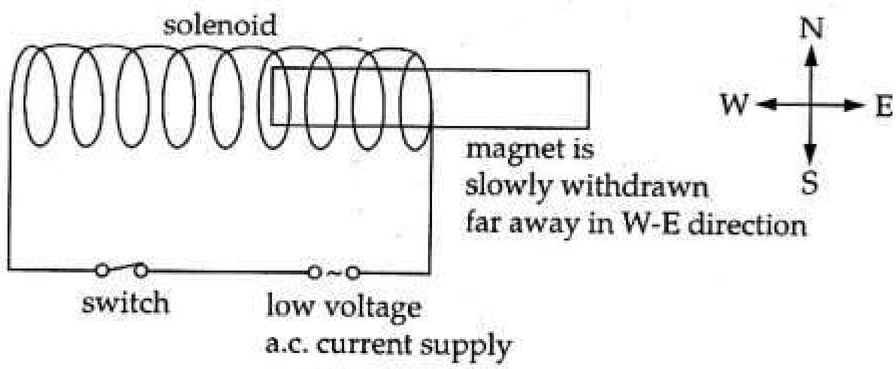
Magnetisation

- The solenoid (coil) is connected to a **D.C supply**.
- A strong magnetic field is produced and the steel bar is magnetised.
- If the current flows in a clockwise direction, this end is the induced S-pole.
- If the current flows in an anti-clockwise direction, this is the induced N-pole.



Demagnetisation

- The solenoid is connected to a **A.C supply**.
- Placed inside the solenoid parallel to the **east-west direction.**
- Slowly withdraw the magnet.



- **This is the most efficient way of demagnetisation.**

A magnet can also be demagnetised by **hammering** or **heating.**

MAGNETIC FIELDS

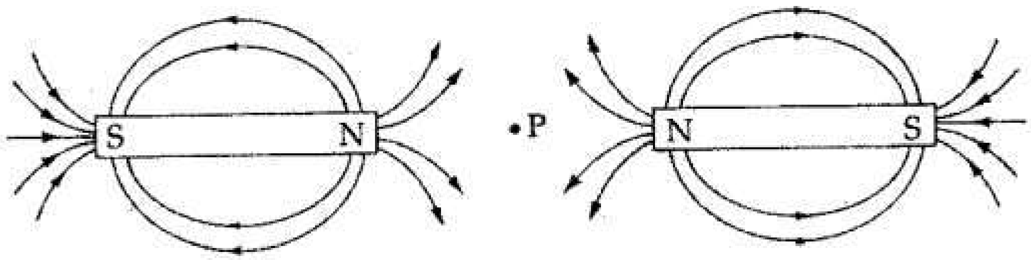
- The region around a magnet where the **magnetic force** can be experienced is known as the **magnetic field.**

Properties of Magnetic Field Lines

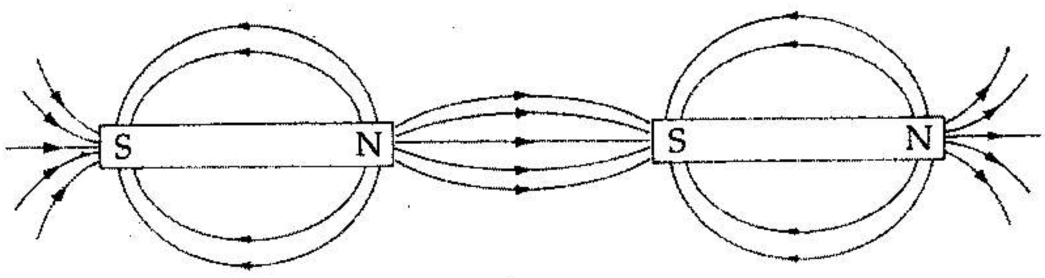
1. The direction is always from N-pole towards S-pole.
2. They do not cross or intersect one another.
3. They repel one another sideways.
4. They are in a state of tension which causes them the tendency to shorten themselves.
5. They region with the higher density of lines has the greater magnetic field strength.

Examples of Magnetic Field Patterns

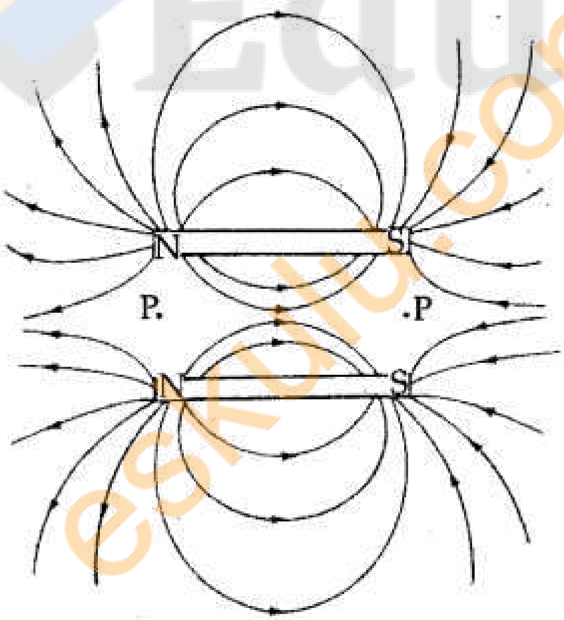
- Two magnets with like poles placed near each other.
- At point P where there is no magnetic effect at all is known as **neutral point.**



- Two magnets with unlike poles placed near each other.



- Two magnets with like poles facing each other. There is no magnetic effect at all at **P.**

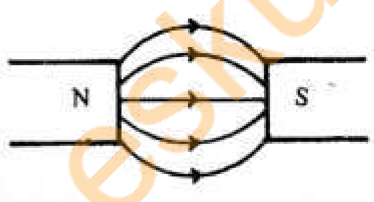


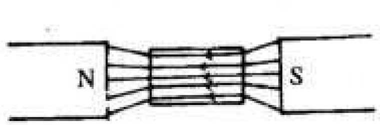
MAGNETIC PROPERTIES OF IRON AND STEEL AND THEIR USES

	Iron	Steel
Type of magnetic material	soft	hard
Magnetic property	easy to magnetise and demagnetise (lose its magnetism easily)	harder to magnetise and demagnetise
Type of magnet made	Electromagnets	Permanent magnets
Uses	▪ Transformers ▪ Audio and video tapes ▪ Electric bells ▪ Magnetic relays ▪ Reed switches ▪ Reed relays	▪ d.c motors ▪ a.c genererators ▪ moving coil galvanometers ▪ moving coil loudspeakers ▪ magnetic door catches

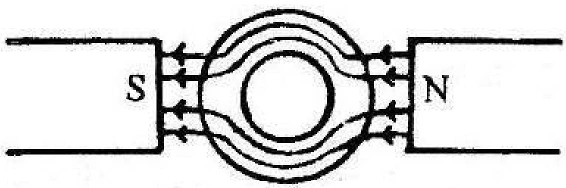
MAGNETIC SCREEING (SHIELDING)

- If a soft iron is placed in a magnetic field, the flux passes through it rather than through air.
- If the soft iron bar is replaced by a soft iron ring the lines of force pass through it and none pass through its centre.





Magnetic flux distorted by a soft iron bar:



CHALLENGING QUESTIONS - 6

1. (a) State the effects that the poles of a magnet have on the poles of other magnets. [2]

(b) Figure 1.1 is a diagram of a bar magnet.

Fig. 1.1

Copy Fig 1.1 and on your copy, draw a diagram of the magnetic field pattern around such a magnet. [3]

(c) Figure 1.2 shows a soft-iron bar placed near the end of a magnet.

Fig. 1.2

(i) Copy Fig 1.2 and on your copy, draw the magnetic field pattern around the soft-iron bar and the S-pole of the magnet.

(ii) Name the magnetic field shown by your answer to (c)(i).

(iii) State one application of this effect. [4]

(d) Explain briefly, with the aid of a series of diagrams, how you would use a plotting compass to show that your answer to (c)(i) is correct. [6]

2. (a) You are given two bars of metal which look to be the same. However, one is a bar magnet and the other is a soft-iron bar. Explain how, without the use of any additional equipment, you could show which bar is the magnet. [3]

(b) Fig. 2.1 shows a small compass placed in a uniform horizontal magnetic field. The compass needle is held in the position shown, so that it cannot move.

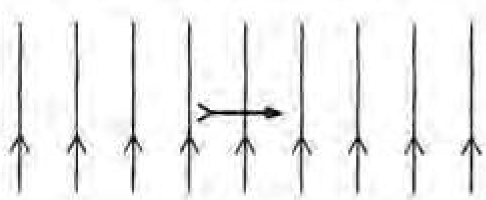


Fig. 2.1

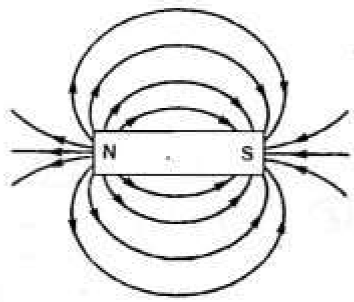
(i) Copy Fig. 2.1 and on your copy draw arrows to show the directions of the two magnetic forces acting on the compass needle.

(ii) State and explain what would happen if the compass needle were no longer held in the position shown. [6]

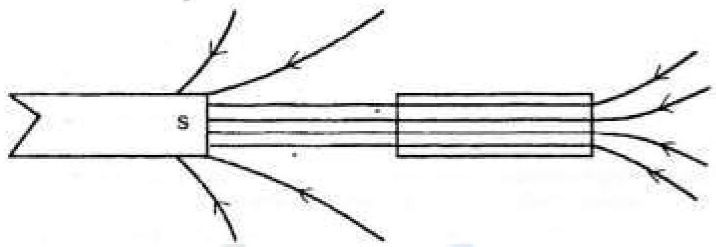
SOLUTIONS

1\. (a) Force of attraction or repulsion. Like poles repel and unlike poles attract.

(b)



(c) (i)



(ii) Magnetic Induction

(iii) Electric bell

(d) Place the magnet and soft iron bar on a piece of tracing paper.

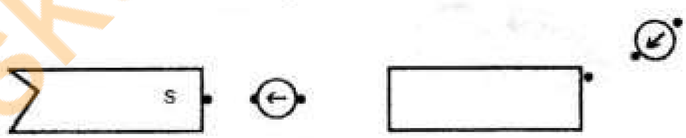
(i) Mark a dot near the south pole of the magnet and one end of the soft iron. Align the compass such that the N-pole of the compass is pointing to the dot. Mark a dot on the paper next to the S-pole of the compass.

(ii) Repeat step (i) for each new dot to obtain a series of dots. Stop when the dot is near to the edge of the paper or the north pole of the magnet.

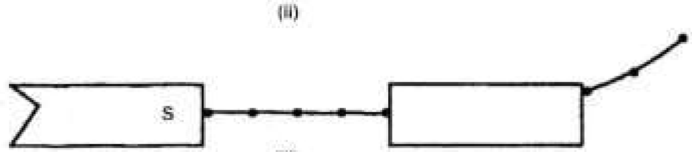
(iii) Join all the dots using a smooth line to represent the magnetic field line.

Repeat (i) to (iii) for other field lines.

(i)

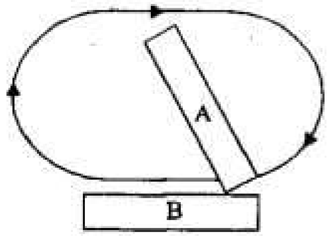


(ii)

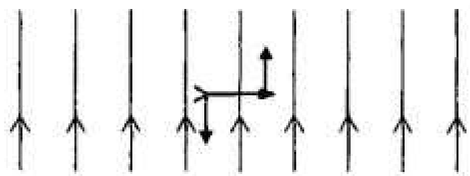


(iii)

2. (a) Label one metal bar A and the other B. Use A to stroke B continuously for some time as shown in the diagram. If either ends of A are still attracted by one end of B, then B must be the magnet. If one end of A is repelled by one end of B, then A is the magnet.



(b) (i)



(ii) The two opposite and equal forces acting on the compass needle produce a net anticlockwise moment which causes the needle to rotate. After the needle rotates anticlockwisely an angle of 90°, the net moment becomes clockwise and causes a clockwise rotation of the needle. The needle will oscillate for a while and finally stop at a position pointing in the direction of the magnetic field.

(a) To test for permanent magnet, repulsion is the only sure test. When attraction occurs, we cannot draw any conclusion as the metal may be a magnetic material.

(b) (i) The arrows representing the two forces must be equal in length as the forces are equal in size. The arrow head of the compass needle is a North pole. It points to the South pole of the magnetic field.

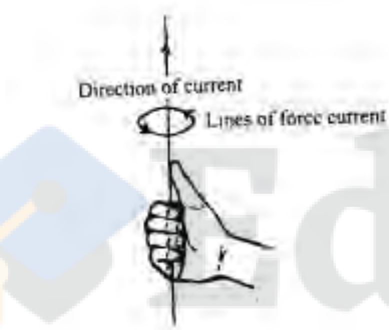
(ii) The moment produced by the two equal forces is called a couple.

ELECTROMAGNETISM

MAGNETIC EFFECT OF A CURRENT

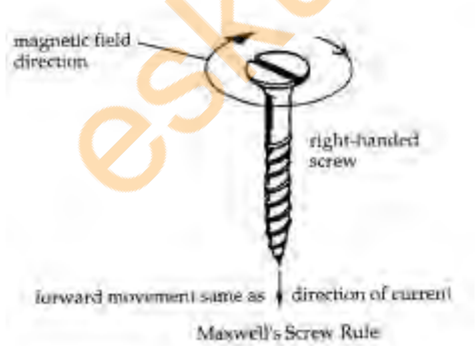
- Electromagnetism is the study of the magnetic effect of an electric current.
- A current-carrying straight wire produces a **circular magnetic field** around it.
- **THE DIRECTION OF MAGNETIC FIELD DEPENDS ON THE DIRECTION OF THE FLOW OF CURRENT. (use Maxwell's Screw Rule or Right – hand Grip Rule)**

Right Hand Grip Rule:



Grip the wire by the right hand in such a way that the thumb points in the direction of the current. **The direction of the curled fingers is the same as the direction of the lines of force.**

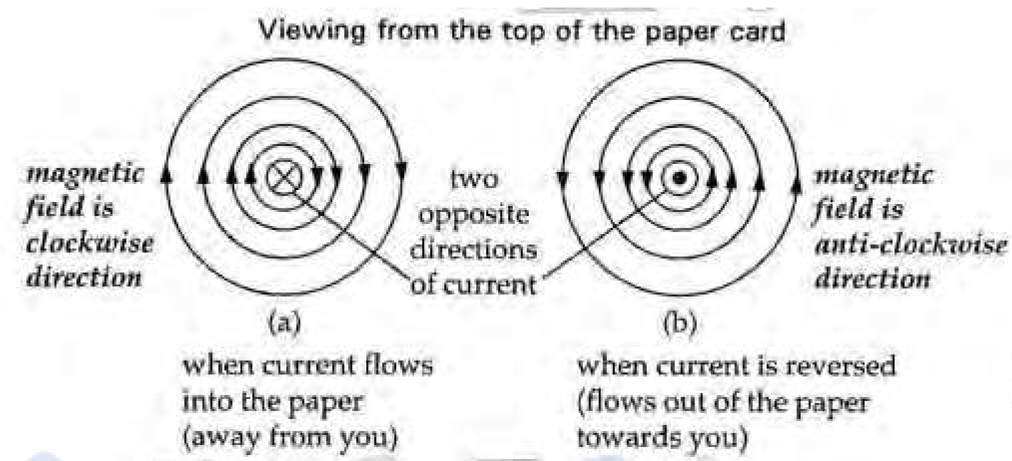
Maxwell's Screw Rule:



The **direction of rotation indicates the direction of the magnetic field.** The **forward direction of the screw is the same as direction of current.**

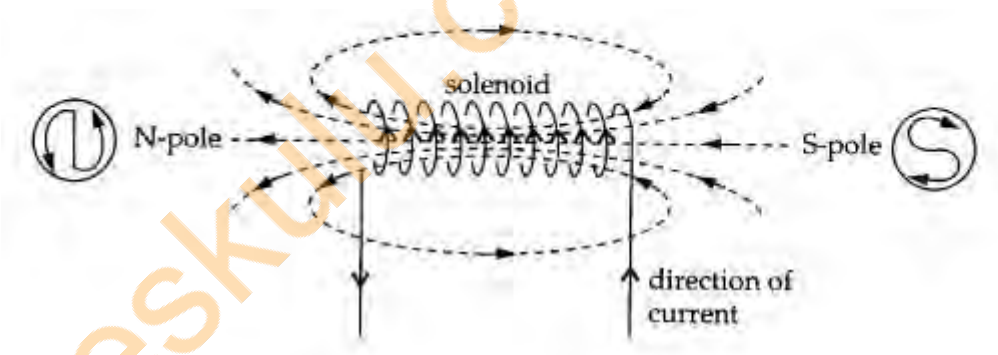
Magnetic Field Due to Currents in Straight Wires

If the flow of current is reversed, the direction of the magnetic field is also reversed.



Magnetic Field Due to Currents in Solenoids

- The magnetic field pattern is similar to that of a bar magnet.
- One end of the solenoid acts like a North Pole and the other end a South Pole.



- **How to know which end is North/South Pole:**
  1. **Apply Right-hand Grip Rule. The end where the thumb is pointing is the induced N-pole.**
  2. When viewed from one end of the solenoid; **if the current flows in a clockwise direction, it's the induced S-Pole. If the current flows in an anti-clockwise direction, it's the induced N-Pole.**

- **WAYS OF INCREASING THE STRENGTH OF THE MAGNETIC FIELD:**
  1. **Increase the size of the current.**
  2. **Increase the number of turns per unit length of the solenoid.**
  3. **Placing a soft iron core inside the solenoid.**

APPLICATIONS OF THE MAGNETIC EFFECT OF A CURRENT

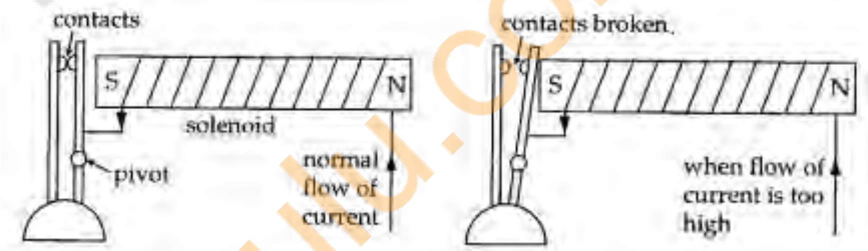
Electromagnets

If a bar of soft iron is placed in the solenoid, the magnetic field becomes concentrated in the soft iron core and the soft iron becomes an **electromagnet.**

When the current of an **electromagnet** is switched off, it ceases to be a magnet.

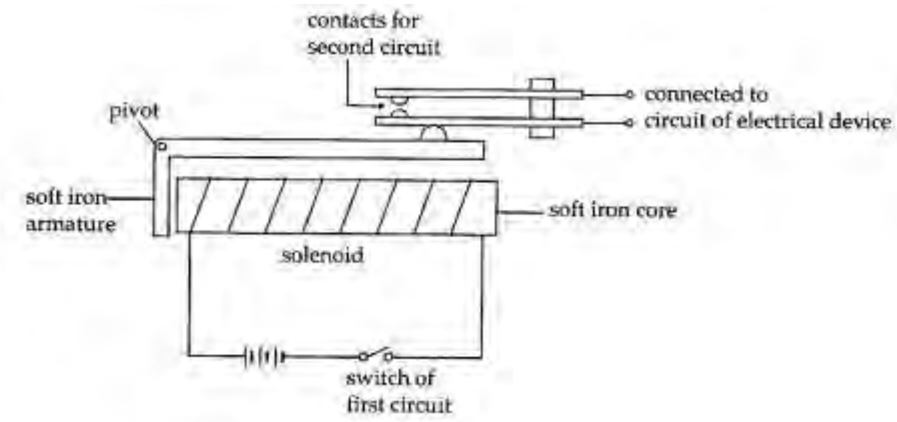
Circuit Breaker

- It cuts off electric current when the current exceeds a certain limit.
- When the flow of current is too high, the strong magnetic force of the solenoid will separate the contacts and break the circuit.



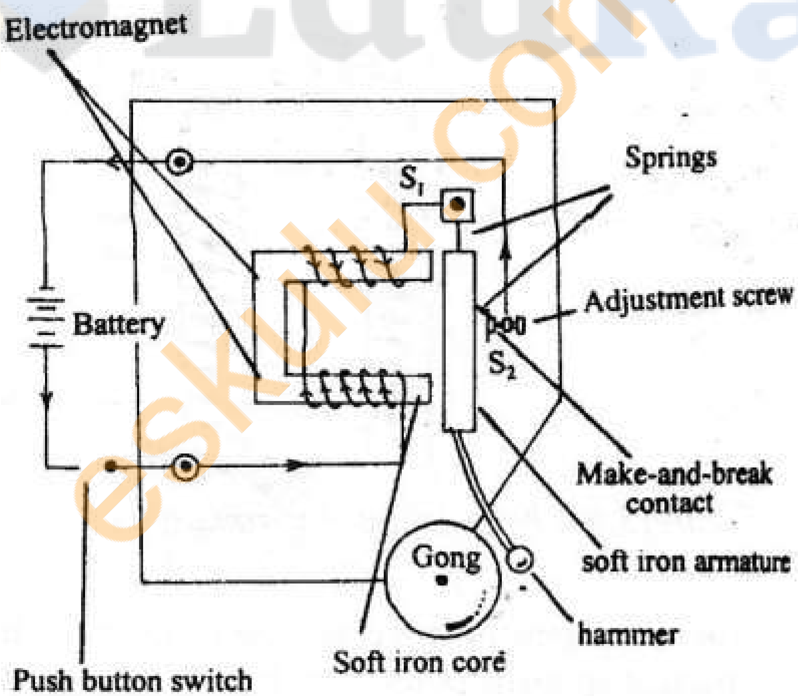
Magnetic Relay

- In a magnetic relay, there are two circuits. The first circuit uses an electromagnet. The second circuit, which can only be switched on by the first circuit, is connected to an electrical device.



- When the switch is closed, the current flows through the solenoid and the soft iron core is magnetised.
- The soft iron armature is attracted by the electromagnet. The top end of the armature is raised and closes the contacts of the second circuit.
- The second circuit is complete and the electrical device is switched on.
- The advantage of using a magnetic relay is that we can use a small current circuit to switch on a large current circuit.

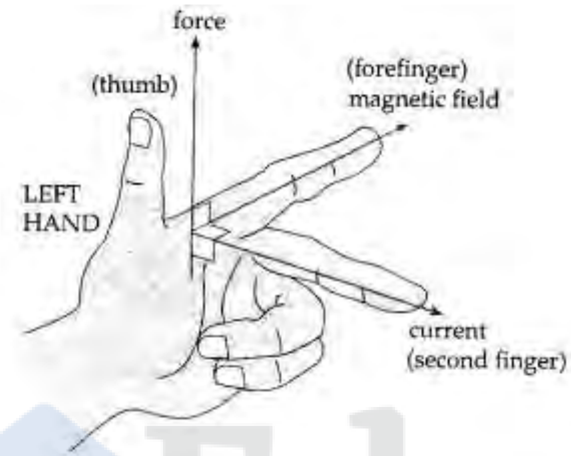
Electric Bell



- When the push-button switch is pressed, a current flows through the completed circuit and the soft iron core in the coils becomes an electromagnet.
- The coils are wound in opposite directions to produce opposite poles.
- The electromagnet attracts the **soft iron armature.** This causes the **hammer** attached to the soft iron armature to hit the gong.
- The **adjustment screw** adjusts the gap between the armature and the electromagnet in order to vary the rate at which the armature with the hammer vibrates to cause a ringing sound.

FORCE ON A CURRENT-CARRYING CONDUCTOR

Fleming's Left-hand Rule



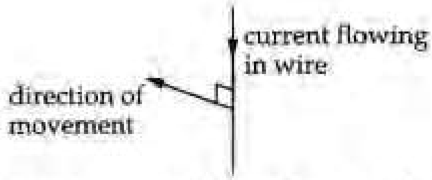
- Place the forefinger, second finger and thumb of your **left hand** mutually at right angles.
- If the **forefinger** points in the direction of the **magnetic field** and the **second finger** in the direction of the **current,** the **thumb** will point in the direction of the **force or motion.**

Ways of Increasing the Force Acting on the Wire:

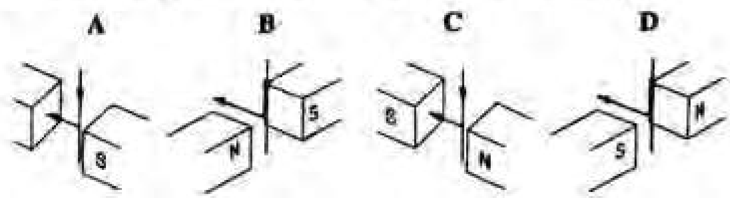
1. Using **larger current.**
2. Using a **stronger magnetic field.**
3. Using a **greater length of wire** inside the magnetic field.

Example

[Q] A current flows in wire hanging between the poles of a magnet. The wire starts to move in the direction shown.



Which diagram shows the position and the polarity of the magnet?



[Ans] D The correct diagram can be found by using Fleming's Left Hand Rule. The direction of magnetic field is from N-pole to S-pole.

Example

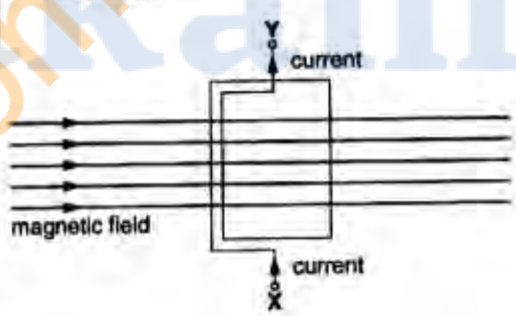
[Q] A coil, carrying a current, is arranged within a magnetic field. The coil experiences forces that can make the coil move. How does the coil move?

A from X and Y

B out of the paper

C along the magnetic field

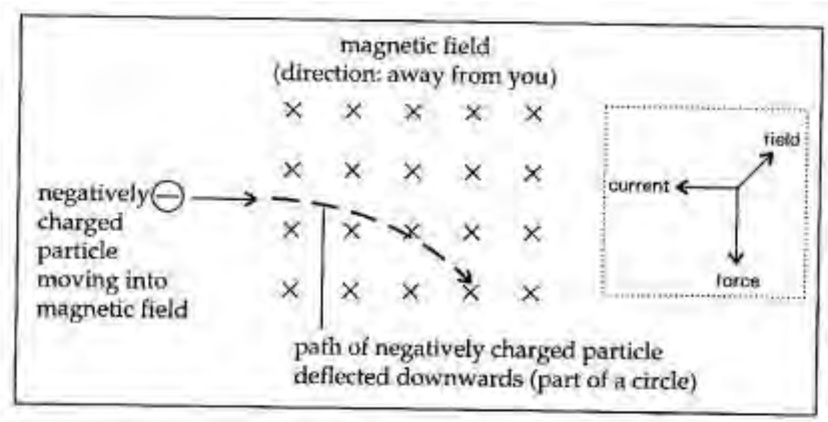
D turns about the axis XY

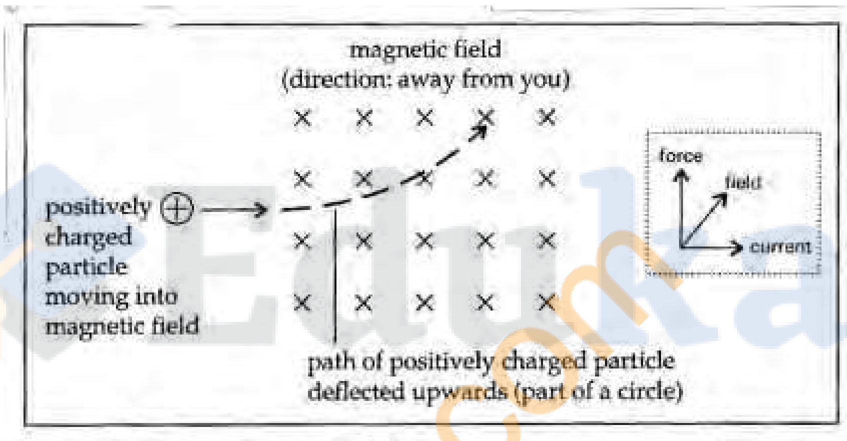


[Ans] D Apply Fleming's Left Hand Rule to determine the direction of force acting on the coil.

Force on a Beam of Charged Particles

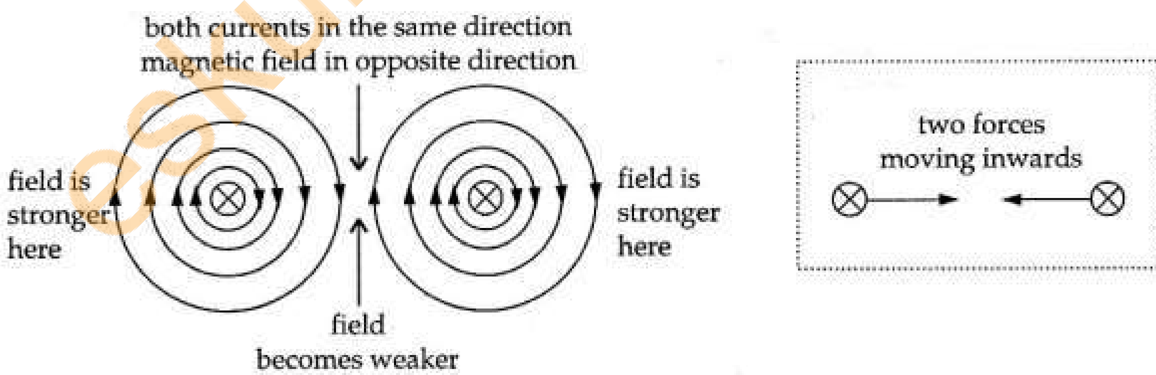
Applying Fleming's Left Hand Rule:



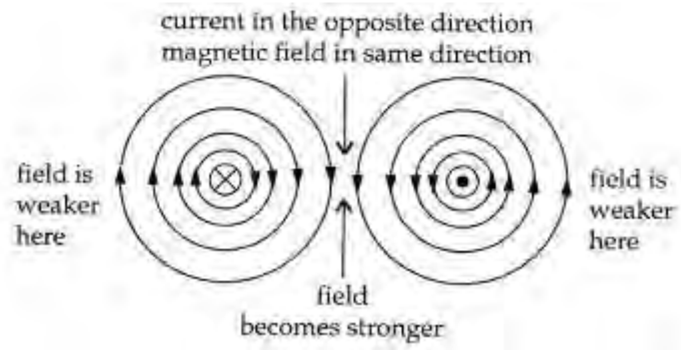


Two Parallel Current Carrying Wires

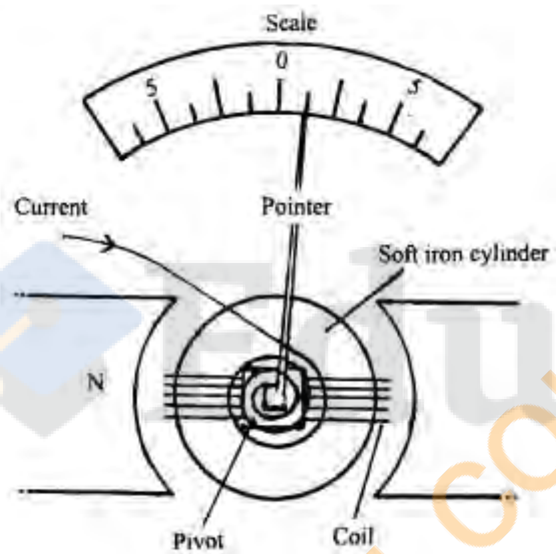
Currents flowing in the SAME directions cause ATTRACTION.



Currents flowing in the SAME directions cause ATTRACTION.



Moving Coil Galvanometer

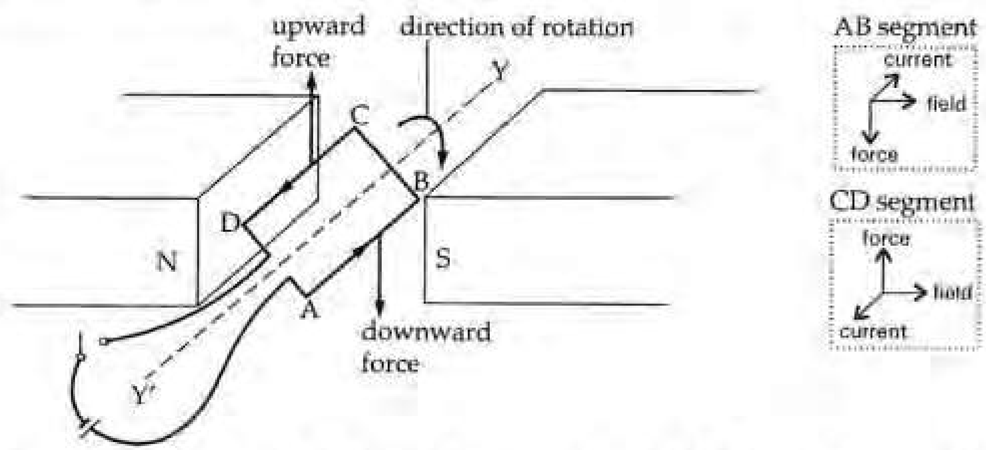


This instrument is used to detect electric currents. It depends on the motor effect for its operation.

When a current flows through the coil it set ups up a magnetic field around the wires. **The size of the deflection of the pointer is proportional to the size of the current.**

D.C MOTOR

- In the figure below, a rectangular coil ABCD is placed in a uniform magnetic field. The coil can rotate freely about the horizontal axis YY'.

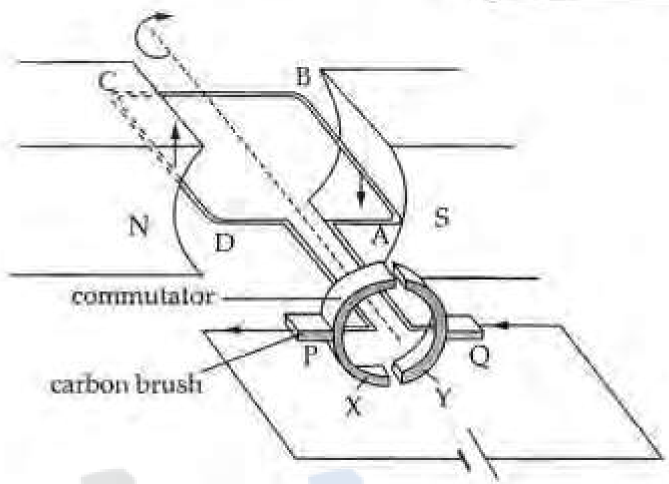


- When the switch is closed, the current flows from point A to point D through the coil.
- Apply Fleming's Left Hand Rule on the wire segments AB and CD. It is found that there is a downward force acting on AB and an upward force acting on CD. Thus the coil turns in CLOCKWISE direction.
- This turning effect of the current-carrying coil can be increased by:
  1. increasing the current;
  2. increasing the magnetic field strength;
  3. increasing the number of turns of the coil and
  4. inserting a soft iron core within the coil to concentrate the magnetic field lines.

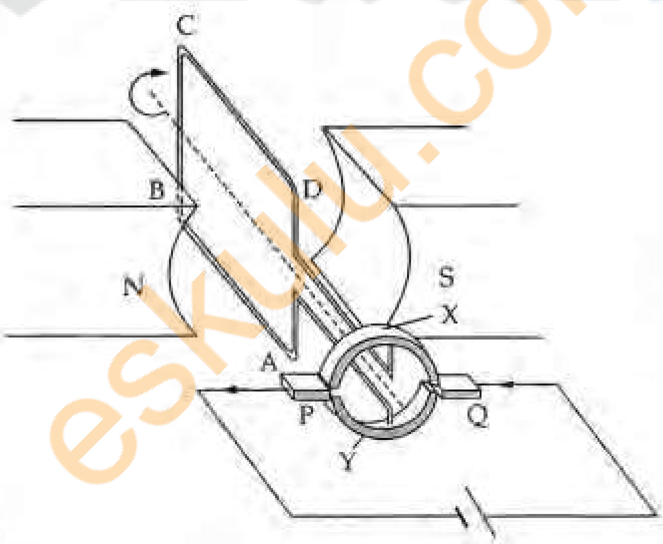
Principles of a D.C. Motor

- A direct current electric motor (d.c. motor) consists of
  - Two permanent magnets with circular poles (N and S),
  - A coil (ABCD) connected to a split-ring commutator (X and Y are not in contact) and
  - Two carbon brushes (P and Q) connected to an external battery
- The commutator (XY) will rotate when the coil rotates. The two carbon brushes are made to press lightly against the commutator (to have contact) so that the current can pass through.
- The following figures show how the coil is set into motion when current flows through it.

- When current flows from A to B and C to D through the coil, arm AB experiences a downward force and arm CD experiences an upward force.
- These forces produce a turning effect and cause the coil to rotate in a clockwise direction.

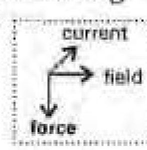


- When the coil turns to the vertical 90° position, the split ends of the commutator are now in alignment with the carbon brushes. The contact is broken and the current is cut off temporarily.

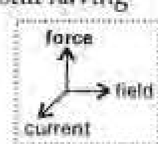


Take note

If current is not cut off temporarily, AB in other half still having downward force

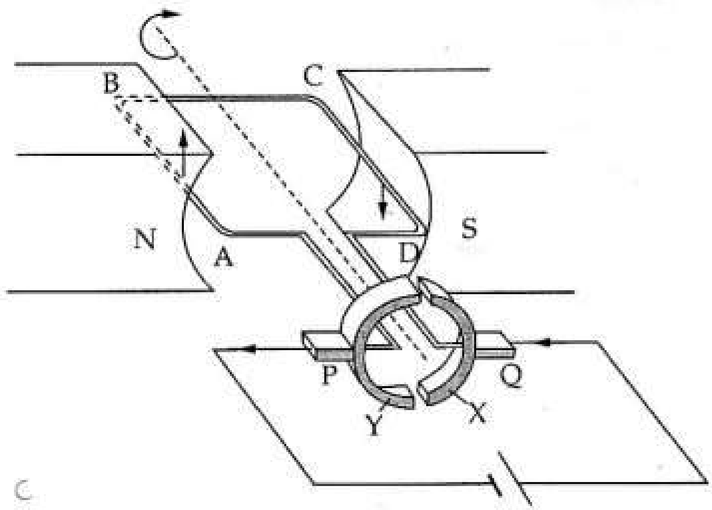


CD in other half still having upward force



Because of **inertia,** the coil will keep rotating. So arms AB and CD cross over to the other half of the magnetic field without experiencing any turning effect generated by the current until the commutator is in contact with the carbon brushes again.

- Once the commutator and the carbon brushes are in contact again, the current is able to flow in the same direction, now from D to C and B to A. So arm DC experiences a downward force and arm BA experiences an upward force.
- Hence, the coil continues to rotate in a clockwise direction.

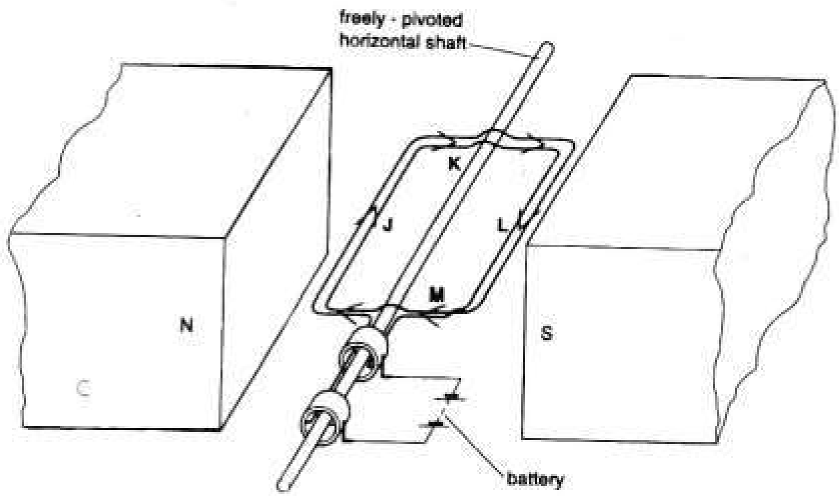


Ways of Increasing Rotating Speed of a Motor

1. **Increasing the current**
2. **Increasing the magnetic field strength**
3. **Increasing the number of turns of the coil and**
4. **Placing a soft iron core into the coil**

CHALLENGING QUESTIONS – 7

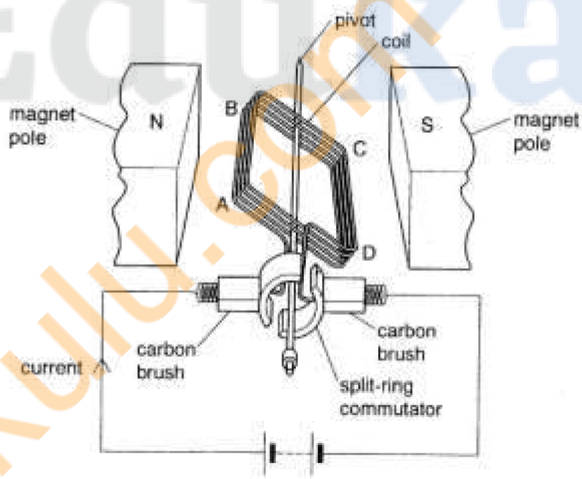
1. The figure shows a rectangular current-carrying coil mounted on a freely pivoted horizontal shaft between the poles of a permanent magnet. The connections to a battery and the direction of the current in each side of the coil are shown; the sides of the coil are labelled J, K, L and M.



(a) Draw arrows to show the directions of the forces, if any, acting on the sides J, K, L and M. [3]

(b) State what will happen to the coil as a result of these forces acting on it. [2]

. The following is a diagram of a d.c. motor.



(a) (i) State the direction of movement of side AB and of side CD when the current is in the direction shown.

(ii) Explain the reason for your choices of direction. [3]

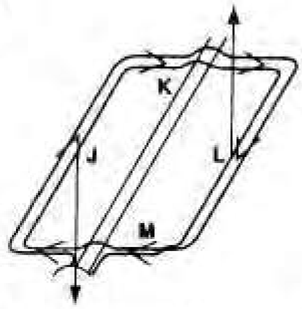
(b) When the coil ABCD is vertical, the brushes line up with the gaps in the split-ring commutator. The coil rotates past the vertical position. Explain what happens

(i) to the current in the coil.

(ii) to the forces on the sides AB and CD of the coil [2]

SOLUTIONS

1. (a)



(b) The forces acting on the coil produce a net anticlockwise moment about the shaft when viewed from the front. Hence the coil will rotate in an anticlockwise direction.

(a) Two arrows should have the same length as they represent two equal forces. There is no force acting on the sides K and M as the direction of current is parallel to the magnetic field.

(b) There is no continuous rotation as slip rings are used instead of commutators. The coil will oscillate.

2. (a) (i) side AB: downwards

side CD: upwards

(ii) The direction of force acting on each side of the coil is given by Fleming's Left Hand Rule and is perpendicular to both the direction of current flowing through the wire and the direction of magnetic field.

(b) (i) The direction of current in the coil is reversed.

(ii) Each force reverses its direction so that the coil continues to rotate in the same direction.

(b) (i) At first, current is flowing from A to B and C to D. When the coil is at the vertical position, the split-ring commutator is not in contact with the carbon brush and therefore no current flows. Because of inertia, the coil will continue to rotate and the commutator touches the carbon brush again. However the current is then flowing from B to A and D to C.

(ii) The function of the split-ring commutator is to ensure that the motor rotates in one direction.

REFERENCES

Pixabay.com
Keypoints GCE Physicis K L Poon
L Muunyu Physics 10 - 12