THE KINETIC THEORY OF MATTER

- ✓ All matter is made up of tiny particles (molecules, atoms or ions) The tiny particles are invisible to the naked eyes
- ✓ These particles are always in motion or higher the temperature the faster they move on average
- ✓ Heavier particles move slowly than lighter ones at a given temperature
- ✓ The kinetic theory of matter is used to explain the behavior of matter.
- ✓ It can also be used as a scientific model to explain how the arrangement of particles relates to the properties of the three *states of matter.*

The State Of Matter

SOLID

In a solid substance;

- The particles are packed closely together in an orderly manner.
- There are strong forces of attraction between the particles
- The particles can only vibrate above their fixed position
- They have a fixed volume (definite volume)
- There is a fixed shape (the shape is not changed easily) in other word, a solid substance has a definite shape.
- There is low energy content in a solid substance as movement is restricted
- There is a high density, density is the mass per unit volume of a substance or how well a substance packs.
- The particles are incompressible. Compressibility is how well a substance can be squeezed,
- There is low expansion rate. Expansion shows how well a substance increases its volume when heated

LIQUID

In liquid substance, the following properties exist

- The particles are packed together not in orderly (regular) manner
- The particle, are held together by strong forces of attraction but weaker than the forces in a solid.
- The particles move throughout by sliding over each other, this movement makes them to collide against each other.
- The liquid substance does not have a fixed shape but takes the shape of a container
- The substance can not be compressed because the particles are packed closely although they are arranged in a disorderly manner.
- Has a fixed volume since the particles cannot be compressed
- Has high density

- Has a medium expansion rate (the expansion rate is somewhere between those of solids and gases)

GASES

In a gaseous substance, the following properties exist;

- The particles are very far apart from each other and are in a random arrangement
- There is weak force of attraction between the particles (weak IMF)
- The particles have highest energy content as movement is at random.
- Particles move freely at random in all the space available
- Can easily be compressed because the particles have more space between them compared to the particle of liquids or solids.
- Have no fixed volume this is because the particles are free to move anywhere within the container in which they are held, they fill the entire space of the container
- Have lowest density this is because molecules are very far apart, so they occupy a large volume .this gives law density from D=M/V
- Have a large expansion rate

EXPLAINING THE CHANGES OF STATE OF MATTER

1. BOILING /EVAPORATION CHANGE FROM LIQUID TO GAS

- When a liquid is heated the particles of the liquid gain kinetic energy and start vibrating at a longer distance (move faster) as the temperature increases.
- Eventually the particles have enough energy to completely break the force holding them together (the IMF)
- Particles are now able to move free and far apart
- The gas is formed, the temperature at which liquid changes to gas is called the boiling point.
- Boiling point is the temperature at which a liquid substance change into a gaseous substance at a normal pressure

2. MELTING

This is a change from solid to liquid

- When a solid substance is heated, the particles in the solid gain kinetic energy and vibrate more vigorously.
- The particles vibrate faster as the temperature increase until the kinetic energy they gain is able to overcome the forces that hold then at a fixed position at this point ,the solid becomes a liquid the temperature at which this happens called the melting point.
- *Melting point* is the temperature at which a solid substance changes into a liquid substance at a pressure.

3. FREEZING

This is a change from liquid to solid

- When a liquid is cooled the Particles in the liquid lose kinetic energy and move closer to each other forming solid particles.
- As the temperature continues to drop the particles continues to lose energy until they do not have enough energy to move freely
- At this point, the liquid changes to a solid.
- The temperature at which this happens is called the freezing point.
- Freezing point is the temperature at which liquid substance changes into solid at a particular pressure

4. CONDESATION

- When a gas is cooled the particles in the gas lose energy and move slowly.
- As the temperature continues to drop more energy is lost from the particles and they move very slowly
- Eventually, the movement of the particles becomes slow enough for the gas to change into a liquid

5. SUBLIMATION

- Sublimation is the process by which a solid substance changes directly into a gas without passing a through the liquid state. Example of substance that undergo sublimation are iodine, ammonium chloride (NH_4Cl) and Solid Carbon Dioxide

THERMOMETRY

- Thermometry is the process of measuring the temperature of a material or substance
- It is basically the science of dealing with the construction and use of thermometers

TEMPERATURE

- Temperature is a measure of how hot or cold a substance is
- It can also be defined as *the average kinetic energy of the particles in an object*. Kinetic energy is the form of energy associated with the motion of the substance.
- *Kinetic energy is the energy responsible for movement of the particles, when the temperature is high the particles gains kinetic energy and starts to vibrate at a longer distance*
- temperature is an average measure of the kinetic energy of the particles in an object
- Devices which are used to measure the temperature of a substance are called thermometer

TYPES OF TEMPERATURE SCALE

There are various scales that scientist have used in history. The commonly used scales are:

a. The Kelvin temperature scale
b. The Celsius temperature scale
c. The Fahrenheit temperature scale

THE KELVIN TEMPARATURE SCALE

- The SI unit of temperature is kelvin (K)
- The Kelvin scale is the most important scale used in science work.
- Based on this scale, water freezes at the value of 273K and boils at the value of 373k.This temperature scale is based on a single point which is known as the absolute zero. The word Kelvin comes from word Kelvin (William Kelvin who did a lot of work with temperature).

THE CELSIUS TEMPERATURE SCALE

- The Celsius Scale is the modern System of Measuring the Temperature of substance In Celsius scale, we call the freezing point of water as 0^{o}c and the boiling point of water as 100^{0}c. This scale used to be called the Centigrade but the name changed several years ago.
- Conversion between Celsius temperatures and Kelvin (and vice versa) can be performed using on of the two equation below
  $^{0}C = K - 273$………….(i)
  $K = {^{0}C} + 273$………..(ii)

THE FAHRENHEIT TEMPARATURE SCALE

- This is the classic English system of measuring temperature this temperature scale is similar to the Kelvin scale the only difference is that the normal freezing point of water in this scale is 32^{0}F Not 0^{0}F. The normal boiling point of water is designated as 212^{0}F in Fahrenheit scale. There are 180 divisions between these two temperatures when using the Fahrenheit scale this scale is named in honor of German physicist *Daniel Fahrenheit*
- At a temperature of 76 degrees Fahrenheit is abbreviated as 76^{0}F.
- To convert temperature in the Fahrenheit scale to the Celsius scale equivalent use the equation.

  $^{0}C=F-32/1.8$ or $^{0}C=5/9(F-32)$

- Similarly to convert temperature expressed by the Celsius scale to the Fahrenheit scale equivalent use the following equation $^{0}F=1.8^{0}C+32$ or $^{0}F=9/5^{0}C+32$.

ABSOLUTE ZERO

- This is the lowest temperature where molecular motion nearly stops .At this temperature, the molecules have lowest amount of energy .Its value is OK (zero Kelvin) on the Kelvin scale and -273K on the Celsius scale.

- Absolute temperature is the temperature measured on a Kelvin scale and its zero mark is called absolute zero

THERMOMETERS AND HOW THEY FUNCTION

- Thermometers are devices used for measuring temperature. In construction of a thermometer, a thermometric substance is chosen first. Then a temperature scale is defined by means of two *fixed point's lower forced point* and *upper forced point*.

THERMOMETRIC SUBSTANCE

- These are substances that are used in the thermometers as thermometers as thermometric solids, liquids or gases. Their property change uniformly with temperature.

Characteristic of temperature-measuring property of a thermometric substances (thermometric properties)

- The property should remain constant, if the temperature is constant
- The property should change with change in temperature
- The property should be such that the temperature can be taken easily without waiting for a long time.
- The property should have a large change even if the change in temperature is small

TYPES OF THE THERMOMETERS

- There are various types of Thermometers depending on what we want to measure and how the thermometer work .The following are some of the type of thermometer
  a. Liquid –in –glass thermometer
  b. Thermocouple thermometer
  c. Constant volume gas thermometer
  d. Electrical resistance thermometer

1. LIQUID –IN –GLASS THERMOMETER

- This type of thermometer consists of capillary with a thin walled bulb at one end which uses either mercury or colored alcohol as thermometric property.

HOW DOES A LIQUID –IN GLASS THERMOMETER WORK?

- When the thermometer is inserted into the substance to be tested (such as tongue or armpit) heat from the substance causes the mercury or alcohol to expand rise up along the capillary tube and the thermometer shows higher temperature reading. When substance is cold the liquid contracts and thermometer shows lower temperature reading.

➢ Temperature on the thermometer is read by finding the level of the liquid in the capillary tube.

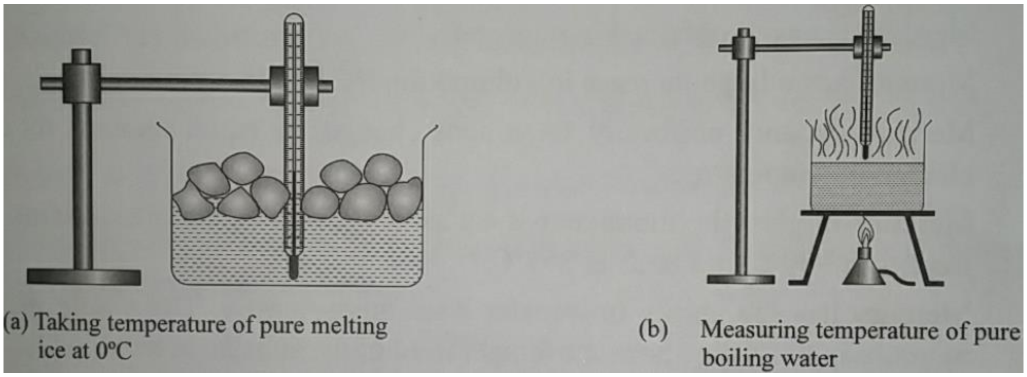
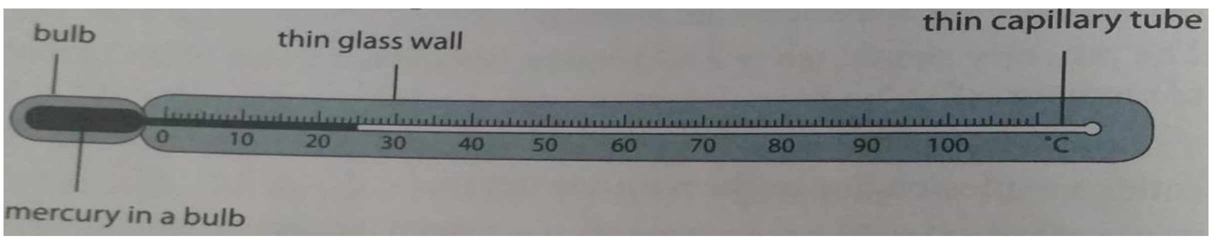


Figure above shows the measuring of ice and boiling water.



Mercury-in glass thermometer

ADVANTAGES OF A LIQUID IN GLASS THERMOMETER

(i) It is Very portable (easy to carry)
(ii) Mercury is easily obtained in pure state
(iii)It is very easy to read when using
(iv)It can be submerged in liquid

DISADVANTAGES OF LIQUID IN GLASS THERMOMETER

(i) Not suitable to measure a temperatures below -39^0 because mercury solidifies at -40^0c
(ii) There may be non-uniformity in the capillary bore of the tube.
(iii) It is brittle
(iv) It cannot measure temperature above 120^0c because it boils above that temperature.
(v) Usually it is the only bulb that is in contact with the body when taking the temperature.

EXAMPLES OF LIQUID –IN GLASS THERMOMETER

➢ The common examples of liquid in glass thermometer:

- Clinic thermometer
- Six`s maximum thermometer
- Minimum thermometer
- Ordinary school thermometer

CALIBRATING A LIQUID –IN GRASS THERMOMETER

- Calibration is the placement of marks on a measuring tool to allow it to accurately work in accordance with the already known standards

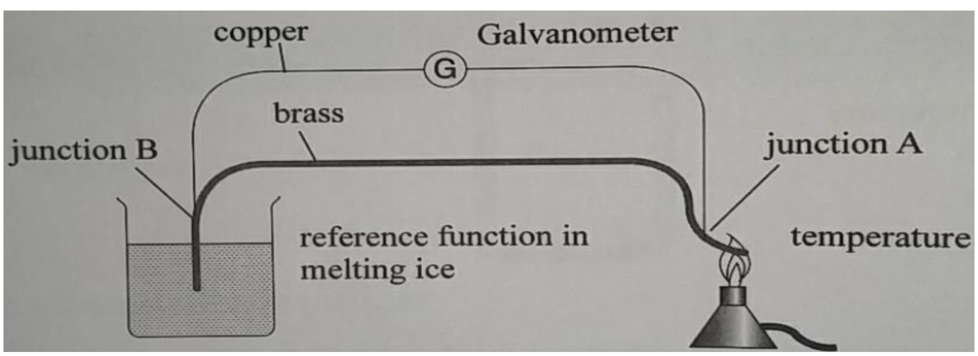
MATERIALS

1. Put the non-calibrated thermometer (a mixture of ice and water)
   Wait until the mercury of column stops moving mark the liquid level as 0^0c living the glass marks or pen
2. Boil the water in the beaker and pure the non-calibrated thermometer in the boiling water. Wait until the mercury column stops massing and mark the liquid level as 100^0c
3. Devise the space between the two marking into two equally spaced divisions the thermometer is calibrated and ready to be used

- Care should be taken when using such thermometer the bold is made very thin so it can easily break.

2. THERMOCOUPLE THERMOMETER

- A thermocouple is a device made by two different wires joined together at their two ends. The two wires are called *thermo element*. There two wires of a thermocouple are joined at the measuring junction and the reference junction.



HOW DOES A THERMOCOUPLE THERMOMETER WORK?

- To measure temperature the measuring junction is connected to a body to be tested while the reference junction is connected to the body with known temperature this is usually 0^0c and it is achieved by putting it in a mixture of ice and liquid water.

- Because there is a temperature difference between the two junctions a current starts to flow in the wires, this means the current or voltage scale can be calibrated with temperature scale in this way current or voltage obtained gives values of unknown temperature direction.

ADVANTANGES OF A THERMOCOUPLE THERMOMETER.

1. It can measure a wide range of temperature of up to 2800^0c.
2. It is strong and compact

CALIBRATING A THERMOCOUPLE THERMOMETER

- By maintaining junction B at an environment of known temperature eg melting ice (0^0c), junction A is dipped on various environments of unknown temperatures e.g. boiling point of pure water (100^0), boiling point of mercury (356.7^0C) and the corresponding currents flowing is recorded. Using the corresponding temperature differences and current values obtained, a temperature scale is developed and calibrated accordingly for use in determining the temperature in the environment.

USES OF THERMOCOUPLE

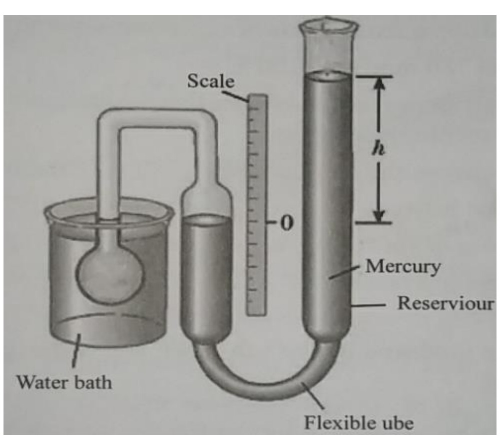
(i) Used in industries eg in kilns, gas turbine exhaust to determine if the required temperature is reached

(ii) It is used in homes, offices as temperature sensors in thermostats.

(iii) Used as flame sensors in safety devices

3. CONSTANT VOLUME GAS THERMOMETER

- A constant gas thermometer measures temperature by making use of the change in the temperature of a fixed (constant) volume of a gas when the temperature changes.
- The mercury manometer has a column particularly filled with mercury that is connected to a flexible tube that has another particularly filled column of mercury called *reservoir* attached to the other end the height of the mercury. The first column is set to as a reference point (zero mark) while mercury in the receiver is allowed to move up and down in relation to a scale of ruler.
- Constant gas thermometer works on the principle of gay –Lussa law which states that the pressure of an ideal gas increase as its temperature increases at constant volume



HOW DOES A CONSTANT VOLUME GAS THERMOMETER WORK?

- To Measure Temperature the bulb is inspected into body to be tested such as water.
- When the temperature increases the volume of the bulb also increases. Similarly when the temperature of the test body is low the volume of bulb also decrease. The pressure of the mercury also changes such that it begins to move up or down and thus away from the reference point
- To stop this movement (which will also stop the gas from expanding) the receiver at the end is physically lifted up or down
- The difference between the reference and receiver height gives the final pressure which is then used to calculate the temperature.

- A practical constant-volume gas thermometer has two fixed points: the lower and upper fixed that were set using known values of temperature for example melting point of pure ice (0^0c) and the boiling point of pure water (100^0c).Using these points we are able to determine the temperature of other substance or environments using the thermometer.

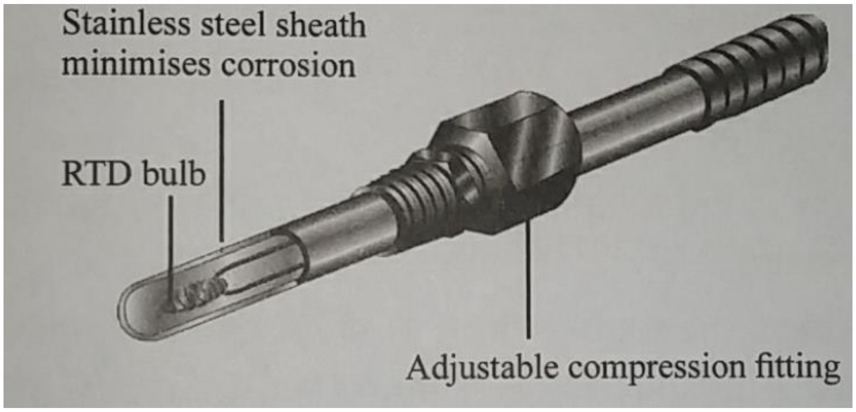
Example:

- Suppose the lower and upper fixed points of a constant-volume gas thermometer are
- 540mmHg at 0^oc and 780mmHg at 100^0c
- What would be the temperature *t* of a substance that produces a pressure difference of 600mmHg on the thermometer?

- Pressure difference between the fixed points= (780-540) mmHg = 240mmHg
- Temperature difference between the fixed points = $(100\text{-}0)^0$c = 100^0c
- *Thus temperature rise of 100^0c produces a pressure of 240mmHg in the gas.*
- The substance produces a pressure rise = (600-540) mmHg = 60mmHg above the lower fixed point.
- Thus the temperature produced by the substance above the lower fixed level

ELECTRICAL RESISTANCE THERMOMETER

- An electrical resistance thermometer is a device used to measure temperature based on the electrical resistance of metal
- It consists of sensing elements that is mostly a length of fine coiled wire, this wire is wrapped around a glass core. The sensing element is also known as resistance temperature detector (rtd)
- A resistance temperature detector work on the principle that the resistance of wire changes as its temperature changes.
- The most accurate and commonly used resistance thermometers are standard platinum resistance thermometers (SPRTs) that use platinum wires



HOW DOES AN ELECTICAL RESISTANCE THERMOMETER WORKS?

- When exposed to a substance to be tested a sensing element changes its resistance due to an increase or decrease in the temperature of the surrounding
- The resistance of the sensing element is measured and compared to the recorded temperature values for different resistances.

ADVANTAGES

- It is very accurate when measuring temperature
- It measures a wide range of temperatures

THERMAL EXPANSION

Temperature

The degree of coldness or hotness of body. For particles to move there is a need of kinetic energy

Temperature is a measure of the average kinetic energy of the substance. The kinetic energy of the substance increases when its temperature increases and this increases molecular motion because the Particles gains kinetic energy and start to vibrate at a longer distance

The SI unit of temperature is kelvin (K) however commonly used unit for measuring temperature is degrees Celsius (^{0}C)

Heat

Heat is a form of energy which passes from a body of high temperature to a body of low temperature. The SI unit of energy is joule (J)

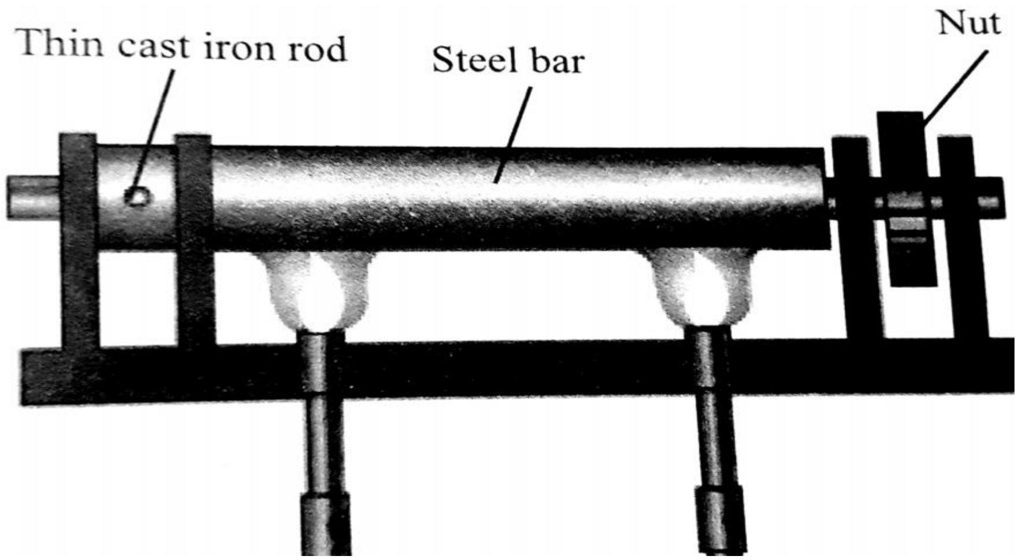
Thermal expansion in solids

When solids are heated, they increase in length, volume and area

Demonstration of thermal expansion in Solids

Fix the steel bar in the frame of bar breaker

Lock the steel bar on the frame by inserting the thin cast iron rod in the hole on the steel bar as shown below, clamp the steel bar strongly and observe what happens to the cast iron

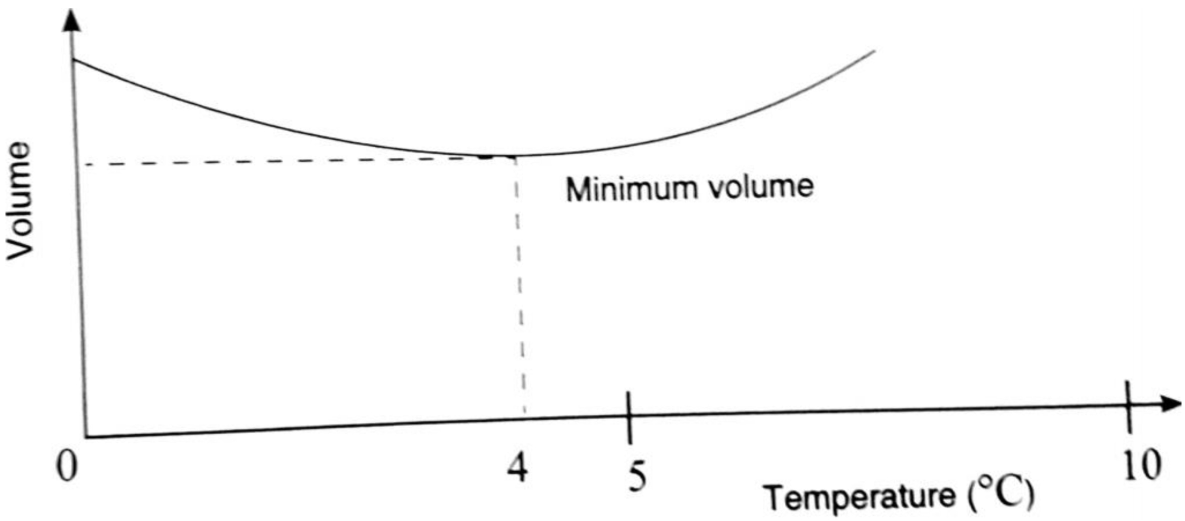


- Heat the steel bar strongly using the Bunsen burners and observe what happens to the cast iron
- Observation: when steel bar is heated strongly the cast iron rod breaks with a loud sound
- Repeat the experiment but in this case, first heat the steel bar strongly and insert the cast iron rod through the hole then clamp the rod firmly observe what happens as the steel bar cools
- Observation: the steel bar is cooled the cast iron rod breaks
- Discussion:
- On heating, the steel bar expands pushing the cast iron rod against the outer frame of the bar breaker hence the rod breaks
- on cooling, the steel bar contract and pulls the cast iron rod against the inner frame of the bar breaker hence the rod breaks
- What happens during thermal expansion?
- When a solid is heated, the molecules vibrate with larger amplitude about their fixed positions; this makes them to collide to collide with each other with larger forces which push them far apart. The distance between the molecules increases and so the solid expands

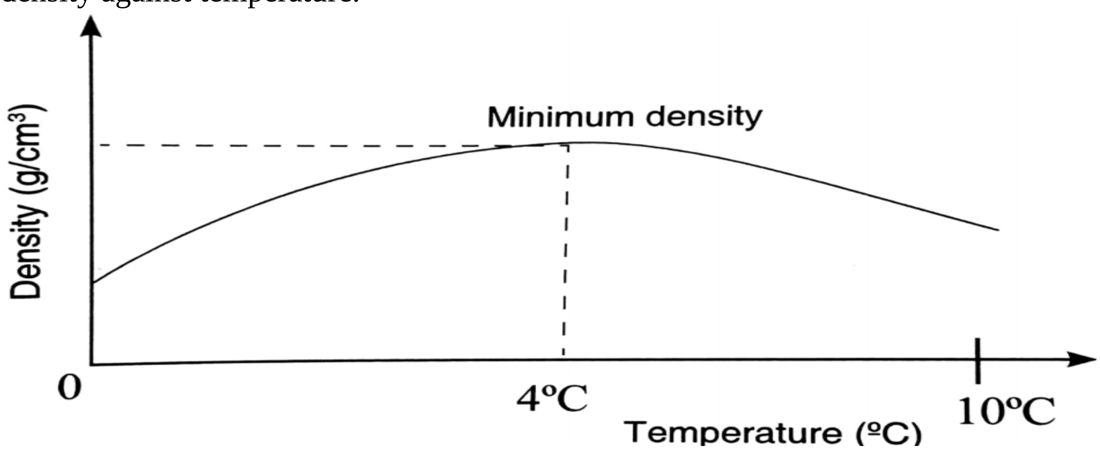
Thermal expansion in liquids

- Liquid expands on heating just like solid but liquid expands more on heating than solid because they have relatively weaker intermolecular forces
- Anomalous expansion of water
- Most liquids expand steadily on heating. Water behaves in unusual/abnormal manner in the sense that when heated at 0^0C, its volume decreases (contracts) as temperature rises from

0^0C to 4^0C.Beyond 4^0C, water expands like other liquids. This unusual (abnormal) behavior of water when it is heated from 0^0C to 4^0C is referred to as anomalous (abnormal) expansion of water. Thus, a fixed mass of water has a minimum volume at 4^0C.



- From the graph, we see that the volume of a fixed mass of water is minimum at 4^0C .At this temperature, the density of water is maximum. The figure below shows the graph of density against temperature.



Effects of anomalous expansion of water

i. Survival of aquatic organisms in freezer of lakes and ponds.
ii. Bursting of water pipes.
iii. Weathering of rocks.

Applications of thermal expansion.

i) Loose fittings of electrical cables.

- The electric wires who transfer electricity are loosely held to allow expansion and contraction, this is seen during hot days the wires sag (expand) and are seen taut and straight (contract) on cold days. If they were tightly held, they would break during cold days causing a lot of destruction.

ii) Separating stuck tumblers/glasses

- Two tumblers stuck together, they can be easily separated by placing them upright in warm water and pouring very cold water in the inner tumbler. The outer tumbler will expand more than inner one hence can be separated

iii) Tooth filling.

- Dentist can do minor surgery to re fill these holes, the material used to refill these holes must have the same coefficient of thermal expansion as tooth itself, this will make both the material and the tooth expand and contract uniformly

iv) Removing tightly screwed covers.

- Bottle tops and container lids are sometimes hard to open, to open them place the bottle in cold water and heat or pour hot water on the cover or lid. The bottle contracts while the bottle top or cover expands making it easier to open the bottle top/lid

v) Use of alloys.

- The measuring tape is made up of alloy of iron and nickel called invar. Invar has a very small change in length when temperature changes

vi) Gaps in railways tracks

- Gaps are left between railways the railways when the railway tracks are laid. The rails are joined together by fish-plates bolted to rails. The oval shaped bolt holes allow the expansion and contraction of the rails when temperature changes

vii) Rollers on bridges

- The ends of steel and concrete bridges are supported on rollers. During hot or cold weather the change in length of the steel bridge may take place without damaging the structure

viii) Expansion gaps in fences

- The gaps are left on the building to allow expansion and contraction. The joints can be horizontal or vertical the joints or opening maybe filled with a highly compressible material that allows the joint to partially close as the brick layers expand

ix) Shrink fitting

- This is a method used to make mechanical joints when axles are to be fitted inside other hollow tubes or parts. The hollow space is made slightly narrower than the axle to be fitted in it.The hollow is heated to expand and while still hot the axle is fitted, the joint is left to cool upon cooling the hollow contract (shrinks) and make a tight grip of the tube or axle fitted in it.

PRESSURE

- Pressure is the amount of force exerted per unit area
- The equation for pressure is the force divided by the area where force is applied (pressure =force/area)
- The IS unit of pressure is the Pascal (Pa)
- One Pascal is the force of one Newton distributed over the area of the square meter ($1Pa=1N/M^2$)

PRESSURE IN SOLIDS

- Substances which are in solid form produce a large amount of pressure if their weight or force is directed over a specific area

Factors that affect solid pressure

1. area
   - Pressure in solid decreases with an increase in area where the force is applied
2. amount of force
   - Pressure in solids increases with an increase in amount of force exerted over a specific area

APPLICATION OF SOLID PRESSURE

- There are many physical situations where solid pressure is important in everyday life .Some there application are as follows

1. When using iron nail; nails are sharp pointed to reduce are in contact with the wood so that pressure is large enough to make the nail sink into the wood.
2. When getting an injection ; we use sharp pointed needles to reduce the area in contact with the body so that pressure is large enough to make the needles easily pierce the body .we therefore need less force to push the needle through the skin
3. Tractors use very wide tires so that their large area reduces pressure against the ground. This prevents tractors from sinking into the ground heavy vehicles which carry heavy goods have big tires to reduce pressure.

GAS PRESSURE

- According to the kinetic theory gases are in a continuous motion and constantly bombard with each other and the walls of any container they are put in. The container experiences an outward force or push each time a molecule striker it and bounces off.
- Many molecules hit the container per second producing a steady force on a given area, hence gas molecules exert pressure on the walls of the container which is called gas pressure

FACTORS AFFECTING GAS PRESSURE

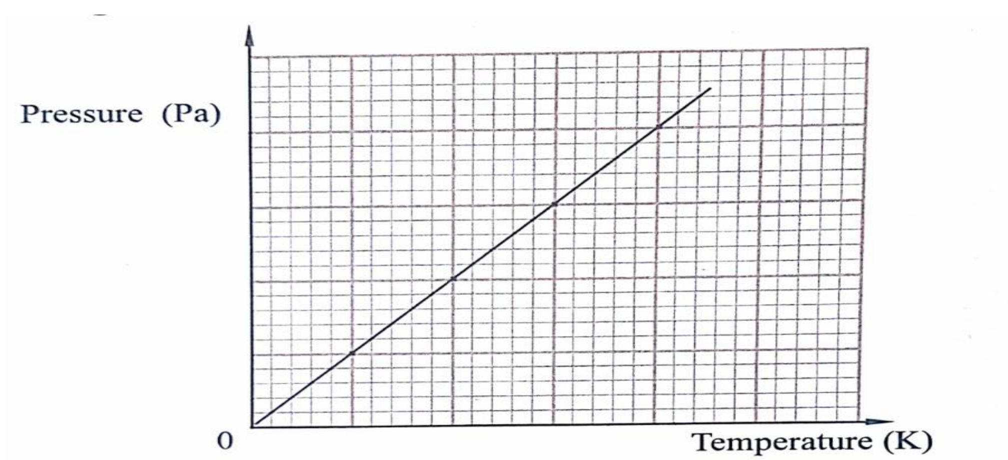
3. TEMPERATURE
   - When temperature of the gases increases particles gains kinetic energy and start to vibrate at a longer distance making more collisions with the walls of the container increasing the pressure.
4. VOLUME
   - When volume decreases the particles takes shortest distance to collide with each other and walls of the container hence pressure increases
5. NUMBER OF PARTICLES
   - The increase in the number of particles increases the pressure because the rate of collisions per second between the gas molecules and walls of the container increases.

GAS LAW

- When studying behavior of a fixed mass of a gas three important quantities are considered on the circumstance a change in one quantity produces a change in one or both of the other two. These laws that relate to these changes are known as gas laws .Gas laws only apply to an ideal gas which has no attraction between its molecules

PRESSURE LAWS (GAY-LUSSAC'S LAW)

Pressure law states that pressure of a fixed mass of a gas is directly proportional to its absolute temperature when its volume is kept constant.



The graph of pressure against temperature

Mathematically,

Pressure (P) α absolute temperature (T)

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

Example

At 25^0c the pressure of a gas is 60cm of mercury. At what temperature would the pressure of the gas fall to 12 cm of mercury.

P_1=60 cmHg T_1=25+273 = 298K

P_2= 12cmHg T_2=?

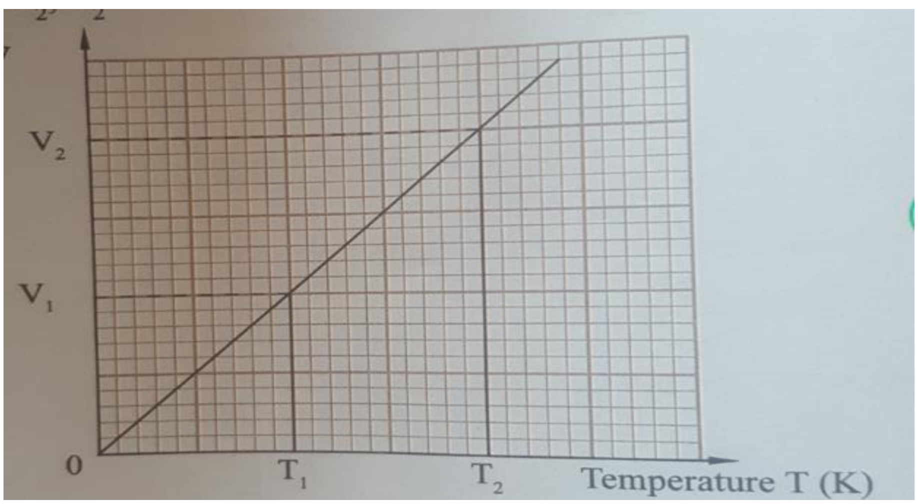
$\frac{60}{298} = \frac{12}{T_2}$

T_2=59.6K

- ❖ This law can be explained using the kinetic theory of matter as follows.
  - ✓ When a gas is heated the average kinetic energy of the molecules increases (i.e. the temperature increases)
  - ✓ The faster moving molecules strikes the walls of the container more frequently.
  - ✓ A larger force is exerted on those walls since the surface area of the walls remains constant, a higher pressure now acts on the walls.

CHARLES' LAW

- ✓ This is the law that gives the relationship between the volume and the temperature of a fixed mass of a gas at constant pressure.
- ✓ Charles law state that the volume of a fixed mass of a gas is directly proportional to absolute temperature of the pressure remains constant
- ✓ This law can be explained using the kinetic theory of gases as follows.
- ✓ When a gas in a closed container is heated ,the average kinetic energy of the molecules increases
- ✓ The temperature of gases increases. As the temperature of the gas increases, the gas particles increase their movement. Consequently, they move further apart and exert a large force against the container walls.



Graph of volume against temperature

- This graph shows that when the pressure of fixed mass of a gas is kept constant the volume change linearly as the temperature increases.

  $= \frac{V}{T} =$A constant 'this summarized in Charles law

- The law states the volume of a fixed mass of gas and constant to pressure is directly proportional to its absolute temperature

Mathematically,

$\frac{v_1}{T_1} = \frac{v_2}{T_2}$

Example:

A gas at 0^0c was found to occupy a volume of $100cm^3$.What will be the volume of the gas at 50^0c.Assume the pressure of the gas to be constant.

$\frac{v_1}{T_1} = \frac{v_2}{T_2}$ $v_1 = 100cm^3$ $V_2=?$ $T_1=0^0c +273k = 273k$ $T_2=50^0c+273k = 323K$

$\frac{100}{273_1} = \frac{v_2}{323}$ $V_2=118.3cm^3$

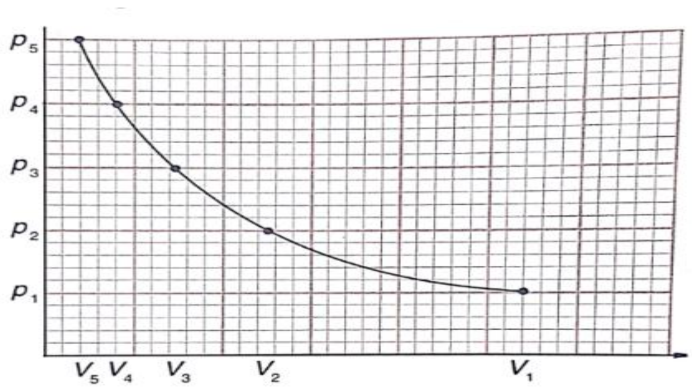
BOYLE'S LAW

This states that the volume (v) of fixed mass of a gas is inversely proportional to the pressure, provided that the temperature is kept constant.

$p_1 v_1$=K

The relationship between the pressure (P) and volume is given by

$$p_1 v_1 = p_2 v_2$$



The graph of pressure against volume

In Boyle's law as the temperature of the gas is constant, the average kinetic energy of the gas molecules is constant. When the volume decreases, the number of collisions per second increases as the molecules take less time between any two collisions. The gas pressure therefore increases. When the volume is increased the number of collisions per second decreases since the molecules spend more time in between any two collisions, this results in a decrease in pressure as observed in Boyles law.

Example:

Oxygen is compressed at constant temperature until its pressure rises from 82cmHg to 140cmHg.If the final volume of oxygen is 50cm^3, find the initial volume of oxygen

V_1=? P_1=82cmHg

V_2 =50cm^3 P_2 = 140cmHg

$$p_1v_1 = p_2v_2$$

82 x V_1=140 x 50

V_1=85.37cm^3

THE COMBINED GAS LAW

- The three gas laws Boyles, Charles and pressure law can be combined into form an ideal gas law. This ideal law relates the changes in pressure, volume and absolute temperature

From Boyle's law, temperature is constant

PV=constant ------ (a)

From Charles law, pressure is constant

$\frac{V}{T}$= constant--------(b)

Pressure law,volume is constant

$\frac{P}{T}$ =constant------(c)

Combining the LHS of a,b,c and equating it to constant, we get

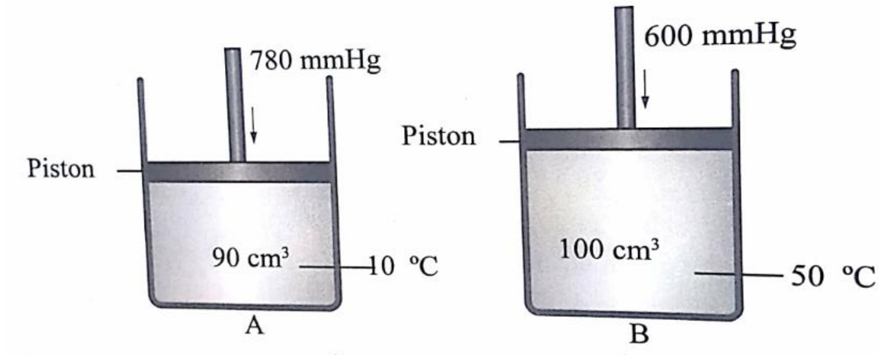
$\frac{PV}{T}$ = constant

This is the general equation connecting P,V and T

$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$ this is called *ideal gas law*

Standard temperature and pressure

The volume occupied by fixed mass of a gas depends on its pressure and its temperature.Consider two gases are different.Inorder to compare the volumes of gases, we need to have them at the same temperature and pressure.0^0c temperature and 760mmHg pressure are chosen as standard states of the gas. The 0^0c temperature and 760mmHg pressure are called standard temperature and pressure (s.t.p).760mmHg can be written in short as 1atm



Example:

Compare the volumes of the gas in A and B in Fig above at (s.t.p)

Gas A

P_1=780mmHg P_2=760mmHg

V_1=90cm^3 V_2=?

T_1=10^0c + 273=283K

$V_2=\frac{(P_1V_1T_2)}{T_1P_2}$

For A, $V_2=\frac{(760x90x273)}{283x760}$=89.10cm^3

Gas B

P_1 = 600mmHg P_2=760mmHg

V_1=100cm^3 V_2=?

T_2=273k

$T_1 = 50^0c + 273K = 323K$

$V_2 = \frac{(P_1 V_1 T_2)}{T_1 P_2}$

$V_2 = \frac{(600x100x273)}{323x760} = 66.73cm^{3s}$

APPLICATION OF GAS LAWS

Boyles law

1. **Working of bicycle pump**
   - The washer in the pump allows air to enter the barrel during the upstroke, but during the down stroke, the air does not escape to the outside. The air is compressed in the barrel. This leads to the volume of air decreasing as the pressure increases. When the pressure of the air in the pump is greater than in the inner tube, the valve opens and allow more air into the tube, further increasing the pressure.
2. **Action of syringe**
   - When drawing fluids into the piston a syringe is pulled making the volume inside the syringe to increase. This leads to corresponding decrease in air pressure. The pressure outside the syringe is greater forces the liquid fluid into the syringe. When the syringe is on reverse the volume reduces and pressure inside the syringe increases forcing the liquid out.
3. **Action of the lungs**
   - During inhaling the lungs expand increasing the volume as the pressure inside them decrease. The pressure outside being greater it forces air into the lungs
   - During exhaling the lungs contract increasing the pressure as the volume decreases forcing the air out.

Charles law

1. Slightly inflated rubber tyres left in bright sunlight swells up. This is the reason why motorists are discouraged from over inflating their tyres because they can burst on hotter day
2. A football inflated inside and taken outdoors on a cold day it shrinks slightly with air inside obeying Charles law
3. To flying hot air balloons, balloonists apply Charles law. As the air inside the balloon is heated, its volume increases. The density of the balloon reduces as the air inside is heated and expands. This enables the balloon to fly.

Pressure law

1. The gauge pressure in steel belted automobiles tyres reads reads a higher value when the car is travelling on a hot path than when it is moving on a cold path

2. An aerosol can thrown in the fire explodes; since the pressure inside the can increases with an increase in temperature.

PRESSURE IN LIQUIDS

- Unlike solid liquids do not have a definite shape they take the shape of a container in which they are put like the solid liquids exert pressure .A solid exert pressure only on the surface area in contact with its surface but a liquid exert pressure on all the walls of the container.

FACTORS AFFECTING LIQUID PRESSURE

Pressure of the liquid depends on the following factors

a. The depth within the liquid (height of the liquid column h)
b. The density of the liquid (d)
c. The strength of the gravitational fold at that point(g)

DEPTH OF THE LIQUID

- The pressure exerted by a liquid increases as depth increases, this is so because liquid pressure also depends on the weights of the liquid on top increases and in turn the pressure rises
- Points of the same level have the same pressure because the weight of the liquid above the is the same
- Conversely we can deduce that in a static liquid all points at the same level are at the same pressure.

DENSTY OF THE LIQUID

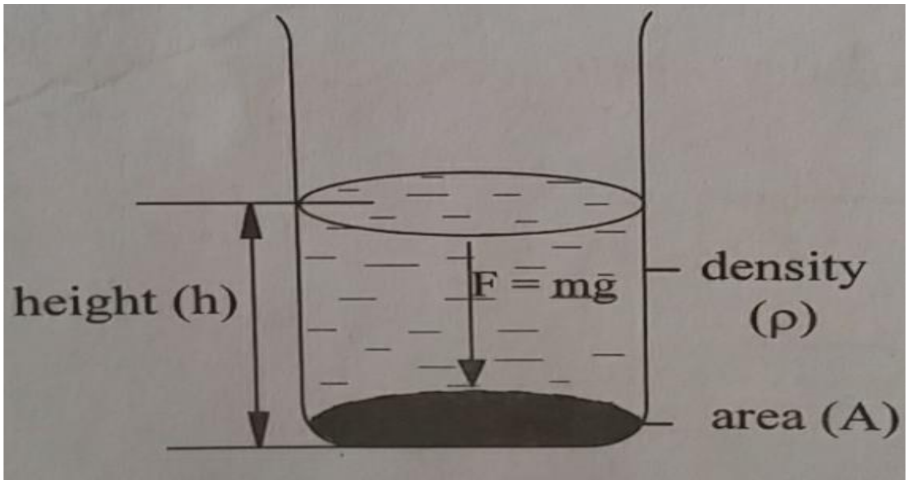
Liquids with greater density exert more pressure than liquids with less density .for example; pressure exerted by cooking oil at a depth of 2ocm is less than pressure exerted by water at the same depth.

GRAVITATION FIELD STRENGTH

It has been proven experimentally that pressure is also directly proportion to gravitational field strength

DERIVING THE FORMULAR FOR LIQUID PRESSURE

Consider a liquid with density (d) is put in a container to a depth (h) as shown in figure below.



- At the base the force is actually the weight of the water above It and the area is the base area (A)
- The volume of the liquid =area x depth =Ah
- The mass of the liquid =volume x density =V d
- The weight of the liquid = mass x gravitational field strength

  = M x g

  = ahdg

- Pressure = force/area= weight of the liquid/base area
- Pressure =Ahdg/A=hdg
  P=dgh
- When using this equation make sure density (d) is in kg/m^3 and the depth (h) is in meters the volume of acceleration due to gravity (g) is about 10N/kg.
- The units of pressure are therefore in n/m^2 or paschal the pressure is calculated using this formula is pressure due to liquid any .the total pressure (absolute pre) at a particular depth is the sum of liquid pressure and only other local pressure that act on the liquid surface such as atmospheric pressure (a.t.m)

TRANSMISSION OF PRESSURE IN FLUIDS

- Fluids are substance which are capable of flowing freely, this include all liquids and gas
- The Pascal's principle states that force applied at one end of the vessel is equally transmitted to all parts of the vessel.
- This principle can also be stated as pressure applied at one point in a fluid at rest is transmitted equally to all parts of the fluid
- The Pascal's principle of transmission is also known as the Pascal's law

The property of liquid pressure used in hydraulic machine

- It is incompressible
- Pressure passes on in liquid

A small force applied ona small piston produce a large force on a large piston this is the *principle of the transmission ofpressure in liquids or Pascal principle*.

For Pascal principle to hold the fluid should have the following properties

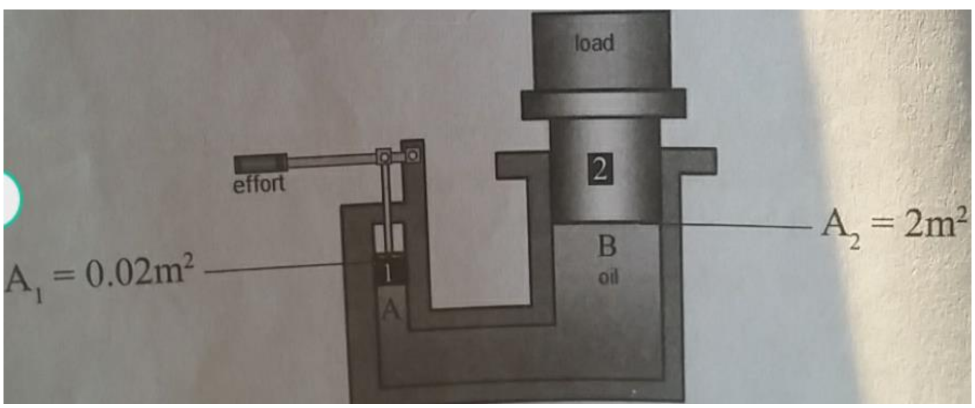
- It should be incompressible
- It should have a wide range of temperature low freezing and high boiling point
- It should not corrode the parts of the system

The principle of transmission has so many application in *hydraulic machines*

Hydraulic machines

- These are the machines that are used to lift heavy loads
- Pressure at *one end* of the vessel is equal *to all parts* of the vessel.
- Examples of hydraulic machines are hydraulic car jerks, hydraulic fork lifter.

Example:



a) Determine
   i. Pressure exerted on the oil by piston 1 at point A if a force of 250N is applied on the handle
   $P=\frac{F_1}{A_1} = \frac{250N}{0.02} = 12500N/M^2$
   ii. Pressure at point B
   Pressure exerted on to the oil by piston 1 at point A is transmitted by the oil to point B. Hence $P_B=P_A=12500N/M^2$
   iii. Force exerted on the piston 2 by the oil
   By Pascal's principle $P_1=P_B$
   Force exerted on the piston 2 by the oil

$P_1 = P_B = P_2 = \frac{F_2}{A_2}$

$F_2 = P_2 \times A_2 = 12500 N/m^2 \times 2m^2 = 25000N$

b) State three properties of the oil that makes it suitable for use in yhe hydraulic lift

- Oil is incompressible
- Oil has a high boiling point and low freezing point
- Oil does not corrode the parts of the system

ATMOSPHERIC PRESSURE

- A gas exerts pressure on the walls of container since it is a mixture of gases it also exerts pressure the earth's surface is surrounded by a thick layer of air we live under a vast *column* of air called *atmosphere*
- The density of air varies from the earth's surface to the outer space. Air is denser at the sea level than high up in the mountains .The pressure exerted by air is called *atmosphere pressure*

Effects of atmospheric pressure

- Crushing of the can when the pressure inside it decreases
- Drinking using a straw, atmospheric pressure pushes water up the tube
- Inverted tumbler the cardboard does not fall because the atmospheric pressure keeps cardboard intact

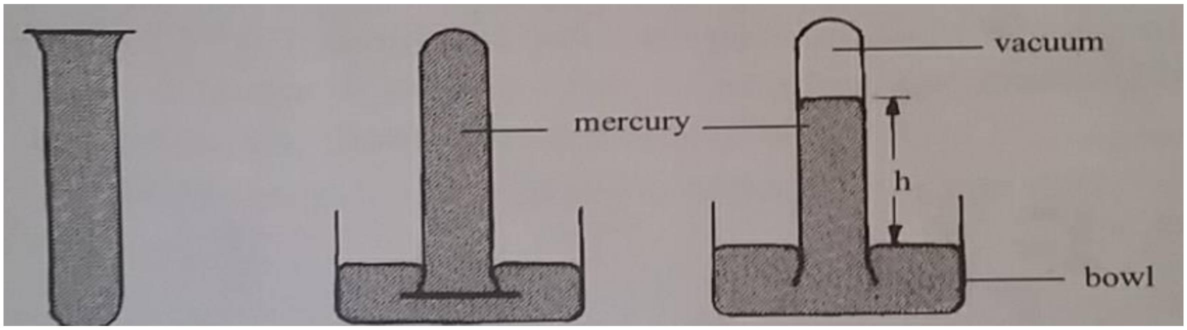
MEASURING ATMOSPERIC PRESSURE DUE TO GASES

- Atmospheric pressure is measured using an instrument called a barometer.

Barometer

- It consist of a thick walled glass tube of about meter that is fitted to a bowl or a dish of mercury

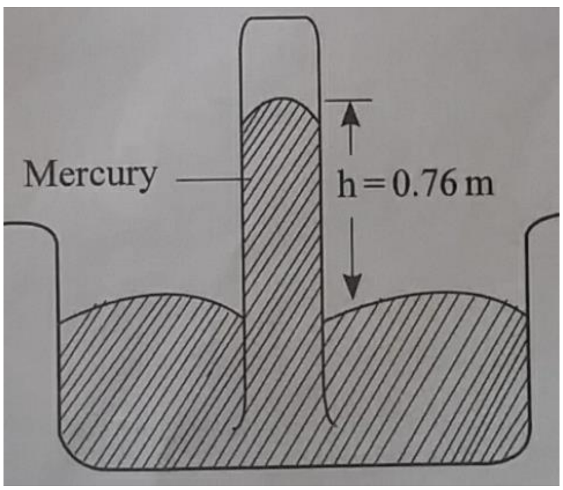
The level of mercury inside the tube drops until the pressure due to the column of mercury equals the atmospheric pressure. The height, h, is a measure of atmospheric pressure. The length of column, depends on the liquid used and the altitude of the place. At the sea level, mercury stands at a height of 760 mm. We say that the atmospheric pressure at sea level is equal to a column of 760mmHg.If water is used instead of mercury the height of the column of water about 10 m. From the mercury barometer readings, the atmospheric pressure is given by:



Atmospheric pressure, P_A=h x density of mercury x gravitational acceleration

Example:

Figure below shows mercury barometer used to measure the atmospheric pressure on the bank of a river



Taking g=10N/kg and density of mercury as 13600kg/m^3.Calculate the atmospheric pressure on the bank of the river.

P=h x d x g

0.75m x 13600kg/m^3 x 10N/kg

P = 102000N/m^3

When the mercury column is 76mm the atmospheric pressure is said to be standard and its value is taken to be 1 a.t.m. or 1 atmosphere

From the mercury barometer reading, the atmospheric pressure is given by

P_A =dgh

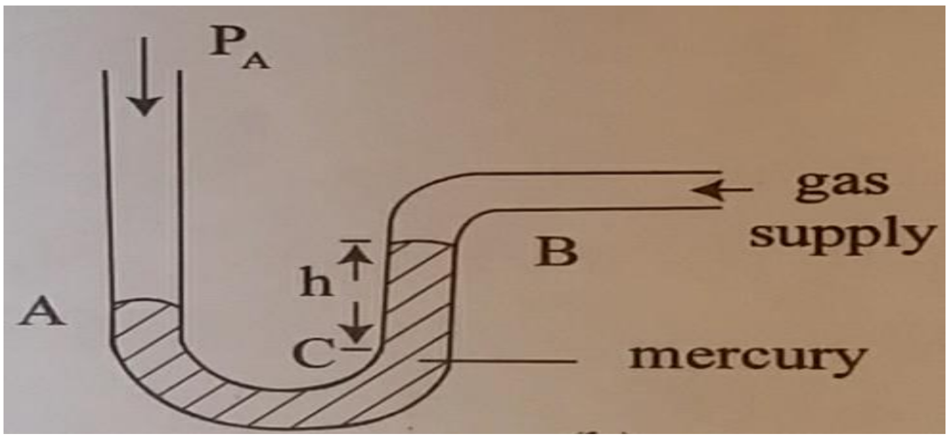
Where d is the density of mercury while it is the column of mercury $p_A$is the atmospheric pressure

MANOMETER

- Manometer is an instruments used to measure gas pressure .It can also be used to measure lung pressure it consists of a transparent tube which contains mercury and a scale of numbers.

One end is left open while the other is usually connected to the gas whose pressure is to be measured

U-tube manometer



Each surface of mercury is acted on equally by atmospheric pressure and the levels are the same before connecting it to the gas supply

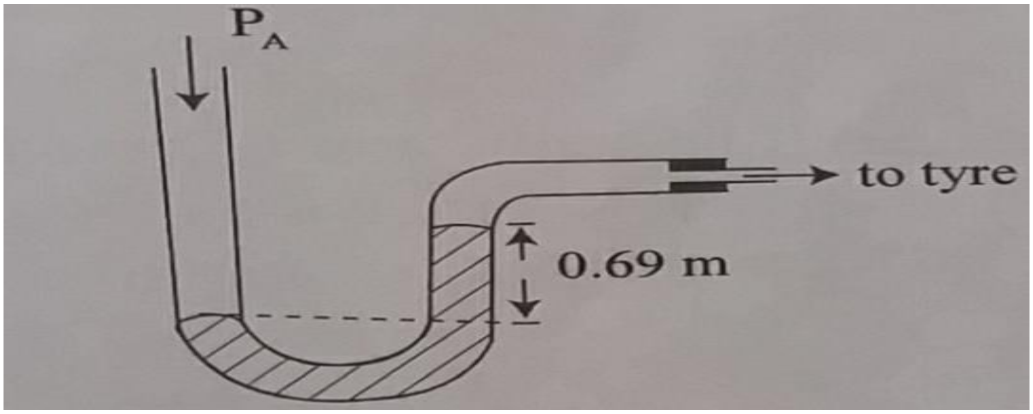
Side A is connected to a gas supplier .The gas exerts a pressure on surface A and level B Rises

Gas pressure = atmospheric pressure + pressure due to mercury

$P_g=p_A+ dgh$

Example:

The figure below is the manometer used to determine the pressure of the gas used to inflate the tyre. The density of the mercury is 13600kg/m^3 and g=10N/kg and atmospheric pressure P_A is1.02 x 10^{5}Pa



Calculate the pressure of the gas

From $P_A=P_g+hdg$

$P_g=P_A-hdg$

$1.02x10^5$pa - 0.69m x 13600kg/m^3 x 10N/Kg

$1.02x10^5$pa - 93840pa

8160Pa

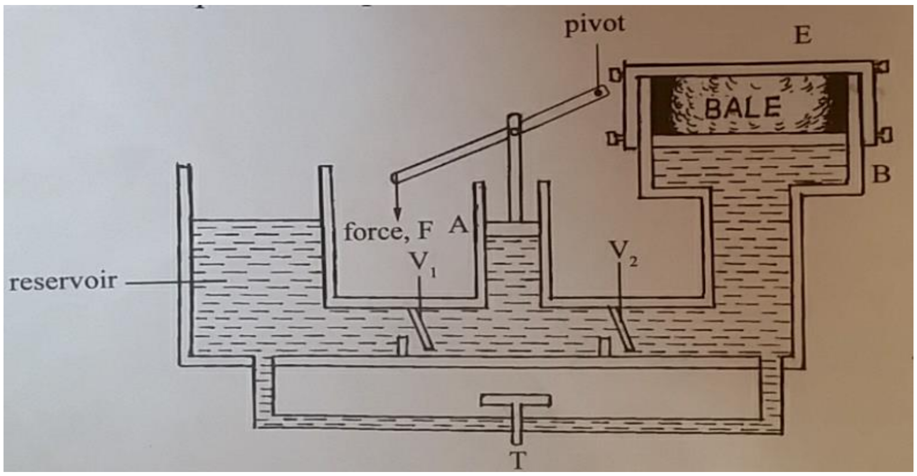
Alternatively pressure in mmHg can be found by subtracting A from B before blowing into the manometer, note the level of mercury and record it as initial reaching

APPLICATION OF FLUID PRESSURE

- *Water supply system*: water supply system or an irrigation supply system of water comes from a receiver on high ground .water flows from it through pipes to any tap that is below the level of water in the reservoir
- The lower the place water is being supplied the greater the water pressure
- *Drinking straw*: when you suck in the straw your lungs expand and air is taken out of the straw .This lowers the pressure in the straw comparing to the atmospheric pressure pushing down the surface of the liquid in the bottle
- Because of the pressure difference the liquid is forced up the straw
- *Construction of dams*; the bottom of the dam is made of thick wells since pressure of a liquid increases with depth
- *Siphon:*a pipe can be used to siphon liquid from a container at a higher level to another at a lower lever .For example we can remove petrol from tank of the vehicle using the siphon method
- *Deep sea diving vessels*: deep sea diving vessels are but with strong materials on the walls to withstand the crushing of fact of sea water a hose

- Pressure pushes inwards from all direction this is because they more deep into the water where pressure is higher as pressure increases with depth.
- *Syringe:* Consist of a light fitting piston in a bared it is used by doctors to give injections to patients.
- When the piston is pulled (up stroke) the pressure inside reduces and the atmospheric pressure on the surface of the liquid pushes the liquid into the barred
- During a down stroke the pressure inside increases and the liquid is expelled from the barrel

Hydraulic machines: This use the principle of transmission of pressure .The material to compressed such as a bale of cotton wool,forgedsteel,bound of book, an oil seed is placed above the piston and against a rigid plate

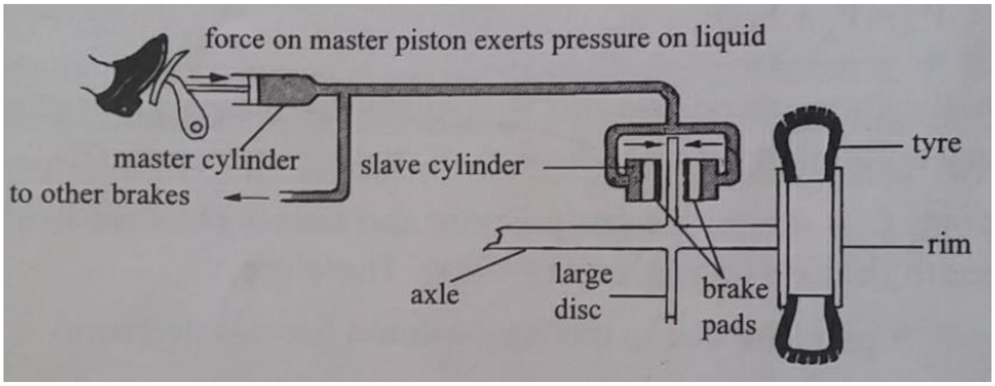


How it works

- When a force is applied on piston a valve (v_1) closes while value 2 (v_2) opens The Pressure is transmitted equal to B through the liquid .This produces a large force that presses the bale against rigid plate E that is fixed above piston B on removing the force on A the valve (v_1 opens and v_2 closes) . As a result more fluid enters through V_1
- Since V_2 is closed the bale is under constant pressure the process is repeated by opening the tap the liquid in B can be returned to the reserve and compressed bale can be removed from the press.

Examples of hydraulic machines

Hydraulic brake



Why the master cylinder is small compared to slave cylinder

So that the master cylinder should multiply force this will make the piston of slave cylinder to push the brake pad

HOW IT WORKS

- When the driver applies force by pushing on the foot pedal pressure is created on the piston of the master cylinder
- This pressure is transmitted equally throughout the brake fluid, when pressure in the brake fluid reaches the wheel cylinder, slave cylinder increases the force because the wheel piston are large in size
- This action pushes the pistons in the slave cylinder outwards so that the brake pads pressure against the rim of the wheel. The friction between the pads and the rim of the wheel shoes stops the vehicle
- When the driver releases the pedal the return spring retracts the shoes back to their normal position thus the wheel will be rotating freely
- *Hydraulic jack:* this is mechanical device used to raise and support a heavy object. The hydraulic fluid used in a jack is oil since oil is self-rubricating.

THE ARCHIMEDES PRINCIPLE

- When objects wholly or partly immersed in a fluid they weigh less than when they are weighed in air this is because they experience an upward push by the fluid is called upthrust or buoyant force
- The displaced fluid weigh the same as the upthrust force this principle works for any fluid and it is called the Archimedes principle
- *Archimedes principle* states that when an object is wholly or partly immersed in fluid the upthrust on it is equal to the weight of the fluid.
- When the cylinder was weighed in air (W_{air}) and when weighed completely immersed in water (W_{water}).The cylinder appears to weigh less in water than in air. The difference

between the weight in air and weight in water (a liquid) is known as *apparent loss in weight* of the body

The magnitude of the apparent loss of weight of a body in a liquid is equal to upthrust exerted by the liquid on the body i.e.

Apparent loss in weight = uphrust=W_{air}-W_{liquid}

Example:

A body of mass 4kg weighs 30N in a liquid. Find the uphrust on the body due to the liquid

Weight in air = mg=4 x10 = 40N

Weight in liquid = 30N

Upthrust = $W_{in\ air}$-$W_{in\ liquid}$

(40 -30)N = 10N

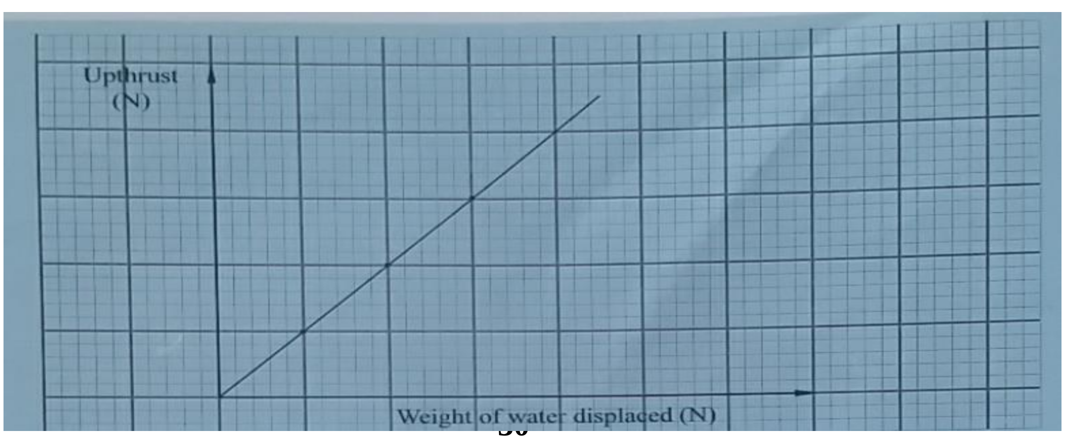
Factors affecting the magnitude of Upthrust

1. Density of the liquid
   As the density of the liquid increases, the upthrust increases and vice versa ie a denser liquid exerts greater upthrust on an object than the less dense liquid.
2. The volume of the body immersed in liquid
   The greater the height, and hence the volume of the portion of the object submerged into liquid, the greater the upthrust exerted on the body.

The upthrust is directly proportional to the weight of liquid displaced

Relationship between upthrust and the weight of water displaced

Graph of upthrust against weight of displaced water



Example:

A concrete block of mass 2.7×10^3 Kg and volume $0.9\ m^3$ is totally immersed in sea water of density $1.03 \times 10^3 kg/m^3$.Find

i. Weight of the block in air

$W=mg$

$2.7 \times 10^3 \times 10 = 2.7 \times 10^4 N$

ii. Weight of the block in sea water

Volume of water displaced =volume of the block = $0.9m^3$

Weight of water displaced=V x d x g

$0.9 \times 1.03 \times 10^3 = 9.27 \times 10^3\ N$

Uphrust=weight of water displaced

$= 9.27 \times 10^3 N$

Upthrust = $W_{air} - W_{liquid}$

$W_{liquid} = W_{air} -$ upthrust

$(27 \times 10^3) - (9.27 \times 10^3)$

$=1.77 \times 10^4 N$

THE LAW OF FLOATATION

- *A freely floating body displaces a fluid of weight which is equal to its own weight.*
- The law of floatation states that floating object displaces its own weight of the fluid in which it float,
- If an object is freely floating the weight of the fluid it displaces is equal to the its own weight (weight of a floating body = weight of fluid displaced)
- The law of flotation is a special case of the Archimedes' principle in that, the *netforce on the body is zero.*

NOTE

- If an object floats, its density must be less than the density of the fluid in which it is floating for example; wood floats in water because its density is less than that of water.
- However steel boat also floats in water, but it hollowed and full of air therefore its average density is less than that of water.

Example:

- An object floats in sea water of density 1.03×10^3 kg/$m^{3.}$ Itdisplaces 260m^3 of sea water. Find the mass of the object.
- Weight of body=weight of sea water displaced
- Mass of body = mass of sea water displaced

  = density x volume

- $(1.03 \times 10^3 \times 260)$ kg = 2.68×10^5Kg

Applications of floatation

a) Floatation of ships
   The boats floats on water displacing some water
b) Sub marines
   These are the types of ships which can float and sink in water. Submarines have internal tanks called *ballast tanks* which can be filled with water or air. A submarine can made to sink by admitting water into the ballast tanks. It can be made to float by expelling water from the tank by compressed air. This makes the average density of the submarine less than that of sea water and hence the sub marine floats.

RELATIVE DENSITY

- The relative density of substance is the ratio of the density o f a substance to that of water. It gives the measure of how many times a substance is denser than water. As the r ate, relative density has no units, mathematically, relative density can be found using the following formulae

- Relative density = $\frac{\text{mass of solid in air}}{\text{mass of an equal volume of water}}$

$$= \frac{mass\ of\ solid\ in\ air}{mass\ of\ water\ displaced} = \frac{weight\ of\ solid}{weight\ of\ water\ displaced}$$

- Weight of water displaced = apparent loss in weight = upthrust (Archimedes principle)

- Relative density = $\frac{weight\ of\ solid\ in\ air}{upthrust\ in\ water}$

- Relative density of solid = weight of the solid in air divide by up thrust in water

Example:

a) Concentrated sulphuric acid has a density of 1.8g/cm^3.Find its relative density

- Relative density = $\frac{density\ of\ concentrated\ sulphuric\ acid}{weight\ of\ water\ displaced} = \frac{1.8\text{g/cm}}{1g/cm} = 1.8$

- This means that 1 cm^3 of sulphuric acid is 1.8 times denser than 1 cm^3 of water. Hence sulphuric acid is denser than water

- **NOTE:***Density of a material in grams per cubic centimeters is thus numerically equal to its relative density.*

b) A body of mass 3kg weighs 22N in kerosene and 20N in water. Find

i. The relative density of kerosene
   - Weight of solid in air = 3 x 10N
   - Loss of weight in kerosene = 30-22 = 8N
   - Loss of weight in water=30-20 = 10N
   - Relative density of kerosene = $\frac{density\ of\ substance}{density\ of\ water} = \frac{8}{10} = 0.8$

ii. Relative density=$\frac{density\ of\ substance}{density\ of\ water}$

   $0.8 = \frac{density\ of\ substance}{1g/cm}$

   Density of kerosene =0.8 x 1g/cm^3 = 0.8g/cm^3

   = 0.8 x 10^{3}kg/m^3 = 800kg/m^3

APPLICATION OF ARCHIMEDES PRINCIPLE

i. *It is used in designing of submarines*
   - Submarines have internal tanks known as ballast tanks which can be filled with water or air.
   - A submarines can be made sink by admitting water into the ballast tank .Can be made to float by expelling water form the tanks by compressed air, this makes the average density of the submariners less than that of the sea water hence the submariners floats.
   - Certain group of fish uses the concept of Archimedes to go up and down the water

- To go up the surface, the fish will fill its swim bladder (air sacks) with gases .If they want to go down, they fill their swim bladder with water, and their density therefore becomes larger than that of water.

ii. *Archimedes principle is also used to determine the relative density of liquid substance.*
   - This is done by using an instrument called hydrometer. It is used to measure the relative density of a liquid .They are also used test the states of charge of a car battery. The relative density of the sulphuric acid in a full charged car battery is about 1.25, but it is much closer to 1 for a flat battery.

Types of Hydrometers

i. **Lactometer**
   - This is used to test purity of milk i.e. to check if any water has been added to the milk. It has a range from 1.015 to 1.045.Pure milk has a relative density of 1.030

ii. **Spirits/wines/beer hydrometer**
   - This determines the percentage of alcohol in beers, wines and spirits.

iii. **A car acid battery hydrometer**
   - Used to test the state of charge of acid batteries. This is done by measuring relative density of sulphuric acid. The relative density of the sulphuric acid in a full charged car battery is about 1.25, but it is much closer to 1 for a flat battery.

NEWTON'S FIRST LAW OF MOTION

The law states that:

- A body continues in its state of rest or uniform motion in a straight line unless compelled by some external force to act otherwise.
- From this law, we can define a force as that quantity which produces motion of body at rest or that which alters its existing state of motion.

Mass and Inertia

- Mass is the amount ofmatter in a substance which inertia is the reluctance of the body to change its state of motion. In this case, we will discuss the relationship between mass and inertia.

Momentum

- Momentum of an object is defined as the product of the mass and the velocity of the object.
- Momentum, $p=m \times v$
- A car mass 600kg moves with a velocity of 40m/s. calculate the momentum of the car.

Momentum = **mass × velocity**

= 600kg × 40m/s

= 24 000 kg/s in the direction of velocity

Impulse

Impulse is defined as the product of force and time

Impulse = Force(f) × Time(t)

SI unit of impulse is the newton-second law (Ns)

When an impulsive force acts on an object it produces a change in momentum of that object. The velocity of that object changes from an initial value(u) to a final value(v) but its mass remains constant.

Impulse = change in momentum

Ft= mv – mu

NEWTON'S SECOND OF MOTION

It states that the rate of change of momentum is directly proportional to the resultant force and it takes place in the direction in which the force acts.

$$\boldsymbol{force(F)a} = \frac{\textbf{change in momentum}}{\textbf{time taken}}$$

$$\boldsymbol{Rate\ of\ change\ of\ momentum} = \frac{\mathbf{mv-mu}}{\mathbf{t}} = \mathbf{m}\left(\frac{\mathbf{v-u}}{\mathbf{t}}\right)$$

But $\boldsymbol{a} = \frac{\mathbf{v-u}}{\mathbf{t}}$

Thus, F α ma

F=kma where k is constant of proportionality

this is the representation of Newton's second law. The relationship F=ma shows that the greater the force applied on an object the more acceleration it causes on the object.

If mass is 1 kg and acceleration is 1m/s^2, the force is 1N. This is the definition of 1 newton i.e. 1 newton is the force which when it acts on amass of 1 kg, it gives it an acceleration of 1m/s^2.

Example A truck of mass 2.5 tones accelerate at 7.5 m/s^2. Calculate the force generated by the truck's engine to attain this acceleration.

F=ma =2.5 × 7.5m/s^2

=18 750 N

NEWTON'S THIRD LAW OF MOTION

This states that whenever a body A exerts a force on body B,the body B exerts an equal but opposite force on body A

This is sometimes stated as to every action there is an equal and opposite reaction

Common experiences due to newton's third law of motion

i. When running, or walking a person exerts a backward force on the ground.The ground exerts a forward push on the person.This makes walking possible
ii. When agun is fired the bullet travels in one direction while the gun recoils backwards
iii. A balloon will always move in the opposite direction when the air inside is released.This is the principle that rockets and jet engines use,the force (action) of air coming out exerts an equal and opposite force(reaction) on the balloon making it move.

Conservation of linear momentum

Consider two objects A and B of masses m_A and $m_B$moving in the same direction with different velocities
On collision, A pushes B with a force F_A and B reacts by pushing A with an equal and opposite force F_B.That is F_B=-F_A
Total momentum before collision = total momentum after collision
Total momentum before collision=$m_Au_A+m_{BUA}$
Total momentum after collision=$m_Av_A+ m_Bv_B$
$m_Au_A+m_{BUA=}m_Av_A+ m_Bv_B$
The law of conservation of momentum states that when two or more bodies collide, their total momentum remains constant provided no external forces are acting

Types of collisions

i. Elastic collisions

This is the collision where total kinetic energy is conserved after collision.This is only possible within the atoms
If no other forces are acting,the total momentum and total energy before and after collision is found to be the same.

Example:

A cannon of mass 800kg fired a cannon ball of mass 3kg at a velocity of 120m/s,find the recoil velocity of the cannon
Total initial momentum=total momentum
$m_Au_{A\,+}\,m_Bu_{B=}m_Av_{A\,+}\,m_Bv_B$
3x0 + 800 x 0=3 x 120 + 800 V_B
0=360 +800V_B
V_B = -0.45m/s
The cannon recoiled backwards at a velocity of 0.45m/s.The negative value in the velocity shows that the cannon moved
(reconciled) in the opposite direction

ii. Inelastic collision

This is the collision where total kinetic energy is not conserved during collision
In this collision two bodies stick together after collision and move together with a common velocity

Example:

A ball of mass 3kg moving with a velocity of 4m/s collides with another ball of mass of 2kg which is stationary,after collision the two balls stick together,calculate the common velocity for the two masses

Momentum before collision= $m_A u_A + m_B u_B$

(2x0) + (3x4)

=12kgm/s

Momentum after collision

(m_A+m_B) x V = (2+3)V

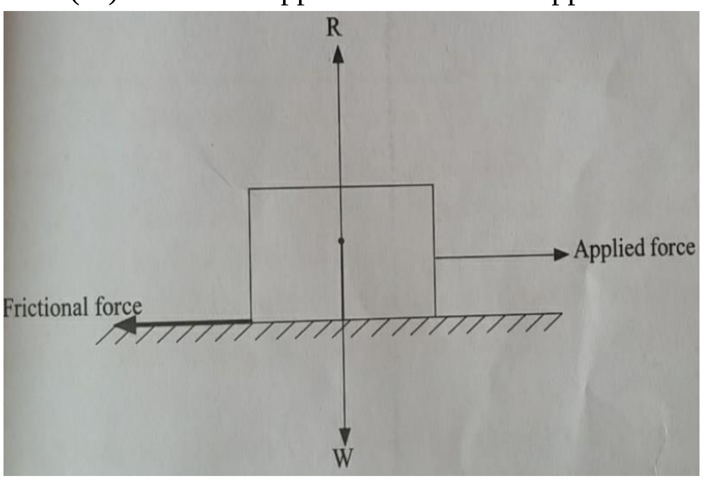
Momentum before collision =momentum after collision

12=5V   V=2.4m/s

FRICTION

Coefficient of solid friction

A solid block is being pulled over a horizontal surface by an applied force F andFrictional force(Fr) acts in the opposite direction to oppose the movement of the block



- When a block is just about to move the solid the solid friction is called static friction.Static friction is the force opposing motion between surfaces when the surfaces are just about to move.
- When the block is moving,the friction force is reduced and is called dynamic friction. Dynamic friction is the force opposing motion when there is relative motion
- F=μR where μ is constant called coefficient of static friction.The coefficient of static friction μ is the ratio of static frictional force to the normal reaction R
- The coefficient has no units since it's just the ratio
- For a body to move larger force than the limiting static frictional force (F_s) has to be applied,when a body is sliding along the bench with constant velocity,the frictional force is now called kinetic or dynamic friction (F_k).It is calculated as $F_k=\mu_k R$ where R is the normal force and μ is the coefficient of kinetic friction

Example:

A force of 25N limits the motion of a block of mass 50kg which is being dragged on the horizontal ground, calculate the coefficient of static friction force

$F_s=\mu_s R$ where μ is the coefficient of static friction

Weight of the block=Normal force=50kgx 10N/kg=500N

$25=\mu x500$

$\mu=0.05$

Viscosity

This is the measure of how easily a fluid flows.

If the friction force is comparatively low as in water, the viscosity of the liquid is low; viscosity is high if the fluid resistance is high. The resistance due to fluids is called viscous drag

Terminalvelocity

This is maximum downward velocity attained by any object falling through the fluid when forces are balanced.

At terminal velocity, downward force is equal to upward force

For example, when an object is falling through the liquid it experiences three forces weight of the body (W),Upthrust force(U) and viscous drag (F)

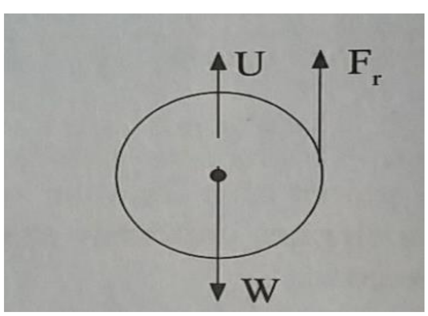
Resistive media

This is the media that offers some opposition to the movement of particles through it.Air and liquid offers resistanceto the movement of particles through it.

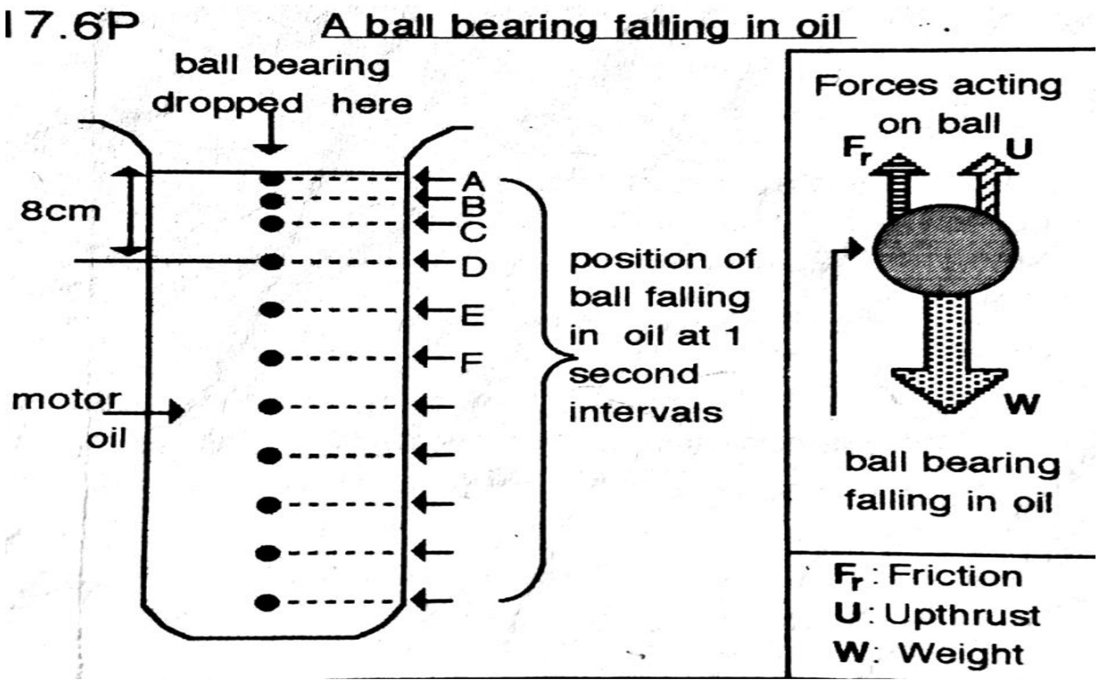
Falling in liquid

A particle falling in a liquid experiences three forces:

- Weight(w): this is downward force acting on the object falling in the fluid
  Weight(w) = mass(m) x gravity(g)
- Upthrust force(U):this is the upward force acting on an object falling in an object. This force does not change
- Friction force (Fr):this is a force acting downward



Consider a ball bearing falling in a tall jar containing liquid



For the first seconds the ball bearing will accelerate because then downward force is greater than the upward force

W >(U + Fr)

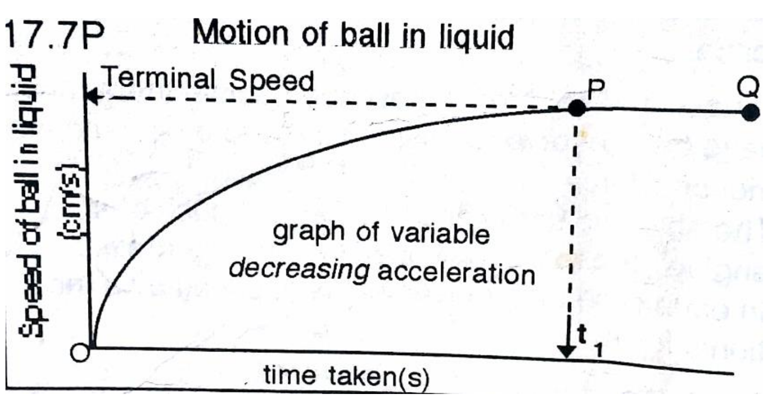
According to newton first law of motion unbalanced forces cause an object to accelerate.

As the velocity increases Friction force (Fr) also increases and it reaches a point where downward force is equal to upward force

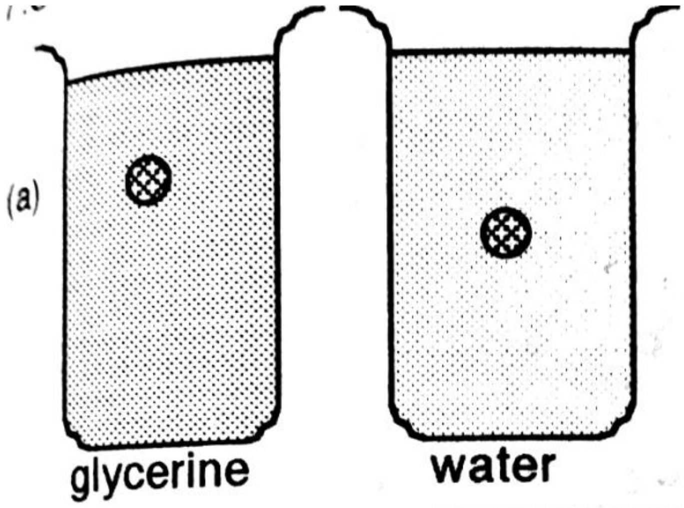
Downward force=upward force W=(U+Fr)

When the forces get balanced the ball bearing attains the terminal velocity according to newton 1st law of motion. The ball bearing moves at this velocity until it hits the bottom.

The graph to show the falling of object in liquid



Consider the ball bearing falling in water and glycerin of different viscosity



For the first few seconds both balls accelerate because downward force is greater than upward force

W > (U + Fr)

In glycerin

As the ball bearing accelerates the velocity increases and friction force also increases since it is more viscous and the forces get balanced faster.

W = (U + Fr)

The ball bearing in glycerin accelerates for shorter time before the forces get balanced and it takes shorter time to attain terminal velocity because it is more viscous so friction force is large,because of that it takes longer time to hit the bottom.

Water

The ball bearing in water accelerates for long time because it is less viscous (friction force) so it takes longer time to attain terminal velocity and it takes shorter time to hit the bottom.

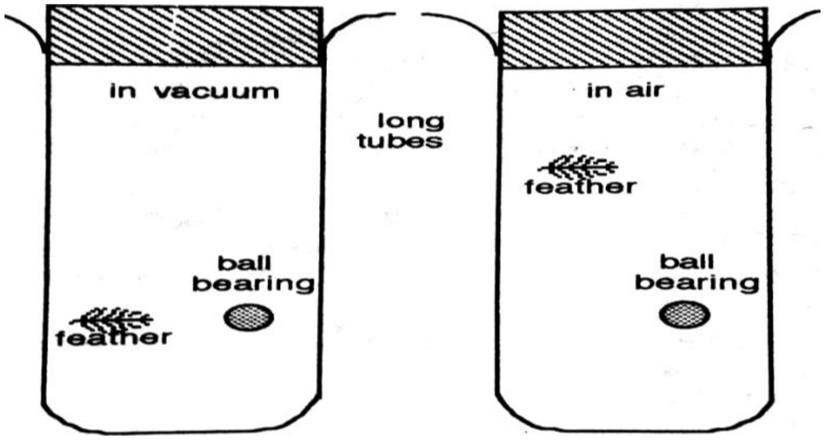
Falling in air

When a particle is falling in air it experiences two forces

- The weight(W) acting downward
- Friction force acing upwards

In air upthrust force is negligible so it’s less important

Consider the feather and ball bearing falling in air



Feather

For the first seconds the feather accelerates because downward force is greater than upward force w>fr

As the feather accelerate friction force increases the forces get balanced and the feather attains terminal velocity

Downward force=upward force

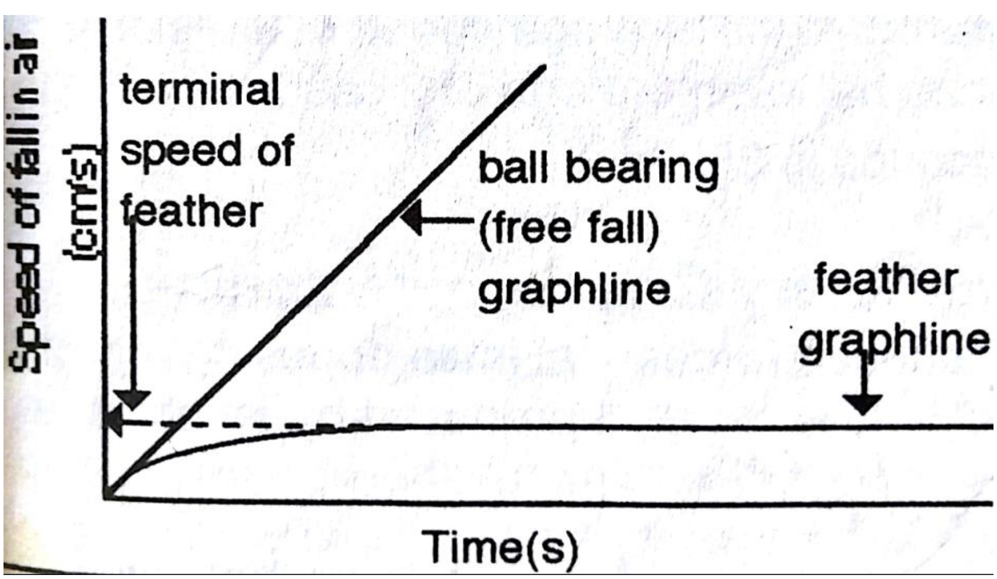
W=fr

The feather moves at terminal velocity until it reaches the ground. The feather will take short time to accelerate and short time to attain terminal velocity because it has large surface area so it experiences more friction force.

Ball

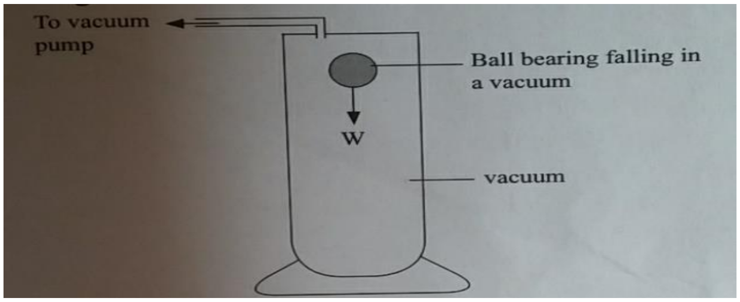
It takes longer time to accelerate because it experiences less friction force.It takes longer time to attain terminal velocity and it takes shorter time to hit the ground.

The graph of falling in air



Falling in vacuum

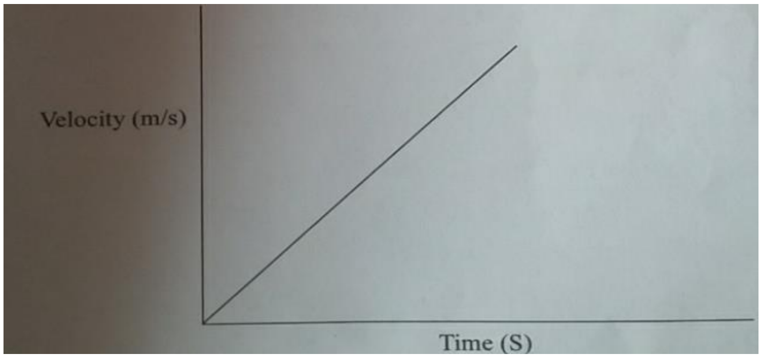
In a vacuum, there are no air molecules so no friction force, the force acting on the particles in a vacuum is only the downward force which is weight (w).
A particle in a vacuum fall under a "free fall".



Falling in the vacuum

Free fall is the falling of the particle in a vacuum with no friction force but only with acceleration due to gravity.
In a vacuum if a ball bearing and feather are dropped at the same time they will hit the bottom at the same time because they will fall with the same acceleration due to gravity since they experience no friction force because there is no air molecules.

Graph of falling in vacuum



The particle under 'free fall'

HOOKES LAW

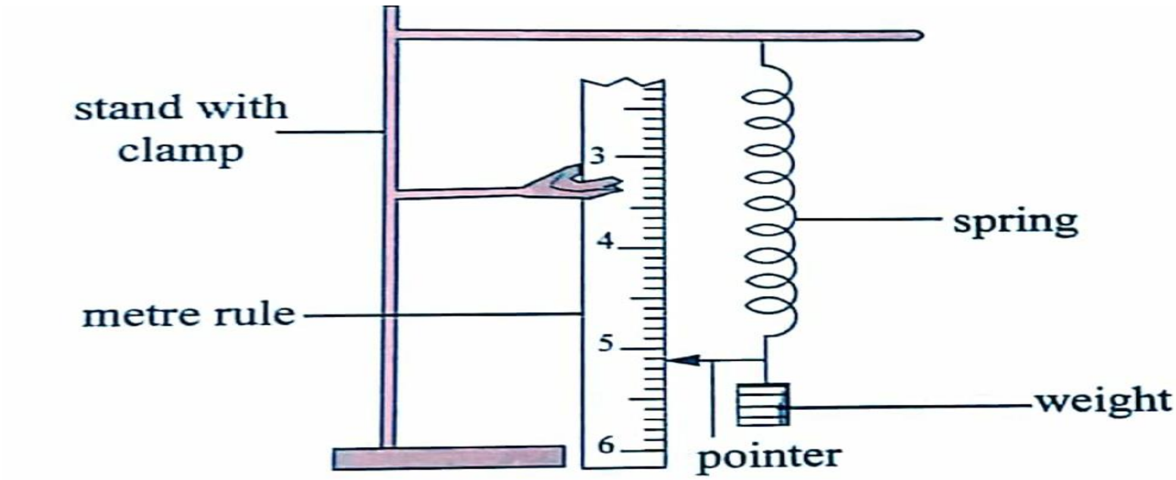
Robert Hooke did a lot of research work on stretching of materials. He performed different experiments involving

i. Stretching of spiral spring
ii. Stretching of wires
iii. Loading horizontal beams fixed at one end

From these experiments He discovered the relationship between the *applied force* and the **extension** of the material. This relationship is referred to as ***Hooke's law***

To investigate the relationship between the extensions produced in a spring and the force applied

Set up the apparatus as below. Note the initial position X of the pointer before the weight is loaded

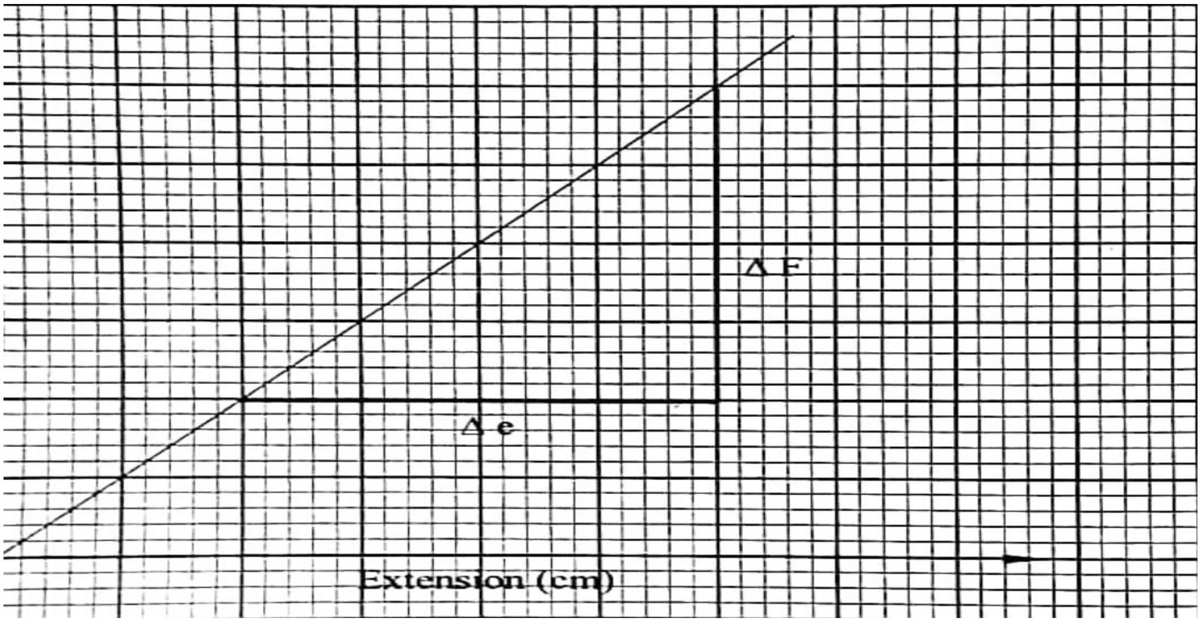


Load the spring with a 50g mass and record the new pointer reading. Unload the spring and observe what happens to the pointer

Repeat the above step with 100 g, 150g, 200g 300g 350g masses and record the readings

Mass (g)	Force(N)	Final reading (y cm)	Extension y-x
50			
100			
150			
200			
250			
300			
350			

Graph of applied force (N) and extension (cm)



The graph of a force against extension gives straight line graph passing through the origin.

Gradient = $\frac{\Delta f}{\Delta e}$

The spring constant, (k) = $\frac{\Delta f}{\Delta e}$

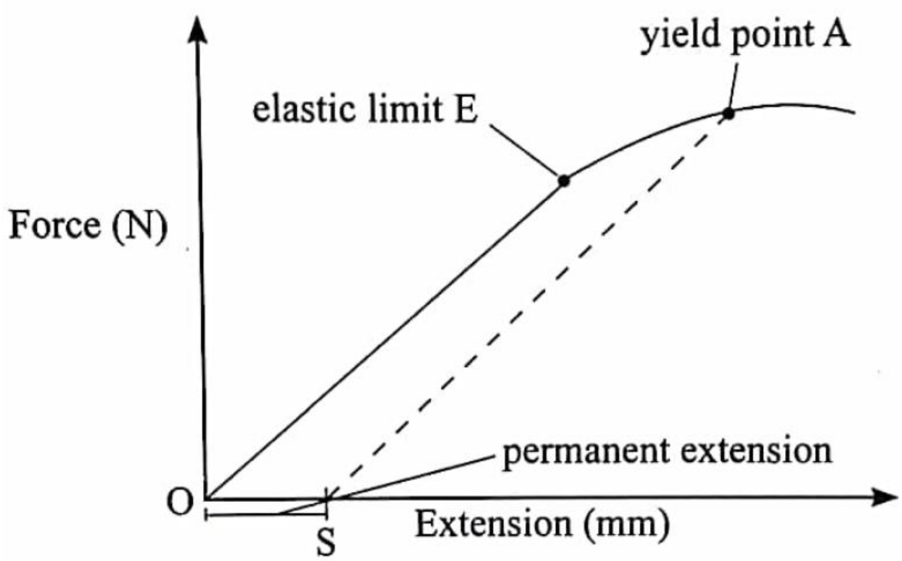
The extension produced is directly proportional to the force applied. Each time the pointer is unloaded the pointer returns to the original position.

The materials that are able to recover their original shape and size after unloading are called *elastic*

If more weights are added to the spring, a point is reached where the extension is no longer proportional to the applied force. This point is called the *elastic limit*

The pointer does not return to the original position when the load is removed once the elastic limit is exceeded .the spring is said to have been *permanently deformed* i.e. it acquires a permanent extension

The graph of a force against extension after the spring has been permanently deformed



The graph is said to undergo *elastic deformation* along OE. When a material is undergoing elastic deformation it is said to obey Hooke's law. The spring is said to undergo *plastic deformation* along EA. Hooke's law is no longer obeyed beyond point E. If the weights are further added, a point is reached beyond which the material loses its elasticity, this is called *yield point.*

Hooke's law states that provided the elastic limit is not exceeded, the extension of a spring is directly proportional to the load applied on spring.

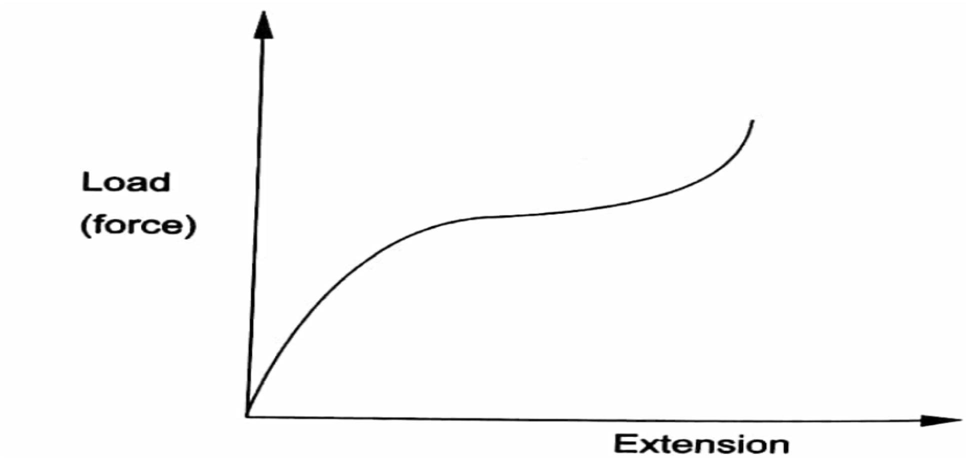
Mathematically, the applied force F is directly proportional to the extension, e, i.e

$F \alpha e$

F=ke where K is constant of proportionality called *the spring constant*

Hence $K=\frac{F}{e}$

- The SI unit of the spring constant K is newton-meter (Nm)
- If the spring is repeated with a spring of different number of turns the spring constant changes. Springs of different materials or dimensions have different spring constants. When experiment is repeated by compressing the elastic material, similar results are attained where the compression force is directly proportional to the compression.
- The spring constant is a measure of *the stiffness* of the spring; the stiffer the spring the larger the value of its *spring constant*
- If the *rubber band* is used in the experiment, by increasing the load (forces), a graph shown below is obtained. The graph is not a straight line showing that rubber does not obey hooks' law



Example

A sack containing drugs and narcotic substances intercepted by the police, was weighed on the spring balance and the spring balance stretched by 3 cm. the owner was arrested and finally jailed after the court case. If the sack had a mass 200g, calculate the spring constant of the spring balance

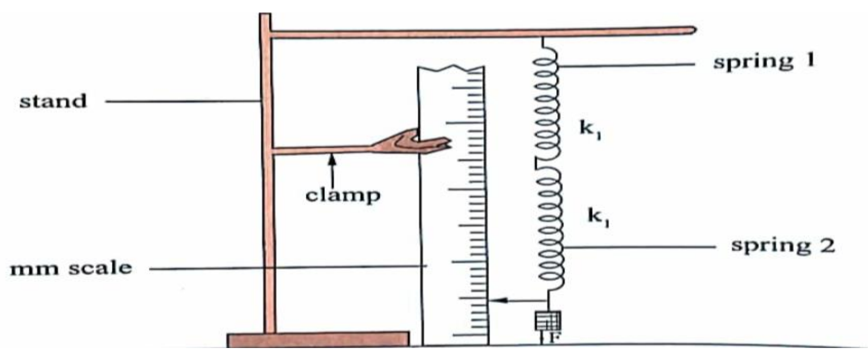
F=Ke

$K=\frac{F}{e}$ $\quad k = \frac{(mg)}{e}$

$K=\frac{\left(\frac{200}{1000}\right)X10}{\left(\frac{3}{100}\right)}=$ 66.67N/M

Combination of springs in series and parallel

Determine the Spring Constant of Two Springs Arranged In Series



DISCUSSION

While a single spring produces an extension e, two identical springs arranged in series produces an extension of 2e for the same force.

Applying Hooke's law

$F=k_1e$ - for the single spring

$F=k_s2e$ – for two springs in series

Where F is the applied force,K_1 is the spring constant for the single spring, and K_s is the spring constant for the two springs connected in series.

Since the same force is used

$k_s2e= k_1e/2e$

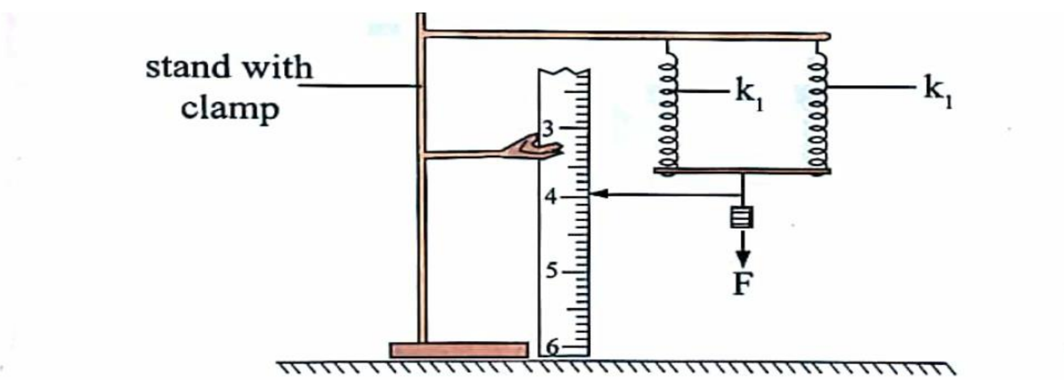
$k_s= \frac{1}{2}k_1$

This experiment shows that the *spring constant for two identical springs in series is equal to half of the spring constant of one spring.*

In general the spring constant, K_s, for n identical springs in series is given by the expression

$K_s = K_1/n$ where K_1 is the spring constant for one spring and n = 1, 2, 3…… n is the number of springs. This arrangement produces a less stiff spring system than one spring

To determine the spring constant for two springs in parallel



The experiment with the two springs connected in parallel as shown below

You should observe that while a single spring produces an extension, two identical springs produce an extension $\frac{1}{2}$e, for the same force.

Applying hooks law,

$F=k_1e$ ..... - For the single spring

$F=k_p x\ (\frac{1}{2}e)$ ……for parallel springs

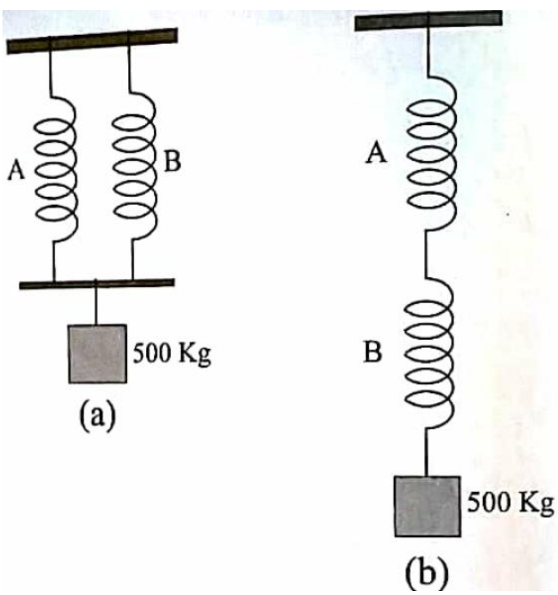
$k_1e = \frac{1}{2}K_pe$

$K_p=2k_1$

In general, $Kp=nK_1$ where n= (1,2,3…n) is the number of springs and K_p is the spring constant for n springs in parallel. This arrangement produces a *stronger or stiffer* spring balance

Example

Fig below shows two system of identical springs. If each spring has a spring constant of 50N/cm. Calculate the total extension produced by the load attached in each system.(assume the spring is weightless).



In system (a)

Toatal springs constant,

K_p = nK where n is the number of springs

$K_p=2 \times 50 = 100N/cm$

From hooks law

F=Ke

e=$\frac{F}{K}$, but F=W=500 x 10 = 5000N

$= \frac{5000N}{100N/cm}$ = 50 cm

In system (b)

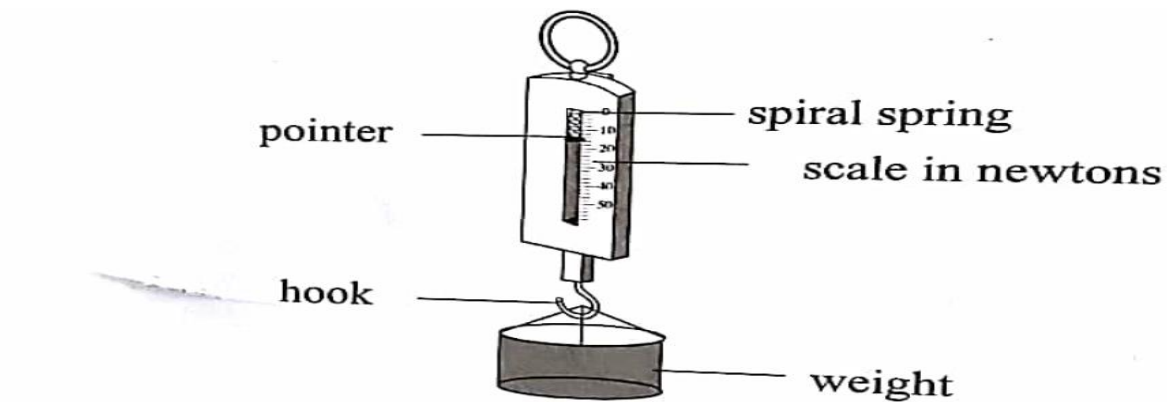
Resultant spring constant

$K_s=\frac{K}{n}$

$K_s = \frac{50}{2}$ = 25N/cm

Extension, e, = $\frac{5000N}{25N/cm}$ = 200cm

APPLICATION OF HOOKES LAW



i. Used in making of spring balances
ii. which are used to measure weights of various substances.
iii. Elasticity in materials e.g. springs is applied in making spring beds, diving boards
iv. Stretching and compressing of spiral springs helps in designing spring shock absorbers or shock breakers used in car suspensions
v. Elastic materials are used in making rubber bands, rubber shoes
vi. Elastic materials are used to make catapult used for hunting birds
vii. Elastic materials are used to make equipment's used in trampoline games used children.

Uniformcircular motion

If the radius sweeps equal angles in each second, the angular velocity of the body is uniform and the body is said to execute uniform circular motion.

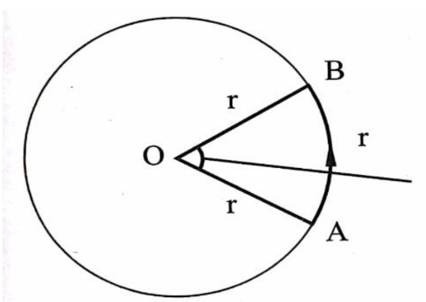
Angular displacement

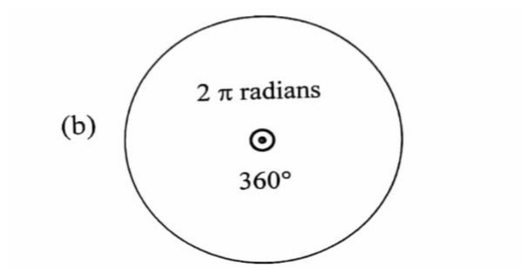
Consider a particle moving along a circular path. As the particle moves along the arc of the circle from A to B,the line OA (radius r) joining the particle to the centre of the circle sweeps through an angle,the angle swept is called *angular displacement*,it is measured in radian

The length of the arc AB is equal to the radius r of the circle,theangle subtended by this arc at the centre of the circle is equal to *one radian*

One radian is the angle subtended at the centre of a circle by an arc of length equal to the radius of the circle.

If the length of the arc is 2 times the radius, then the angular displacement is 2 radius. For the whole circle, the length of the arc is its circumference, i.e. 2πr. The angular displacement is therefore 2π radians.



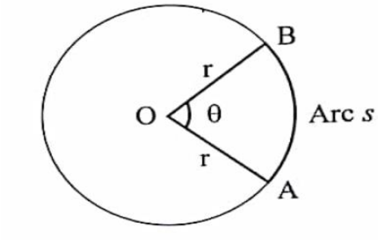


The angle at the centre of a circle is 2π radians. It is also equal to360^0. Therefore, 2π radians= 360. From this, we see that,

1 radian = $\frac{360^0}{2\pi} = 57.3^0$

If the angle at the centre of a circle is 1 radian, then the length of the arc is r units. If the angle at the angle at the centre is Θ radians, the length *s* of the arc AB of the circle is given by

S=$\frac{r}{1rad}$xΘrad = rΘ



Arc length

Angular velocity

Is the rate of change of angular displacement?

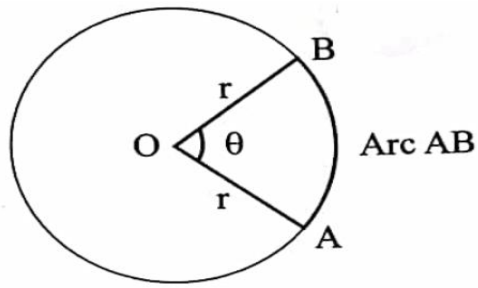


Fig. 5.8 Angular velocity

Angular velocity w = $\frac{angular\ displacement}{time} = \frac{\Theta}{t}$

The SI units is radians per second(rad/s)

Relationship between angular velocity and frequency

For one complete circular motion, $\Theta=360^0$ =2πradians and the time taken t=T,(referred to as periodic time)

Hence w=$\frac{\Theta}{t} = \frac{2\pi}{T}$ since the frequency of revolutionary f=$\frac{1}{T}$,we get 2πf

Therefore angular velocity=2π x frequency (f)

Relationship between angular velocity and linear velocity

Linear speed v = radius (r) x angular velocity(w)

Example:

A ball tied to a string is rotated at uniform speed in a circle of radius 10cm, it takes 1.5s to describe an arc of length 6cm.calculate its

a) Tangential velocity

   Linear velocity v=$\frac{x}{t} = \frac{6cm}{1.5s}$ = 4cm/s

b) Angular velocity w =$\frac{v}{r} = \frac{4}{10}$ = 0.4rad/s

c) Periodic time

   w=$\frac{2\pi}{T}$, hence T=$\frac{2\pi}{0.4}$ = 15.7s

Circular Motion and Centripetal Force

Relationship between the force (f) and the speed of revolution (v) 0f a body undergoing in the circular motion

This states the force F required to keep the body in a circular path of constant radius is directly proportional to the square of the speed of revolution

$F \alpha v^2$

Relationship between the force (f) and the radius (r) 0f a body undergoing in the circular motion

The force F needed is inversely proportional to the radius r of the circular path,when the speed of revolution of the body is constant

$F\alpha \frac{1}{r}$

Force is directly proportional to the mass undergoing circular path

$f \alpha m$

From the observation, the force F required to keep the body in circular path depends upon three factors

i) The speed of revolution of the body(v)
ii) The radius of the circular path(r)
iii) The mass of the body undergoing circular motion (m)

Centripetal force

This is the force that constrains an object in motions to move in a circular motion

Centripetal is a Greek word meaning seeking centre so this force is called the *centre seeking force*

The centripetal force(F)=$\frac{mv^2}{r}$

Centripetal force in terms of angular velocity

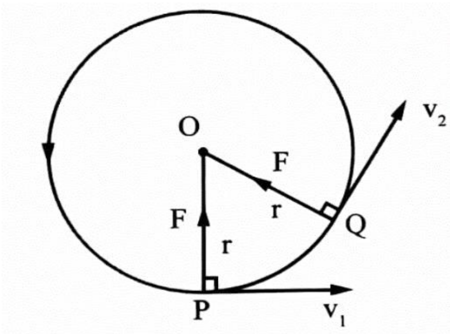
The centripetal force (F)=$\frac{mv^2}{r}$ but v=rw where w is angular velocity,substituting for centripetal force (F)=$\frac{m(rw)^2}{r}$ =mrw^2

F=mrw^2

Centripetal acceleration

When a body executes uniform circular motion,though the speed is uniform the direction of motion is changing. The direction of the motion of the body at point P is along the tangent drawn at P,when the body is at Q it is along the tangent drawn at Q.

The centripetal accleration



For a body in uniform circular motion the linear velocity changes continuously since only direction changes continuously.Change in velocity with time is the acceleration and so during circular motion,the body is accelerating due to continuous change in the direction though the speed remains constant.

Acceleration=$\frac{change\ in\ velocity}{time}$

a =$\frac{v}{t}$

From Newton second law of motion

F=ma but centripetal force F =$\frac{m}{r}v^2$,therefore the centripetal acceleration a, of a body towards the centre is given by

a=v^2/r

The centripetal acceleration acts towards the centre of the circle and is at 90^0 to the tangent at each point

Example

A 5kg mass moves at uniform speed of 18m/s in a circular path of radius 0.5M.Calculate the centripetal force acing on the mass

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

F=$(5x18^2)/0.5$

=3240N

Applications of uniform circular motion

i) A car negotiating a circular path on a level horizontal road

When a car is going around a circular path on a horizontal road, the centripetal force required for circular motion provided by the frictional force F,between the tires and the road

ii) Banked tracks

Formotorist, does not fully depend on the frictional force between the tires and the road,circular paths are given in small banking angle i.e the outer edge of the road is raised alittle above the inner side so that the track is sloping towards the centre of the curve

iii) Leaning inwards of the cyclist

A cyclist going around a curve leans inwards to provide the necessary centripetal force so as to be able to go along the curved track, the part of contact provide the required centripetal force acting towards the centre of track

iv) An aircraft taking a circular turn

When an aircraft takes a turn in a horizontal plane, it must make a correct banking angle in mid air to successfully negotiate a curved path

v) Conical pendulum

Consider the simple pendulum held in the hand, if the hand is swung in a circular pattern, the bob of the pendulum starts revolving in a horizontal circle of radius r. If the speed of the bob is increased gradually the radius of the circle in which the bob revolves also increases,at any stage the part of tension T developed in string provides the required centripetal force for the bob to execute circular motion.

If the speed of the bob increases at a certain maximum value the string may break and the tension in the string is not able to provide the required centripetal force,at this stage the string become horizontal and maximum tension in the string, $T=m\frac{v^2}{r}$

vi) Centrifuge

This is a device that separates liquids of different densities or solids suspended in liquids. The mixture is then poured into a tube in the centrifuge which is then rotated at a high speed in horizontal circle. The tube initially in the vertical position and takes up horizontal position when the centrifuge starts working the matter of low density moves inwards towards the centre of rotation,on stopping the rotation the tube returns to the vertical position with dense matter at the top

iv) Drying the machine

When wet clothes are rotated in a cylindrical drum containing many perforations the clothes move in a circular motion along the drum the adhesive force of the water in the clothes gives up and water breaks off from the clothes and flies off through perforations.

MOMENT OF A FORCE

It is the productof the force(f) and the perpendicular distance (d) from the point to the line of the action of the force. The moment can be clockwise or anti clockwise

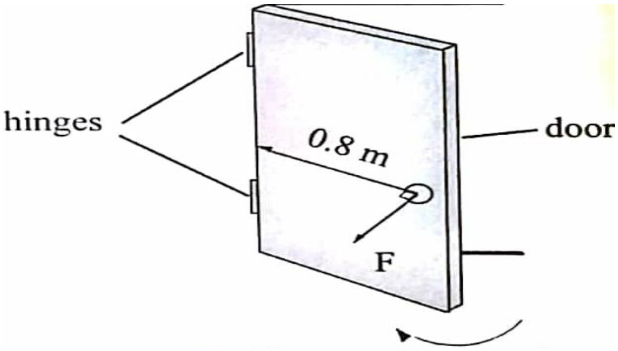
Moment of the force = Force(F) x perpendicular distance(d) from the point to the line of action of the force.

Moment of a force = F x d

SI unit of moment is newton meter (Nm).It is a vector quantity since it has both Magnitude and direction

Example

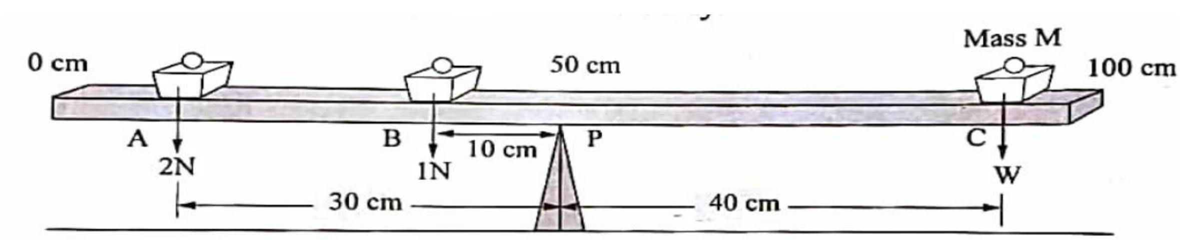
A student applies a force of 10 N to the handle of a door, which is 0.8m from the hinges of the door.Calculate the moment of the force'



Moment of the force= Force x perpendicular distance from the point to the force
(10 x 0.8) = 8Nm

THE PRINCIPLE OF MOMENTS

This states that when a body is in equilibrium under the action of forces, the sum of clockwise moments about any point is equal to the sum of anticlockwise moments about the same point
The principle of moment gives the relationship between two moments that are at the same turning point.
The sum of the clockwise moments=the sum of the clockwise moments about point
Example:
A uniform meter rule is pivoted at its centre,P and 3 Masses are placed at A, B and C as shown in the fig below. Find the value for the weight W of the mass M placed at C so that meter ruler is balanced horizontally

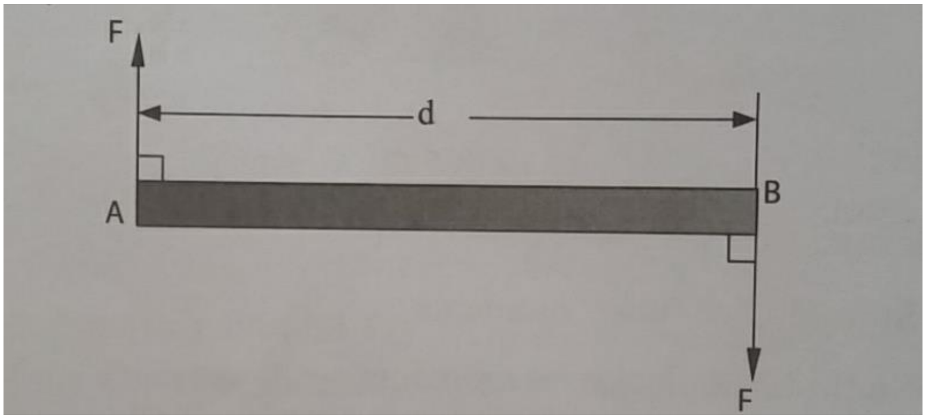


Taking moments about when the meter rule is in equilibrium
Sum of the clockwise moments = sum of the anticlockwise moments
W x 0.4=2x0.3 +1 x 0.1
W=$\frac{0.7}{0.4}$ = 1.75N

COUPLE

Parallel forces which act in the same direction are called parallel *like parallel forces.* Parallel forces which act in the opposite directions are called *unlike parallel forces*

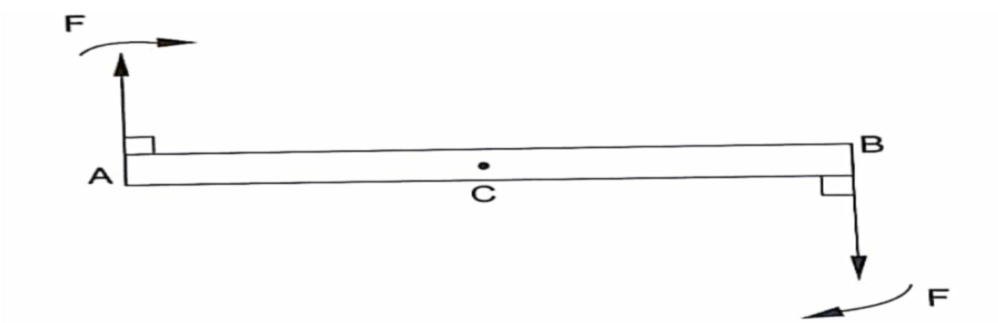
Two equal and unlike parallel forces acting on a body at different points form a *couple.*



A couple produces a turning effect on a body

MOMENT OF A COUPLE

Fig below shows a couple acting on bar AB



Since the pivot is at C, the moment of the force F acting at point A=F x AC, in the clockwise direction. Similarly, the moment of the force acting at point B=F x BC, also in the clockwise direction

Therefore the moment of the couple= (F x AC) + (F x BC)

FAC + BC),but AB=BC + BC

F x AB=F x Arm of the couple

The moment of the couple is called the *torque*

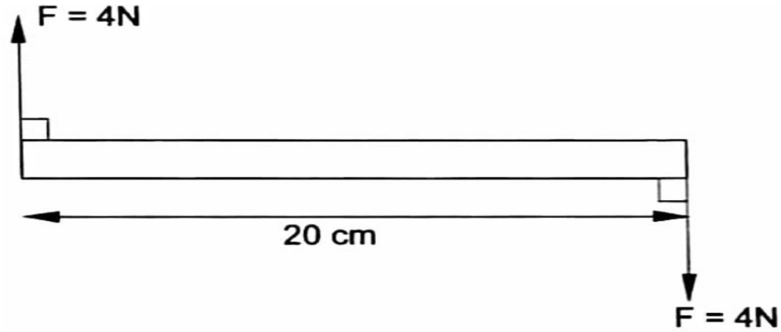
Torque is the total rotating effect of a couple and is given by the product of the forces and perpendicular distance between the forces

Torque = F x perpendicular distance AB

SI unit is the Newtonmeter (Nm)

Example

In fig below each force is 4N and the arm of the couple is 20 cm, calculate the moment of the couple



The moment of the couple = F x perpendicular distance

4N x 0.20m

= 0.8Nm

Real life examples of couple are observed when

- Forces are applied by hands to turn a steering wheel of a car or bicycle handles
- A water tapis closed or opened
- A cork is removed from the mouth of the bottle using cork-screw

Application of the moment of a force

i. Opening or closing the door

ii. Opening a bottle using a bottle opener

iii. A pair of scissors or garden shears in use

iv. Children playing on a see saw

v. Wheelbarrow being used to lift some load

MAGNETISM

WHAT IS THE MAGNET

A magnet is any ferrous material that can attract other metallic objects.

TYPES OF MAGNETS

1 Permanent for example, Bar magnets

2 Temporary for example, Electromagnets

Domain theory of magnetization

This states that inside a magnet there are small regions in which the magnetic direction of all dipoles are aligned in the same directions

A dipole is the smallest particle of magnetic material. It is equal to an atom in electric conductor

Magnetization is the process of making a magnet from a magnetic material

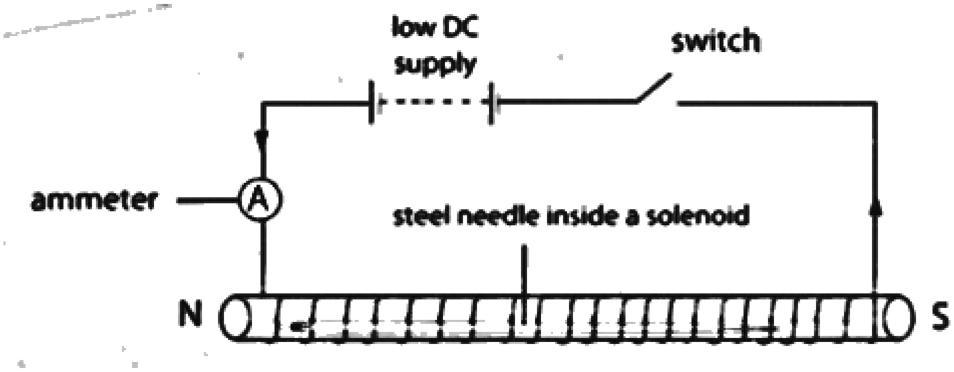
When material is fully magnetized, the domain walls move and molecular magnets align

METHODS OF MAKING A MAGNET

1. Electrical Method:

Place iron bar in solenoid, which has been connected to high direct current (DC) for some time.

The iron in solenoid becomes magnet only when the current is passing

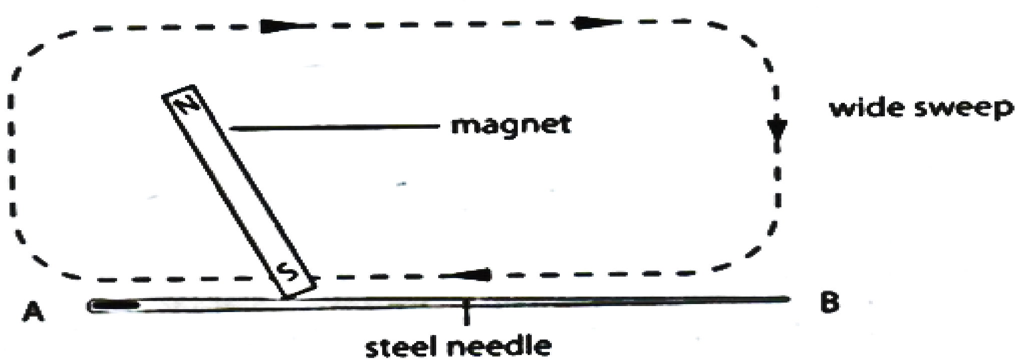


The current flowing in a coil has magnetic effect. It induces magnetism to the iron needle. Such a magnet is known as an electromagnet.
The polarity of the magnet produced depends on the direction of the electric current.

2. Stroking Method:

(i) Single Stroking

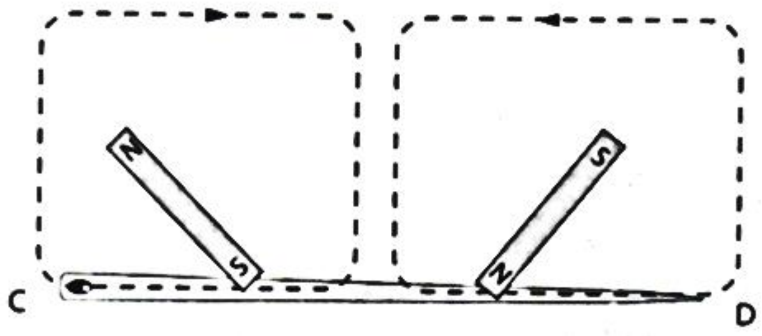
A piece of steel e.g. Steel needle placed near a magnet becomes magnetized. However the magnetism acquired usually disappears when the magnet is removed. This magnetism may be enhanced by stroking.



The endpoint B becomes S-pole and A becomes N-pole
The magnetic materials last touched by the magnet acquire a polarity opposite to the one touching it.

(ii) Double-Stroking or Divided Stroking

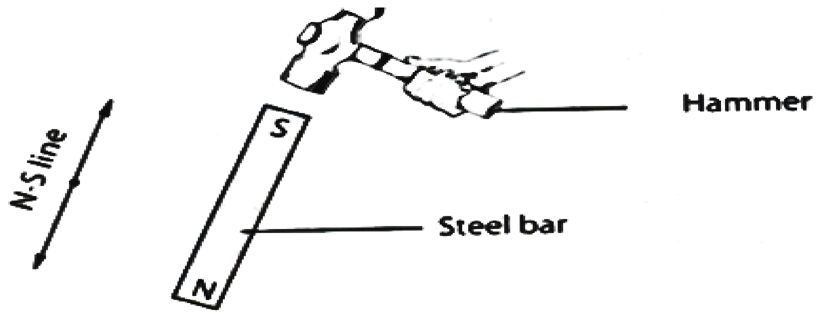
The stroking should begin at the two middle of the steel each time making sure that the two bar magnets are lifted far away from steel once you reach the ends.



It is observed that end C becomes a N-pole while end D becomes S-pole

3. Hammering;

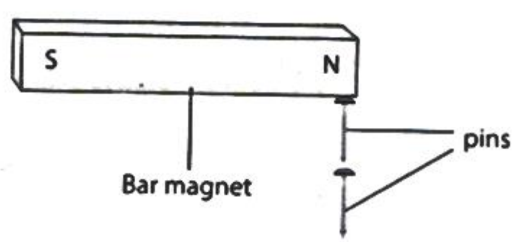
Hammer one end of a steel bar fixed in North-South direction several times

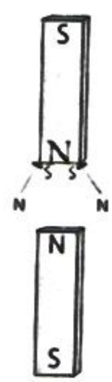


The steel bar becomes a weak magnet. The lower end becomes a weak north pole

In this method the influence of earth's magnetic field is used to magnetic the steel bar being hammered.

4. Induction:





The first pin becomes magnetized by the magnet through a process called induction and then gets attracted to the magnet. The induced pole nearest to the magnet is of opposite polarity to that of the inducing magnet. The second pin gets magnetized by the first pin in the same process. This shows that it is the presence of the bar magnet that sustains the magnetism between the first and second pin.

DEMAGNETISATION

Demagnetization is the process through which magnets lose their magnetism.

The demagnetization process can be influenced externally by giving the molecular magnets enough energy to overcome the forces holding them direction. The energy can be provided by heating, hammering, or dropping the magnet on hard surface

WAYS OR METHOD OF DEMAGNETISATION

A. Hammering

Hammering a magnetized material placed in the East-West direction or dropping it violently on a hard floor several times makes disorganizes the alignment of dipoles hence loses most of its magnetism.

B. Heating:

Heating a magnetized material until red hot and cooling it, suddenly when resting in East-West direction makes it lose its magnetism by disorganizing the alignment of dipoles.

C. Electrical Method

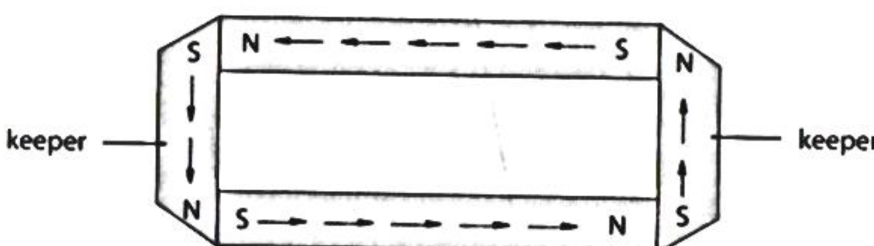
Placing a magnet in a coil placed in East-West direction and passing an alternating current (A.C) demagnetizes the needle.

themselves in on direction

CARING FOR MAGNETS

(a) Storing Magnets

A bar magnet loses its magnetism with time due to self-demagnetization. To minimize this, soft iron bars called keepers are placed across their ends. So the dipoles find themselves in a closed chain or loops round the magnet and the keepers with no free poles available to upset the domains. The soft iron keepers are used since they are easily magnetized by induction.



(b) Avoid demagnetization

A permanent magnet should not be;

- Heated

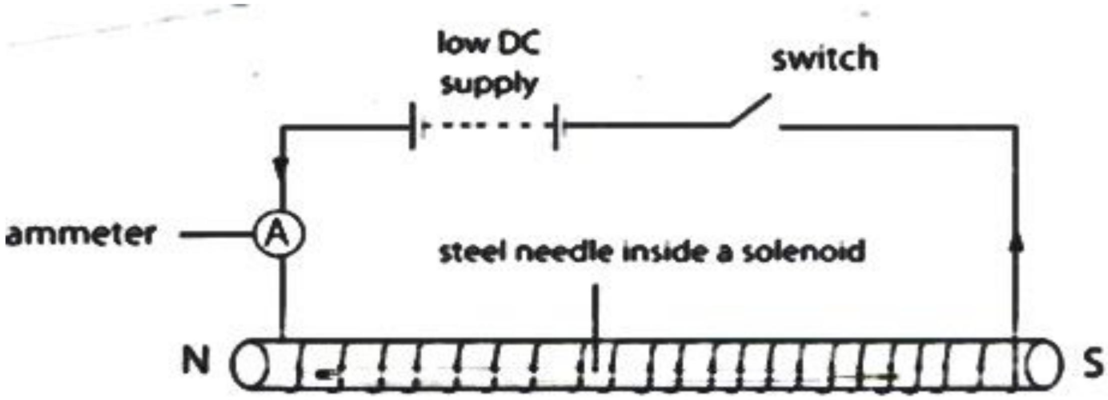
- Dropped constantly
- Exposed to an alternating magnetic field.

ELECTROMAGNETISM

Electromagnets are temporary magnets made by placing the ferrous material e.g. soft iron in solenoid (coil) of a direct current, when switch is closed it becomes a magnet and demagnetizes when switch is off.

Electromagnets are the magnets only when current flows

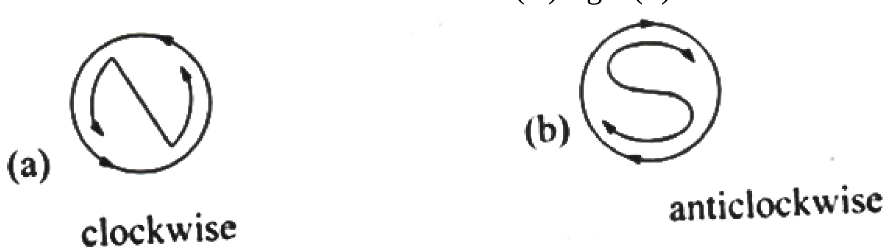
Figure below shows the electromagnet.



After the switch is closed the iron nail will become a magnet because current have magnetic effect and it induces in the nail which now becomes a magnet.

THE POLARITY OF ACOIL (SOLENOID) CARRYING AN ELECTRIC CURRENT

View the coil from both sides in turn (fig a).If the direction of the current through the end is viewed is clockwise, then that end is found to be south(S) pole Fig a (i).If the direction is anticlockwise the end becomes North Pole (N) fig a (ii)



MAKING ELECTROMAGNET STRONGER

Strength of electromagnet increases with

i. Increasing current when number of windings per unit length remains constant
ii. Increasing the number of turns per unit length when current is constant
iii. Using soft iron core this increases the induced magnetic forces

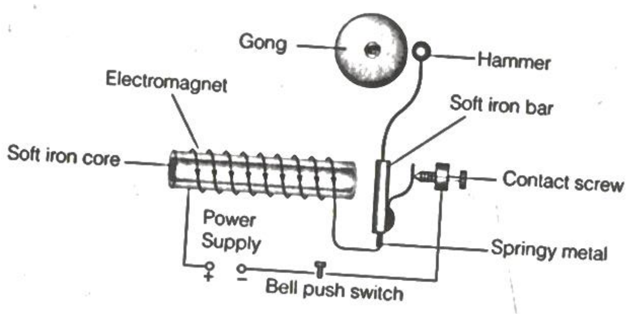
ADVANTAGES OF ELECTROMAGNET (TEMPOLARY MAGNET) OVER PERMANET MAGNET

i. The magnetism of an electromagnet can be switched on and off as required
ii. The magnetism can be increased by increasing current
iii. It can easily be controlled than permanent magnet because their polarity can be changed by changing the direction of the current

USES OF ELECTROMAGNETS

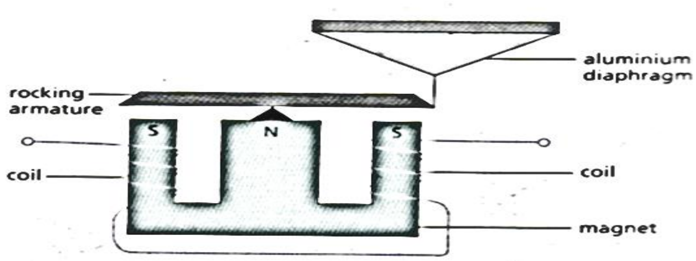
1. **Used in Electric Bell**

   How Electric Bell works



   When the bell switch is pushed, the circuit is completed the current flows. The soft iron core attracts the soft iron bar. As it is attracted the hammer strikes the gong and at the same time the contact between the contact screw and soft iron bar is broken and this break the circuit. The soft iron core loses its magnetism and the springy metal returns the soft iron bar to its original position hence re-establishing the contact with the contact screw and the cycle begins again.

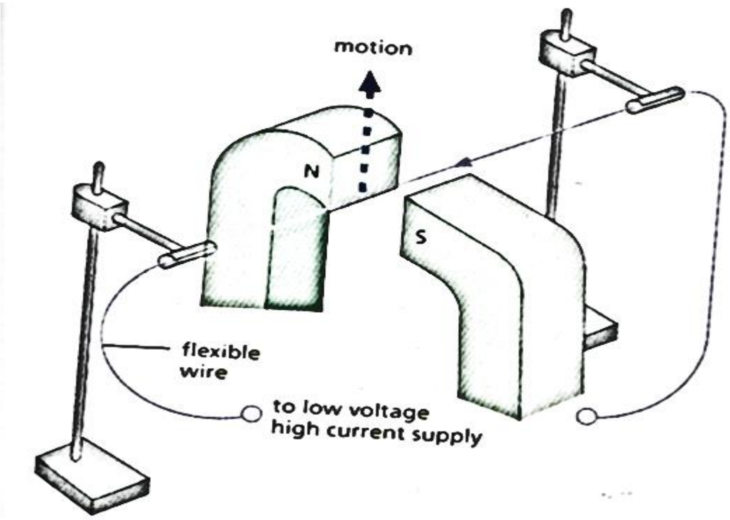
2. **Telephone receiver**



   The telephone receiver converts electrical energy into sound energy. The fluctuating current passing through the coil of the electromagnet makes the iron diaphragm to vibrate with different amplitudes depending on the current. The vibrating diaphragm converts electrical pulses into sound waves

3. Used in generators(dynamos)
4. Used to separate ferrous materials from non-ferrous materials
5. Used in the transformer to induce current

FORCE ON CURRENT CARRYING CONDUCTOR IN THE MAGNETIC FIELD



A conductor carrying current placed in magnetic field experiences a force. This is called **Motor effect**

The magnitude of the force acting on **a conductor carrying current** in magnetic field is affected by

a) Amount of the current: the more the current the greater the force
b) The strength of the magnetic field: stronger field gives stronger force
c) Angle between the magnetic field and the conductor :Force is maximum at an angle 90^0
d) Length of the conductor in the magnetic field: longer the length of the conductor the greater the force

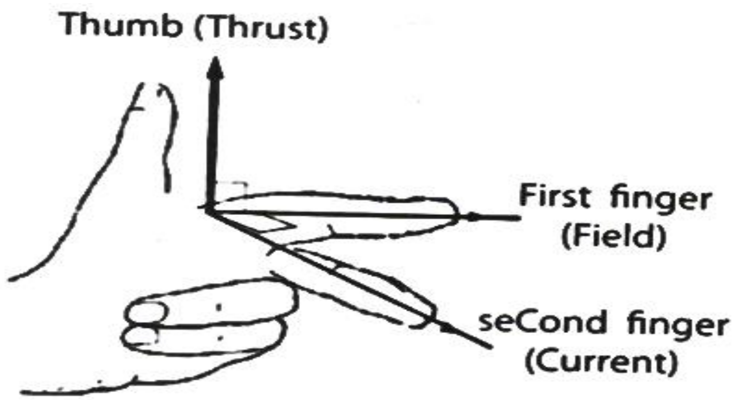
For **coils**,

Use more number of turns in the coil this gives greater force

DETERMINE THE DIRECTION OF FORCE ON CURRENR CARRYING CONDUCTOR

1. Flemings left hand rule:

When the thumb and the first two fingers of the left hand are held at right angles to each other, the First finger points in the direction of **F**ield, the se**C**ond finger points in the direction of the **C**urrent and Thumb points in the direction of Thrust or **F**orce on the conductor.



This is applied in electric motor

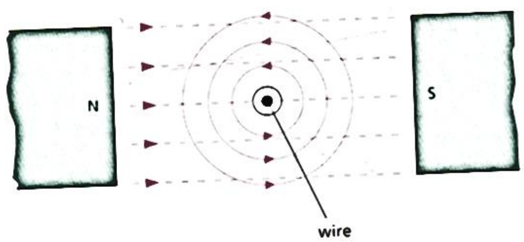
In applying the rule, remember how magnetic field and current are defined

i. The field direction is from **N**-pole to the **S**-pole
ii. The direction is from the positive(+) terminal of the battery round to the negative(-).This is **convectional current** direction

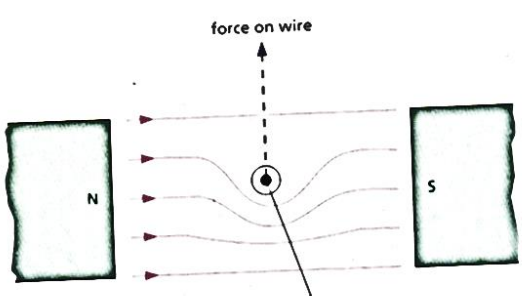
Fleming's left hand rule only applies if the current and field directions are at right angles

If current and field are in the same direction, there is no force

DIRECTION OF THE FORCE



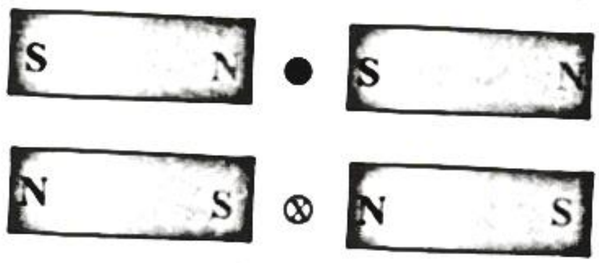
a



At **A** the magnetic field lines due to two magnets will cancel magnetic field lines due to the flow of current

O → conductor perpendicular to the plane of the paper, current is getting out of paper

ϴ → current going into the page



MAGNETIC FIELD DUE TO ELECTRIC CURRENT

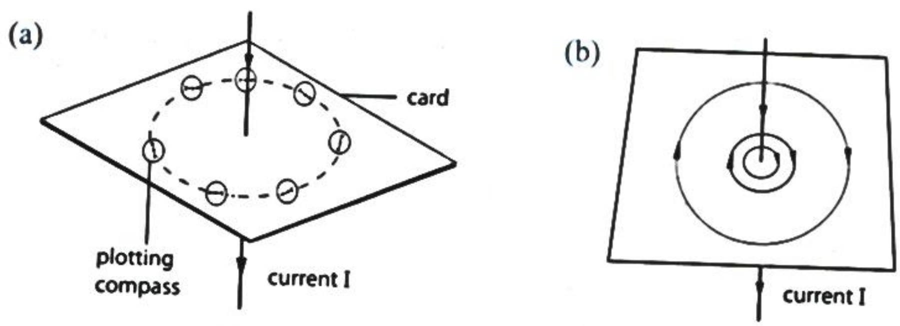
When iron fillings are sprinkle on the card and allow the wire carrying current pass through the centre of the card. Iron fillings settle in particular pattern depending on the magnetic field present

From this we can conclude that wire carrying current produces magnetic field

Features of the field produced

i. The magnetic field lines are circular
ii. The field is strongest close to the wire
iii. Increasing the current increases the strength of the field

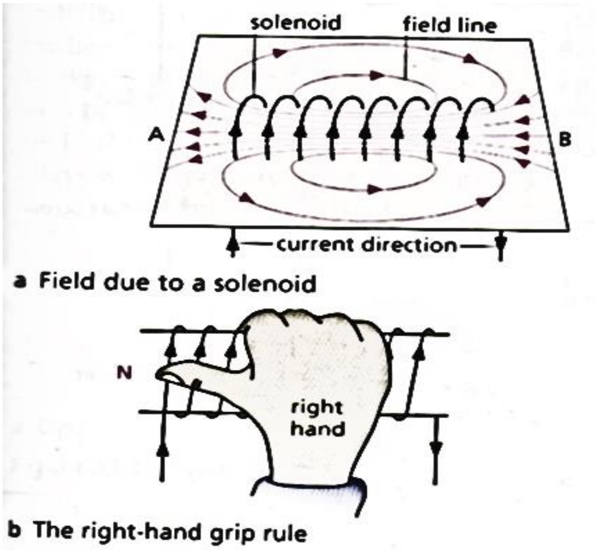
DIRECTION OF A MAGNETIC FIELD



When current direction is reversed the compass needle points in the opposite direction. This shows that the direction of the field reverses when current direction is reversed

RULES FOR DETERMINING THE DIRECTION OF MAGNETIC FIELD

a) Right hand grip rule(Thumb rule)



a Field due to a solenoid

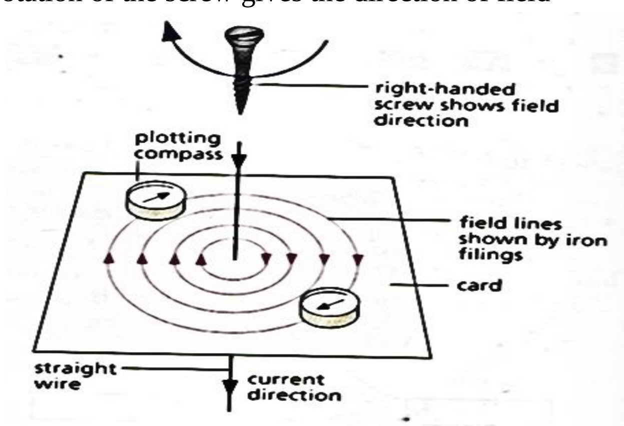
b The right-hand grip rule

This states that if the fingers of the right hand grip the solenoid in the direction of the current (conventional current), the thumb will point in the North Pole.

b) Right handed corkscrew rule

When holding and turning screw in your right hand with screw pointing in the direction of the current. Now turn the screw clockwise so that it advances in the direction of the current

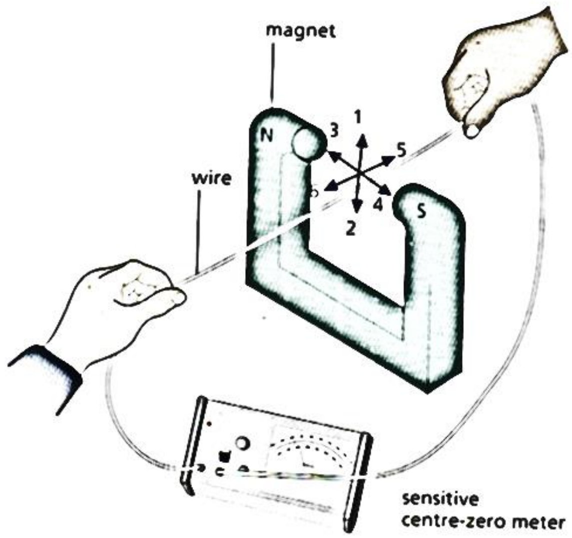
The clockwise rotation of the screw gives the direction of field



The corkscrew rule

ELECTROMAGNETIC INDUCTION

Let’s consider the diagram below



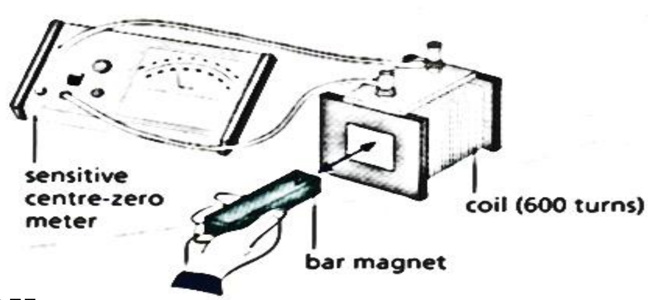
If the conductor is moved up and down between the two magnets the magnetic field lines of the two magnets cut the conductor and small current is induced. This is shown by deflection of the sensitive galvanometer.

The process of inducing current in the wire by moving it across magnetic field is called **Electromagnetic induction**

Electromagnetic induction can take place in **two** ways

i. Moving a conductor between the two magnets
ii. Moving the bar magnet into the solenoid (coil)

Lets consider moving a bar magnet into the solenoid



OBSERVATION

a) When magnet is introduced into the coil, the pointer of the galvanometer shows deflection in one side but retains to the zero position when magnet is brought to rest
b) When the magnet withdrawn from the coil, the pointer deflects but in the opposite direction but when the magnet stops to move the pointer once again returns to zero position
c) Similar effects are observed when the coil moves instead of the magnet
d) No deflection is observed when the coil and magnet are moved at the same time in the same direction

CONCLUSION:

Current is induced whenever there is relative motion between the coil and the magnet hence current flows in the circuit

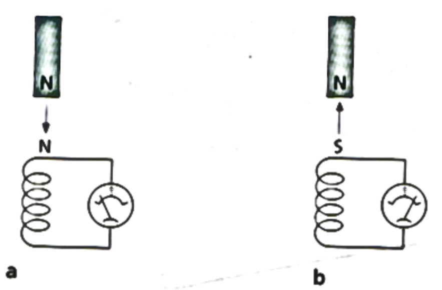
HOW TO INCREASE THE STRENGTH OF INDUCED CURRENT IN THE COIL

a) Moving the wire at higher speed, this increases the rate at which the magnetic flux cut the conductor inducing current
b) Using a stronger magnet, this increases the strength of the magnetic flux
c) Increasing the number of turns of the wire or increasing the length of the conductor between the magnets.

LAWS OF ELECTROMAGNETIC INDUCTION

1. Faraday's Law of Electromagnetic induction
   The electromotive force (e.m.f) induced in the conductor is directly proportional to the rate of change of the magnetic flux linked to the conductor
2. Lenz's Law (Direction Law)

The direction of the induced current is such away that it opposes the change producing it.

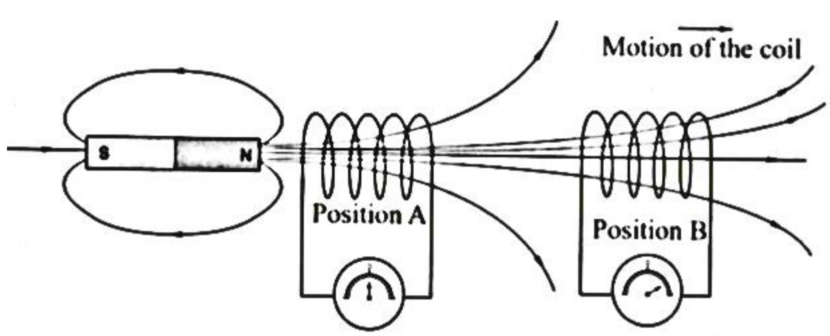


When North Pole is moved towards the coil, the current flows in such away as to oppose the introduction of the North Pole. A north pole (N) is therefore induced at the top end of the coil to repel the incoming north pole of the magnet

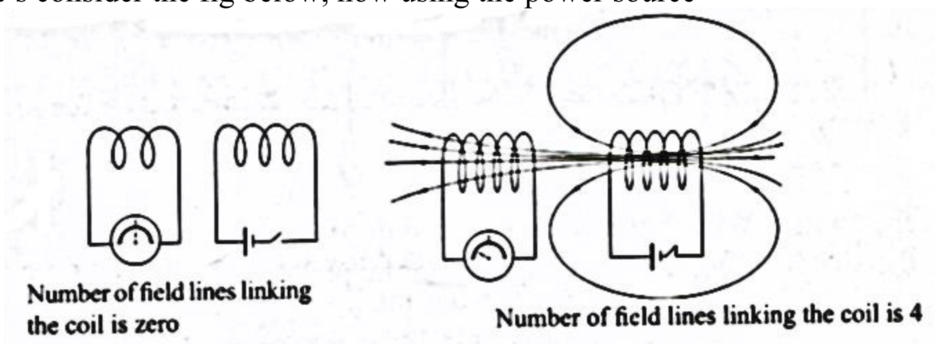
Application of electromagnetic induction

i. Induction coil
ii. Moving coil microphone
iii. A simple d.c generator
iv. A simple a.c generator

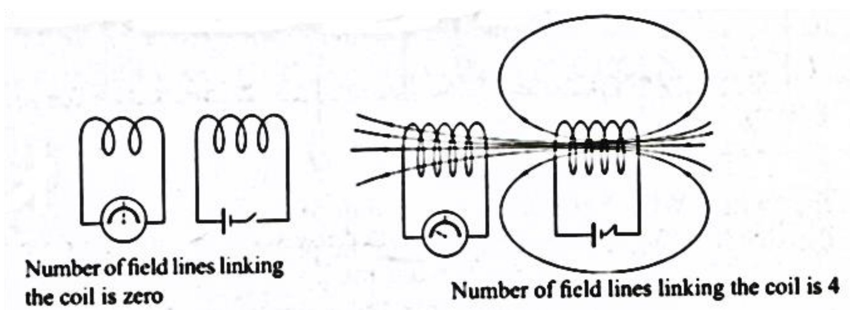
MUTUAL INDUCTION



When Bar magnet is moved in a coil **A** it produces magnetic field lines which now cuts the coil **B** inducing current which is seen by deflection of sensitive galvanometer.
Let's consider the fig below, now using the power source



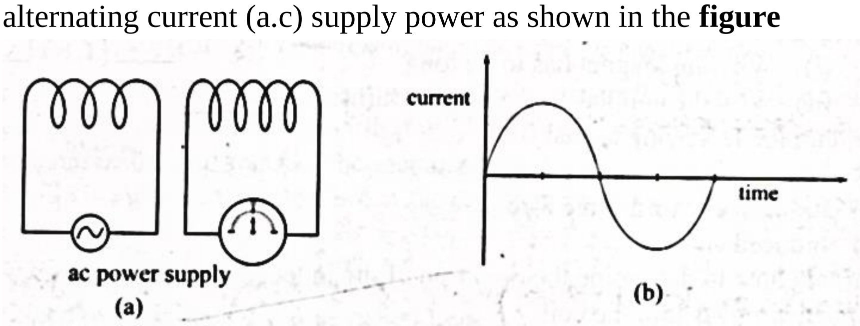
With no current in the electromagnet, no electromotive force (e.m.f) is generated because there is no cutting and re-cutting the coil to induce current
closing the switch to allow current to flow



When switch is closed current flows and this build up magnetic flux (field) in **one coil** and this field cut the other coil and induces the current in **it**

MUTUAL INDUCTION

It is the change in the current through one coil which brings about induced e.m.f in the coil
The circuit that induces the electromotive force is called Primary circuit while the circuit where the e.m.f is induced is called secondary circuit.
Although the two coils are not connected changes in current in the primary circuit induces an electromotive force in the secondary circuit.
The switching on and off of the current can be achieved by replacing a battery with alternating current (a.c) supply power as shown in the **figure**



WHY SOFT IRON CORE IS USED IN THE COIL

a) Soft iron increases the induced e.m.f because it can be easily magnetized and demagnetized
b) Soft iron core also helps to concentrate the magnetic field lines in the secondary coil

FACTORS AFFECTING THE MAGNITUDE OF INDUCED E.M.F IN THE SECONDARY SCHOOL

a) Increasing current in the primary coil, i.e. induced e.m.f in the secondary coil depends on the e.m.f in the primary coil. The induced e.m.f in the secondary coil is directly proportional to the e.m.f in the primary.
b) Increasing number of turns in the secondary coil.

APPLICATION OF MUTUAL INDUCTION

a) Car ignition system
b) Heart pace maker**:** pulses of the current through primary circuit in the pace maker unit induces pulses of current in a secondary circuit in the patient's chest. This triggers heart beat.
c) Used in transformers to induce current in the secondary coil.

TRANSFORMER

This is the device that is used to step up or step down voltage
It uses the principal of Electromagnetic and mutual induction

HOW TRANSFORMER WORKS

When alternating, current is applied to the primary coil changing magnetic field lines (flux) are produced. These magnetic field lines (flux) now cut the secondary coil inducing current in the secondary coil

WHY ALTERNATING CURRENT (A.C) IS USED IN TRANSFORMERS

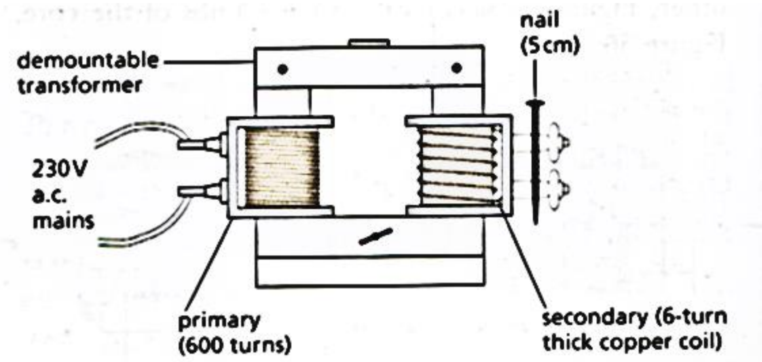
Alternating current moves to and fro so it creates magnetic field lines (flux) which cut the secondary coil inducing current in the secondary.

WHY DIRECT CURRENT IS NOT USED IN THE TRANSFORMER

Direct current produces fixed magnetic field lines which cannot cut and re-cut the secondary coil inducing current.

WHY SOFT IRON CORE IS USED IN THE TRANSFORMER

a) It increases the induced e.m.f because it can easily be magnetized
b) It helps to concentrate magnetic field lines in the secondary coil



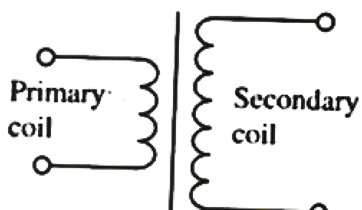
TYPES OF THE TRANSFORMER

1. STEP UP TRANSFORMER

This transformer has more number of turns in the secondary coil than in the primary coil. This transformer step up or increase voltage but at the same time decreases current for efficiency transmission of power.

POWER LOSS IN THE TRANSMISSION

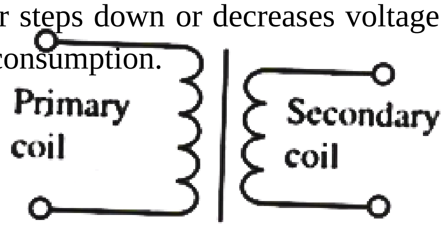
Power is transmitted at high voltage low current to avoid power loss because current cause heating (I^2R) so it means power will get lost. Now because of this step-up transformers are located at the station to transmit power at low current high voltage.



(b) Step-up transformer

2. STEP-DOWN TRANSFORMER

This transformer has more number of turns in the primary coil than in the secondary coil. This transformer steps down or decreases voltage at the same time it increases current for home and industrial consumption.



(a) Step-down transformer

The voltage of the induced current in the secondary coil relative to the primary coil depends on the ratio of turns in each coil

$$\frac{Vprimary}{Vsecondary} = \frac{Nprimary}{Nsecondary}$$

The relationship between the current and number of turns

$\frac{Nsecondary}{Nprimary} = \frac{Iprimary}{Isecondary}$

If the machine is an ideal that is its 100% efficiency

Input power (primary coil) =Output power (secondary coil)

$V_pI_p = V_SI_s$

$\frac{Vs}{Vp} = \frac{Ip}{Is}$

Input power is the energy per second supplied to the primary coil

Output power is the energy per second supplied to the secondary coil

EFFICIENCY OF THE TRANSFORMER

Efficiency is used to indicate how effective a transformer is in transferring the input energy to power output.

Efficiency is the ratio of the power output to power input expressed as percentages

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

Example

The step up transformer has an input supply of 20V and delivers an output of 250V.This transformer is 80% efficient and the secondary coil is connected to a 250V-100W

Work out the following

SOLUTION

a) Primary current

Input power=Vp$\times$ Ip

20Ip=input power

Efficiency=$\frac{out\ put\ power}{input\ power} \times 100\%$

80=$\frac{100 \times 100}{20Ip}$

Ip=$\frac{100 \times 100}{80 \times 20}$

Ip=6.25A   Input primary current is 6.25A

b) Input power

Power=voltage $\times$ $current$

$20 \times 6.25 =$ 125watts

Input power is 125 watts

c) Secondary current (**I**s)

Output power =100W

$Power = voltage \times current$

$100 = 250 \times Is$

Is=0.4A

The output current is 0.4A

d) Turns ratio

$$\frac{Ns}{Np} = \frac{Vs}{Vp}$$

$\frac{Ns}{Np} = \frac{250}{20}$ $= \frac{12.5}{1}$ ratio is 12.5:1

Turns ratio is 12.5:1

e) If there are 50 turns in the primary coil. How many turns are there in the secondary coil

Np=50

$$\frac{Ns}{50} = \frac{12.5}{1}$$

Ns=625 turns

FACTORS AFFECTING THE EFFICIENCY OF THE TRANSFORMER

a) Resistance of the coil

- As current flows in the coils, the wires heat up and energy is lost in form of heat
- Energy=I^2R.This method of losing energy is called Joule-heating

How to minimize energy loss in this way

- Thick copper wires of low resistance are used where large currents are to be carried

b) Eddy currents

- When the magnetic field changes, small amount of currents called eddy currents are induced in the core of the transformer. This heats up the core and energy is lost inform of heat

How to minimize energy lost in this way

- Use laminated core, the core is divided into small sheets that are insulated from each other. This reduces the magnitude of the eddy currents

c) Hysteresis losses

- The magnetization and demagnetization of the core by alternating magnetic field requires energy. This energy heats up the core and is lost as heat energy. This method of losing energy is called Hysteresis loss

How to minimize this energy loss

- The core must be made up of soft magnetic material that is easy to magnetize and demagnetize e.g. soft iron

d) Flux or Magnetic leakage
   - Not all magnetic field lines (flux) from primary coil cuts the secondary coil resulting in flux leakage
     How to minimize this energy loss
   - The core must be designed in such a way that almost all magnetic effect due to the primary coil is transferred to the secondary coil e.g. using a loop

Electric power transmission

- Electric energy generated at the power plant is transmitted to the consumer area through national grid system which consist of a network of transmission cables carried over through structures called pylons
- Due to some electrical resistance (R) of transmitting cables some electric energy is lost in form of heat according to the equation ($P=I^2R$) in the transmission cables

How to reduce power loss

i) Very thick transmission wires are used
ii) The transmission wires are made of metals like cooper of low electrical resistance to reduce energy loss
iii) The electric power is transmitted at high voltage and low current to reduce energy loss according to the equation($P=I^2R$)

ENVIRONMENTAL IMPACT OF POWER GENERATION AND TRANSMISSION

Hydroelectric power plant

- This is a generation of power from gravitational potential energy of water stored in the reservoir. This method is cheaper and has low operational cost.
- The negative impacts:
  i) Dislocation of people living around place when dams are constructed
  ii) Releasing carbon dioxide during construction of reservoirs
  iii) Disrupting the aquatic ecosystems and animal life
  iv) The dam becomes breeding sites for mosquitoes

Nuclear energy

- This power produces a very high energy because of this it needs a lot of water.
- The negative impact:
  i) Nuclear power plant ejects a lot of heat to water bodies this increases water temperature killing aquatic life

ii) Emission of radioactive substance into the environment imposes heath threat to the environment
iii) Nuclear bombs are used by terrorist and extremist groups to kill innocent people
iv) Accidental when the nuclear power plant breaks

Fossil fuels

- This is generation of electricity by burning the fossil fuels to heat water to produce steam that is used to drive the turbines to produce power
- The negative impact:
    i) There is emission of gases such as carbon monoxide and carbon dioxide
    ii) Burning the fossil fuel leads to the production of Sulphur dioxide and nitrogen gas that causes acid rain
    iii) gases produced in the burning of fossil fuels are emitted into the atmosphere that cause the depletion of ozone layer

Biomass

- Some electrical power can be generated by burning crops which are grown specifically for the purpose
- The negative impact
    i) it produces bad gases into the atmosphere

ELECTRONICS

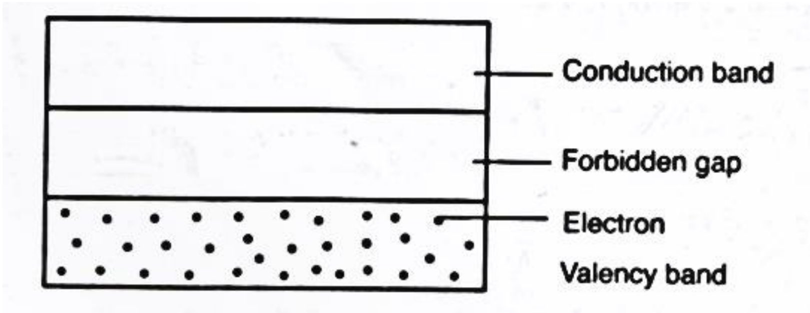
- It is branch electricity that deals with components that use small current e.g. Capacitors, thermostat, diodes and transistors

BAND THEORY

- Material can be grouped per their electrical conductivity properties good conductors, insulators and semiconductors.
- Good conductors: these are materials that allow an electric current to pass through them clearly e.g. copper and zinc
- Insulators: these are materials that does not allow current to flow through them e.g. plastics
- Semiconductor: are those materials whose conductivity lies between that are good conductors and insulators e.g. silicon and germanium

BAND THEORY

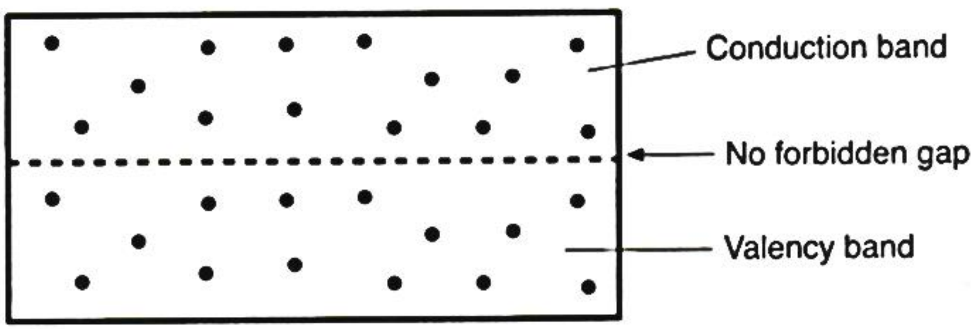
- This theory states that materials are considered to contain two bands in which electrons may be found and these are valence band and conduction band



- The two bands are separated by a gap called forbidden gap (no electrons are allowed in this gap)
- For material to conduct electric current electrons should be in conduction band. However electrons prefer to be in valence band as this is *lowest energy level*
- To move the electrons to the conduction band, energy is needed to cross through the forbidden gap. One way of providing energy is through raising temperature

EXPLANATION OF ELECTRICAL CONDUCTION IN METALS

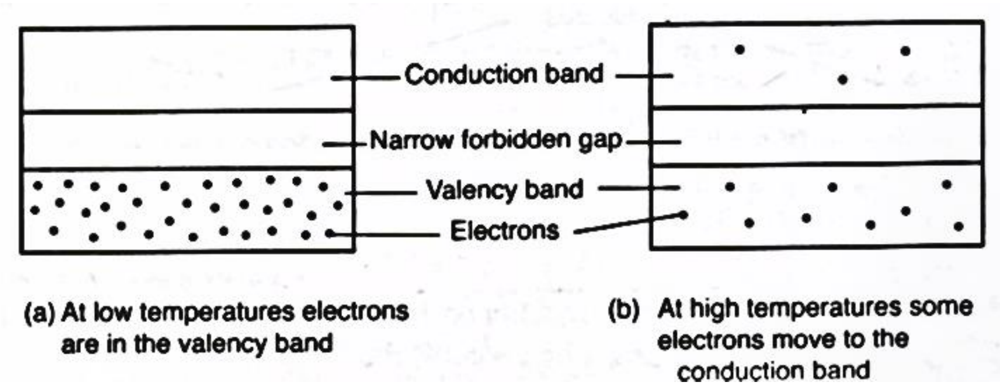
- In metals the valence band and conduction band overlap and hence no energy is needed to overcome forbidden gap



- Overlapping of bands in conductors
- All electrons are free and mobile to conduct electric current.
- If conductors are heated, the internal energy increases and the electrons move in all direction colliding with each other .This explain why metals become poor conductors as temperature increases.

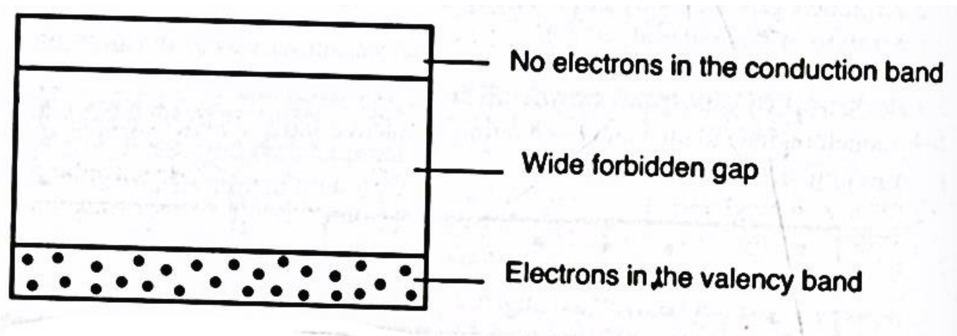
ELECTRICAL CONDUCTION IN SEMI CONDUCTOR

- In semiconductors, the forbidden gap is bigger than in conductors. At low temperatures all the electrons are in valence band. At room temperature some electrons gain thermal energy and cross the forbidden to the conduction band. The material then becomes a fair conductor.
- As temperature is increased, more electrons move to the conduction band and hence its electrical conductivity is increased. This shows that resistance of the semi conductors decreases with increase temperature



INSULATORS

- In insulators, the forbidden gap is so wide that any attempt, say by heating to promote the electrons to conduction band ends up breaking down the material



- The conduction band has no electrons hence cannot conduct electric current

SEMICONDUCTORS

- These are materials whose electrical conductivity lies between those of good conductors and poor conductors e.g. silicon, germanium
- Semiconductors act as insulators when very cold. At 25^0C (R.T.P) they are poor conductors

CATEGORIES OF SEMICONDUCTORS

a) Intrinsic or pure semiconductors
b) Extrinsic or impure semiconductors

A. INTRINSIC OR PURE SEMI CONDUCTOR

- These are made from the same material
- These are materials which increases its electrical conductivity from within itself (internally)
- Intrinsic semiconductors have a narrow forbidden gap between conduction band and valence band. They require only a little added energy for electrons to jump from valence band to conduction band.

WHY CONDUCTIVITY OF THE SEMICONDUCTOR INCREASES WHEN ITS TEMPERATURE INCREASES

- At high temperature the electrons in valence band gains thermal energy and jump the forbidden gap into the conduction band hence conducting the electricity.
- When electrons enter the conduction band it is free to move randomly. Electrical conductivity in intrinsic semiconductors is mainly due to electron hole pair movement.

B. EXTRINSIC OR IMPURE SEMI CONDUCTOR

- These are materials whose electrical conductivity increases by adding small impurities
- The electrical conductivity of pure semiconductor may be increased by adding or introducing small and controlled amount of other materials (impurities) into pure conductor
- The controlled process of introducing or adding small amounts of impurities into pure semiconductor to increase its conductivity is called ***DOPING***
- Pure semiconductor **+** small impurities→→Extrinsic semiconductor
- Impurities used in doping process are elements whose atoms have either *<u>three</u>*(trivalent) or *<u>five</u>* (pentavalent) valence electrons
- Examples of trivalent elements include boron, aluminum, gallium and indium
- Examples of pentavalent elements include phosphorous, arsenic and antimony

TYPES OF THE EXTRINSIC SEMICONDUCTOR

i. N-type semiconductors
ii. P-type semiconductors

1. N –type semiconductor

It is semiconductor formed after doping the intrinsic semiconductor with elements from group 5 of the periodic table (pentavalent) e.g. phosphorous

Let's consider an intrinsic silicon conductor doped with phosphorous. Each Silicon has **four** valence electrons and therefore each atom has **four** neighboring atoms bonded to it. Phosphorous has got **5** valence electrons of which **4** participate in bonding with neighboring silicon atom. The **fifth electron** is left free to roam within the lattice. This is the **electron** that is available for conduction.

The resulting semiconductor has more electrons and it is referred to as N-type semiconductor (N for negative)

*The majority charge carriers are the **electrons***

In this case the phosphorous is said to be donor impurity

Intrinsic semiconductor **+** pentavalent →→ N type semiconductor

E.g. phosphorous.

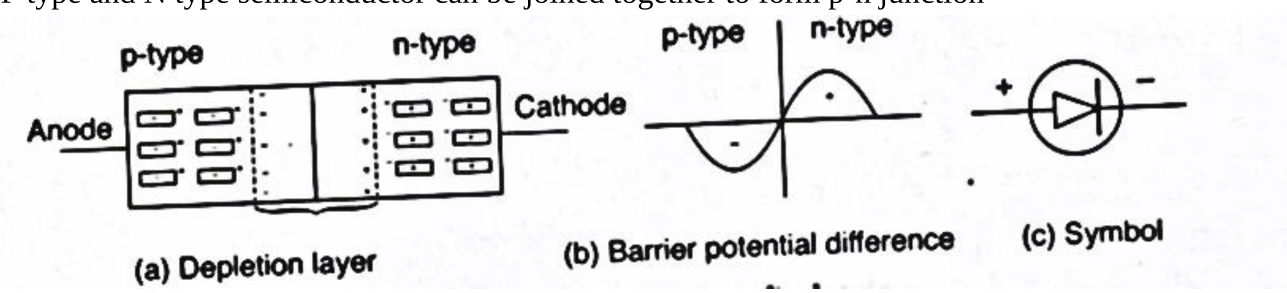
P –TYPE SEMICONDUCTOR

- It is semiconductor formed after doping the intrinsic semiconductor with elements from group 3 of the periodic table e.g. Boron
- Let's consider the crystal of silicon doped with small amount of trivalent atoms e.g. Boron
- Boron has **three** valence electrons which participate in the bonding .This leaves a vacancy in the fourth bond called **hole**
- When a bond is incomplete, it is possible for an electron in the neighboring silicon atom to leave its electron-bond to fill the hole. The electron moving from the bond to fill a hole leaves a hole in its initial position. The hole effectively moves in the direction opposite to that of electron. Boron creates a gap or positive holes in the electron structure. Hence electrons jump from one hole to another
- The resulting semiconductor has positive hole as a charge carriers.
- *The majority charge carriers are **positive holes***
- Pure or intrinsic + trivalent atom→→P –type semiconductor
- Semiconductor e.g. silicon.

EXAMPLES OF SEMICONDUCTOR

1. DIODE OR RECTIFIER (P N JUNCTION)

P type and N type semiconductor can be joined together to form p-n junction



- P-type and N type regions are electrically neutral. Charge movements' results to holes combining with electrons thereby producing net positive charge to the n type region and leaving a net negative charge in the P type region
- The net positive charge in the n type prevents any further movement of the holes from p type to n type
- The net negative charge in the p type stops any further movement of the electrons from the n type to the p type. A region is created which has lost all its free electrons and holes. This region is called **depletion layer**
- When equilibrium has been achieved to resulting device as p-n junction diode
- Due to the movement of charges the junction, a potential difference develops a cross the junction with its polarity such as to prevent further charge movement. This potential difference is called **barrier Potential difference**

Diode or Rectifier

It is a device, which changes alternating current to direct current. Diode allows current in one direction only

Rectification

This is changing of a.c to d.c

Diodes are called Rectifiers because they change a.c to d.c

Types of rectification

i) Half wave rectification

- In this case one diode is used to change ac to dc
- Terminal A is positive during one half cycle and becomes negative during the next half cycle, when A is positive current flows from A through the resistor to terminal B. In the next half cycle, the terminal B becomes positive and current flows from B through resistor to A. During the first cycle, current flows in one direction and during the next cycle the current flows in opposite directions.
- The process of allowing only half of the wave to produce current that flows in one direction is called *half wave rectification*

ii) Full wave rectification

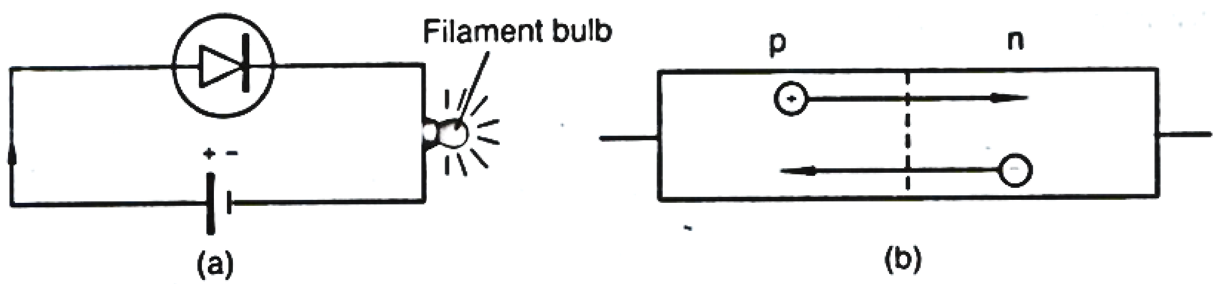
- During the first cycle S_1 is positive and diode D_1 is forward biased. However, during second cycle S_2 becomes positive and diode D_2 becomes forward biased with respect to diode D_1 which now will be reverse biased. In this case, irrespective of the polarities of input terminals, the current flows through the resistor continuously. This a.c has been fully rectified.

Biasing the diode (p n junction)

Forward biase

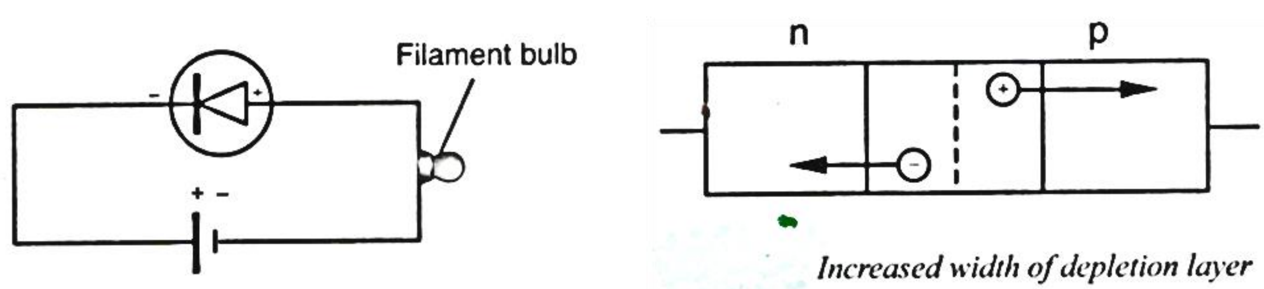
It is connected positive to positive and negative to negative.

The bulb gives out light



The battery gives enough energy to overcome the barrier potential difference and to drive the electrons in the circuit. The holes are also able to move towards the junction and complete circuit

Reverse Bias



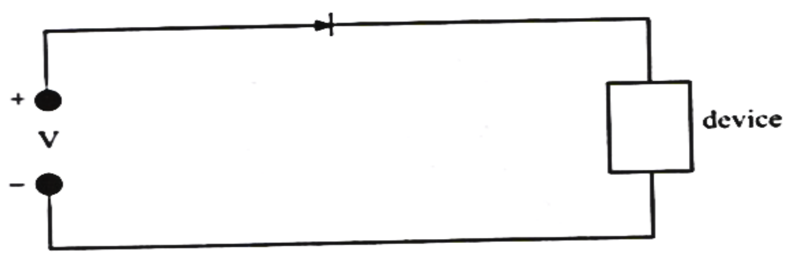
In the reverse bias the bulb does not give light
The electrons and the holes are attracted to the opposite ends of the cell. This increases the width of the ***depletion layer*** and hence increases barrier potential difference. No current can now flow through the diode.

Application or uses of Diodes (p n junction)

- *Protecting Electrical devices in circuit*

Some devices that are operating on direct current (D.C) break down when large voltages are connected in reverse/opposite order to the terminals of the devices.

To protect such devices diodes is connected usually in series with them and reverse in reverse bias. It ensures that the device is protected by offering very high resistance to the flow of the current in the reverse direction when terminals are interchanged.



Using a diode to protect a device.

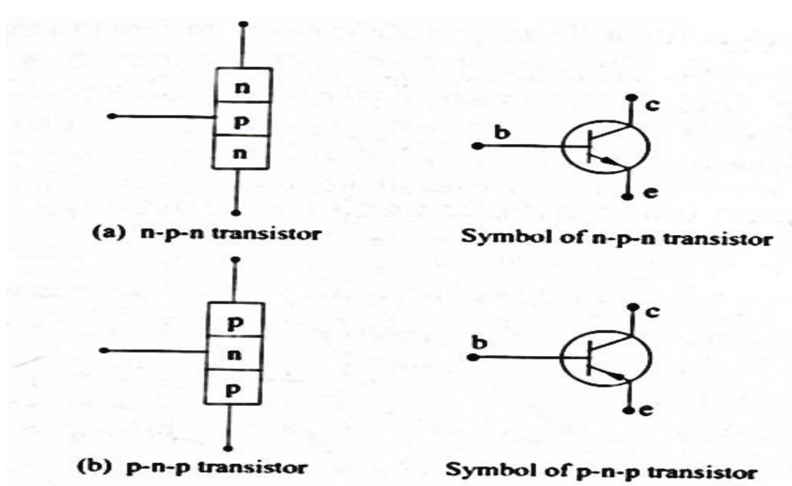
Rectification (Rectifier)

- Not all electrical devices are operated by A.C some need D.C to operate. It is therefore necessary to convert the A.C to D.C
- A p-n junction is used for this purpose. The process of converting the A.C to D.C is called rectification

- The diodes are called rectifiers because they convert A.C to D.C
- Light emitting Diode (LED) is used as indication light on electronic equipment. They are also used for digital display

TRANSISTOR

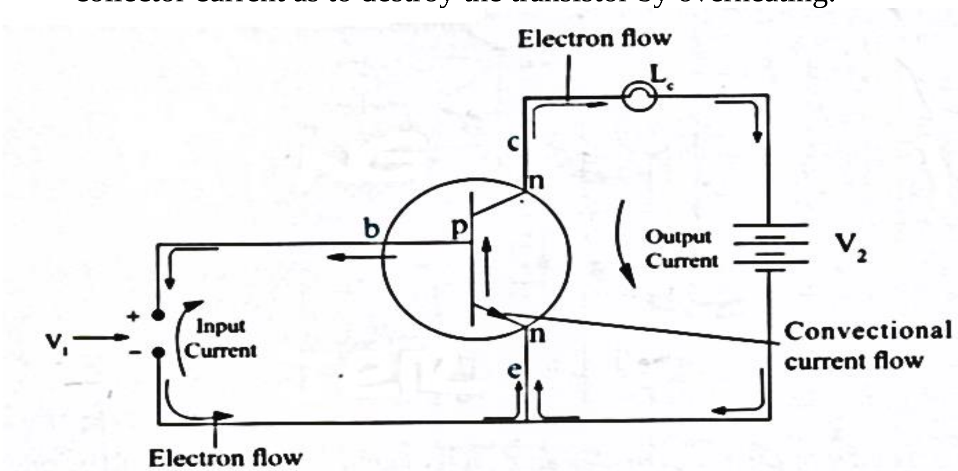
- It is a semiconductor device that controls current as an electronic switch and can also amplify current as well.
- The transistors are in the form p –n- p or n- p- n



- The arrow shows the direction of convectional current flow when transistor is operating
- The emitter (e) emits electrons which pass through the base (b) to the collector(c)
- **NOTE**: n-p-n transistor are more commonly used than p-n-p because current moves faster in them
- Transistors are assembled to different sizes and shapes

HOW DOES TRANSISTOR WORK

- The transistor works in such a way that when the input side conducts i.e. current flows between the base and the emitter(base-emitter) then the output also conducts i.e. current flows between the emitter and the collector(collector-emitter). When the input is off then the output is also off
- Resistor(R) must be in circuit to limit the base current which would otherwise create large collector current as to destroy the transistor by overheating.



The bulb light because it is connected to low current resistor

USES OF TRANSISTOR

- As an electronic switch

ADVANTAGES OF TRANSISTOR AS ELECTRIC SWITCH

- Small
- cheap,
- reliable,
- have no moving parts,
- their life is almost indefinite
- they can switch on and off millions of times a second

THERMISTORS

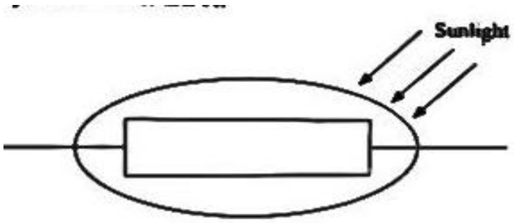
- These contains semiconducting metallic oxides whose resistance decreases markedly when temperature rises either due to heating the thermistor directly or passing the current through it.

USES OF THERMISTOR

- With a meter marked in ^{0}c in series can measure temperature.

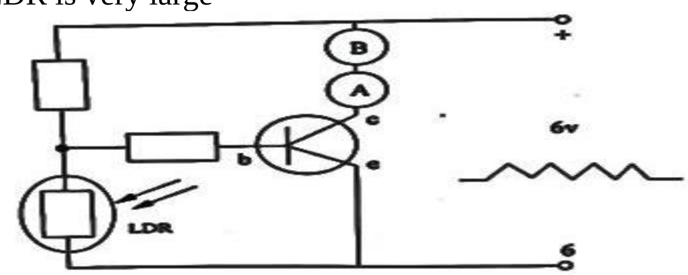
- With the resistor in series it can provide an input signal to a logic gate.
- Used as timers in the degaussing coil circuit of most CRT displays
- Used as current limiting devices for circuit protection

Light dependent resistor (LDR) is called photo resistors. They are sensitive to light; their resistance decrease with light intensity.
When light energy falls on them electrons become more free to conduct and the resistance decreases considerably



Working of light operated switch
LDR have many uses in electronic devices:

- It keeps the bulb on in darkness and off in presence of light. In darkness, the resistance of LDR is very large

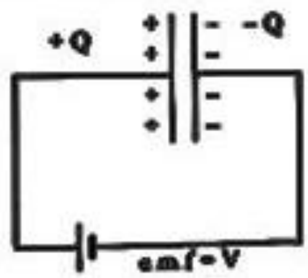


- Light sensors in switching on circuits that require to be triggered by light

Capacitors
A capacitor is a device that stores charges.
It consists of two parallel metal plates held together and separated by an insulating medium called *dielectric material.*

It is measured in micro farad (μF) or Pico farad (ρF)
Types of capacitors

a) Variable capacitor
This is a capacitor is one in which the area of the plate can be adjusted and the dielectric material is usually air



Uses of this capacitor

- Used in turning circuits where radio stations of different frequencies can be selected by changing the value of capacitance of the variable capacitor

b) Electrolytic capacitor
This is the type of capacitor where one plate is always connected to the positive terminal of the battery and other plate to the negative terminal.
They are used:
- power supply circuits such as power packs in the laboratories
- time delay electronic circuits
- to control a lamp in photographic dark or head light of the car

c) metal foil plastic capacitor
A metal foil capacitor has plastic as its dielectric material
Uses of capacitor
- used in ignition system of cars and buses
- used in cameras

Capacitors are used in

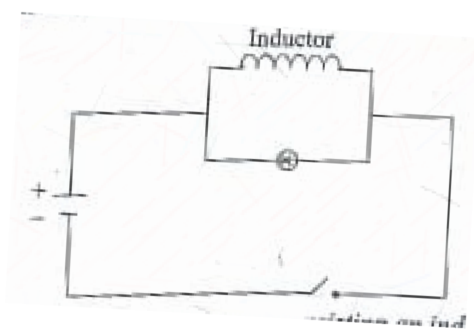
- Turning circuit in radios and T.Vs
- In calculators to supply power for its memory when switched off
- Smoothing of circuits in the conversion of alternating current to direct current
- Re-chargeable batteries
- Time delay circuits
- Used in cameras

INDUCTORS

- Is an electronic component that stores energy in form of magnetic field?
- The inductor measures inductance which is the behavior of a coil of wire in resisting any change of electric current through the coil

How inductor works

- When the switch is closed without the inductor, the bulbs light normally now connects the inductor the bulb glows dimly. Most current should follow the low resistance path through the loop but what happens the bulb burns brightly and then gets dimmer. When the circuit is switched off, the bulb lights brightly and then quickly goes out this is when the current first flows in the coil, the loop builds up magnetic field. At this point the coil inhibits the flow of current. Once the field is built current can flow normally through the wire.
- When the switch is opened the magnetic field around the coil keeps current flowing in the coil until the field dies
- The current keeps the bulb lit for sometimes even though the switch is opened. Therefore, we define inductor as a device that store energy in its magnetic field and trends to resist any change in the amount of current flowing through it.



Uses of inductor

- Inductors are used in making traffic lights that uses loop
- Inductors are used in red light cameras that are used to curb traffic violations
- Light emitting diodes (LED)
- A light emitting diode is a two-lead semiconductor light source.
  - This diode emits light when current passes through it, this is effect is called electroluminescence.

Uses of LEDs

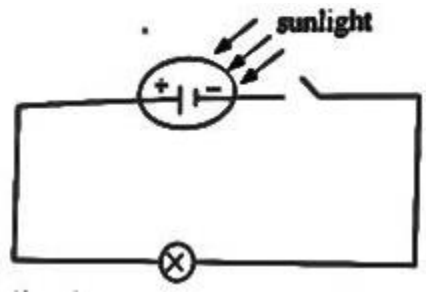
- Aviation lighting
- Automotive headlamps
- Advertising and traffic signals and camera flashes

Photovoltaic cell

This is an electrical devise that converts light energy directly to electric energy by photovoltaic effect. It is called solar cell

How does it work

When sunlight fall on the solar cells, a potential is created across the cells. When the circuit is completed a current flow through the components connected in the circuit



Uses of photovoltaic

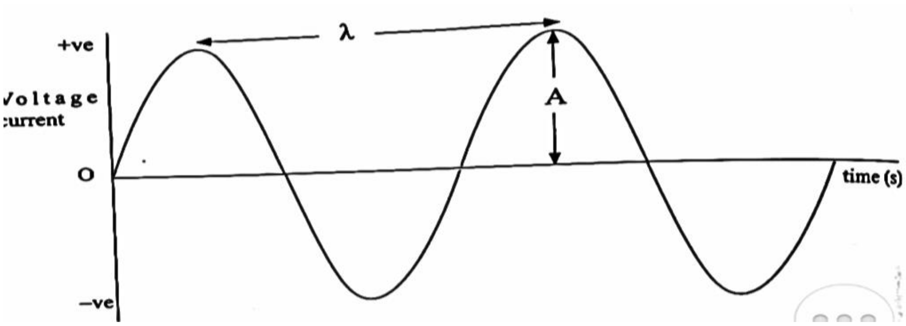
- Used in the manufacture of solar panels
- Can be used to power solar powered cars, boats and airplanes

Electronic circuit and signals

- Number of electronic devices have their output inform of data, sound and video signals. Examples are radio (sound signals) computer, television and mobiles (sound, data and video signals)
- These signals are classified as analogue and digital signals from analogue and digital circuits

Analogue signal

Analogue circuits are electronic circuits that operate with currents and voltage that vary continuously with time and have no abrupt transitions between levels



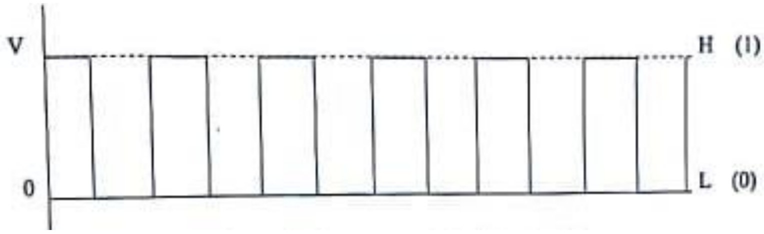
This is a circuit with a continuous variable signal

Characteristics of analogue signals

- Amplitude, maximum displacement of wave particle from its resting position
- Frequency, number of complete oscillation per second
- Phase, these are two points on a wave-front that appears to be the same

Digital circuits and signals

Digital circuits are circuits where signal must be one of two discrete levels.
The signal must be one or zero (1 and 0). This digital circuit produce digital signal



Characteristics of digital signals

- Bit intervals: this is the time required to send one signal
- Digital signals are discrete
- The signal has limited number of defined values such as 1 and 0
- Bit rate it's the number of bit intervals in one second

Advantages of digital signals

- Digital data can be easily compressed and hence transmitted efficiently. This helps in the transmission of large volumes of voice, data and image information
- Digital signals are secure. There is minimal loss of data
- Digital transmission of data is cheaper compared to analogue data

Modulation

The process by which analogue signal is converted into digital signal
The reverse of the process is called demodulation

Logic gates

Logic gates normally use tiny transistors as switches

a) AND gate

Let us use the simple circuit figure below to understand the AND gate. let A and B represents the input circuits of a transistor respectively while lamp L represents the output circuit. Let us use 1 and 0 to represent the *on* and *off* states of any of the three circuits. The states of the two input circuit A and B determines the states of the output circuit L. Table 10.2 summarizes the possible states of the three circuits at an instant. This table is known as the AND truth table

inputs		Outputs
A	B	L
0	0	1
1	0	0
0	1	0
1	1	0

The circuit is called an AND gate because circuit A and circuit B must be on for the output circuit(lamp) L to be on.

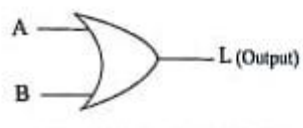
In an electronic circuit the AND gate circuit is represented by the symbol below

b) OR gate

The fig below an OR gate circuit. The input circuits A and B are in parallel and their combined circuit in series with the output L. The table is the truth table for the OR gate

inputs		outputs
A	B	L
0	0	0
0	1	1
1	0	1
1	1	1

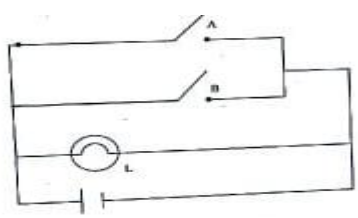
From the truth table, we observe that the output circuit represented by the lamp L will only be on when either A or B or both are on



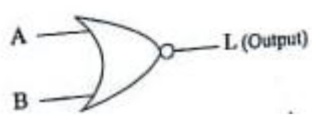
symbol for OR gate

c) NOR gate

Fig below shows a NOR gate circuit. It consists of two circuits A and B and one output circuit L

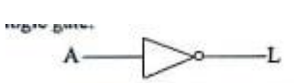


In the NOR gate, neither A nor B should be on for lamp L to be on. This is symbol



d) NOT logic gate

Fig below is a NOT logic circuit. It consists of one input circuit. In consists of one input circuit A and one output circuit L. The truth table for a NOT gate.



In the NOT logic gate the output circuit L is on if A is off.

This is the symbol

The truth table

inputs	outputs
A	L
0	1
1	0

OSCILLATIONS AND WAVES

- Electromagnetic spectrum
- These are the waves having both electric and magnetic field.

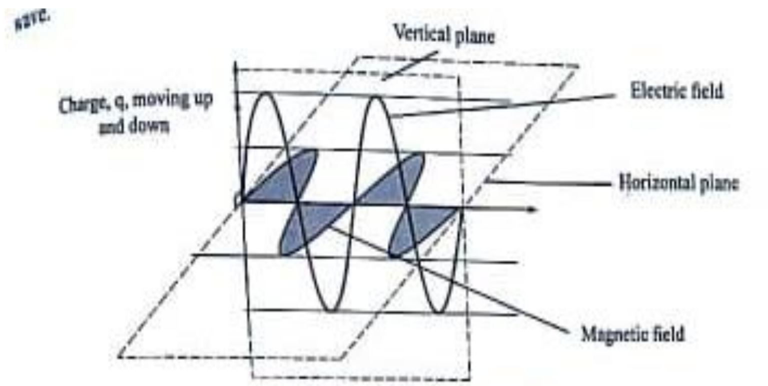


Fig. 11.2: Electric and magnetic fields

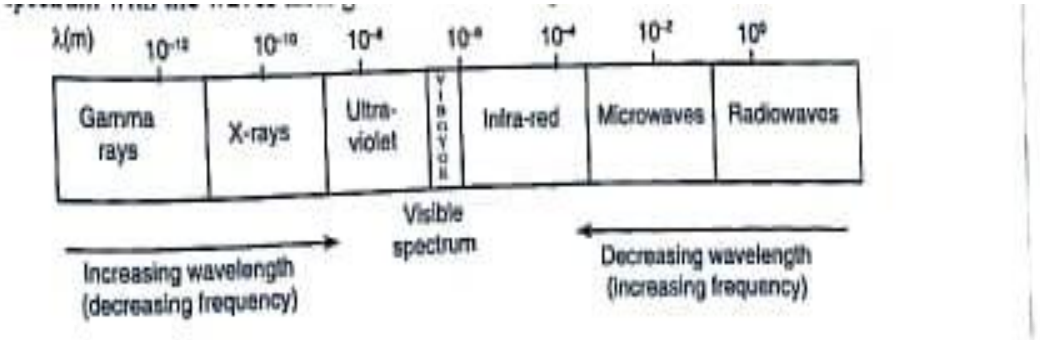
A change in the energy can occur in number of ways:

i. Electron undergoing transition from an orbit of higher energy to one of lower of energy
ii. Oscillations of electrons or nuclei; as the electrons or nuclei oscillate, their kinetic energy changes constantly. The rate of oscillation governs the nature of the radiation to be emitted
iii. Movement of a molecule; this includes vibration, bending, inversion or even the rotation of molecular arrangement

ELECTROMAGNETIC SPECTRUM

- These are waves that are arranged in order of increasing or decreasing wavelength. The electromagnetic spectrum is continuous spectrum, this means that there is no sharp boundary between one radiation and the next. The different types of waves change gradually from one to another. Some radiations even overlap for example X-rays overlap with both gamma rays and ultra violet rays so X rays have the same wave length with gamma and ultra violet radiation.
- The spectrum consists of gamma rays (ϒ), X-rays, ultra-violet (UV), visible light, infra-red (IR), micro waves and radio waves.

Complete electromagnetic spectrum



Overlapping of electromagnetic spectrum

Gamma rays

They have least wavelength and therefore they are located on one end of the electromagnetic spectrum.

They have a range of wave length from 1x10^{-15}m to 1 x 10^{-11}M or below

Gamma rays are produced from within the nuclei of radioactive atoms

X rays

These are produced when fast moving electrons strike and are stopped by a metal target. They range from 1x10^{-13}m to 1 x 10^{-9}M

There is no clear boundary between the gamma rays and X rays

Ultra violet radiation

This bounds the violet ends of visible spectrum. They are produced by arcs (eg carbon arc lamp, electric spark), gas discharge tube, mercury vapor lamp and the sun.it produced with a range of wave length of 1x10^{-9}m to 1 x 10^{-7}m.

UV rays with short wave length overlap with the X rays of long wave length

Visible light

The visible light consists of seven radiations i.e. *violet, indigo, blue, green, yellow, orange* and *red* abbreviated ***VIBGYOR.*** This forms what is referred to as the visible spectrum.it has a range of wavelength of 4x10^{-7}m to 7 x 10^{-7}M.

Visible light is produced by very hot bodies or any *incandescent* object

Infra-red radiation

These are produced by hot bodies e.g. sun, electric fires and furnaces. They have a range of wave length 1x10^{-6}m to 1 x 10^{-3}M

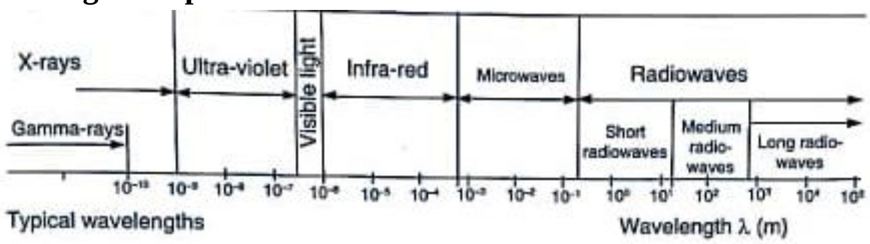
Infra-red is a radiant energy. Red hot bodies emit red light and infra-red

Radio waves

These are waves produced from electrons moving in conductors. Radio waves have the greatest wave length and therefore are found on the other end of the spectrum. They have the wide range of wavelength $1x10^{-3}$m to 1 x 10^{6}M.

This region is subdivided into micro waves, radar and television waves.

Fig below shows the range of wave length of wave length for the different radiations of electromagnetic spectrum



Properties of electromagnetic waves

i. Carry no charge
ii. Are transverse in nature
iii. Under suitable conditions, they undergo reflection, refraction, diffraction and show interference effect
iv. They travel through the vacuum
v. Can be emitted or absorbed by matter
vi. Obey the *inverse square law* i.e. intensity(I) is inversely proportional to the square of the distance from the source r^2
vii. Possess energy E that is directly proportional to its frequency, i.e. $E\alpha f$. Hence $E=hf$ where h is the Planck's constant

Methods of detecting electromagnetic waves

Gamma rays

They are detected by photographic plates or films and the device called *Geiger muller tube.* The photographic plates contain chemicals which are sensitive to gamma rays.

X-rays

These are detected by photographic plates or fluorescent screens. When X rays fall on a fluorescent screen (a screen coated with zinc sulphide), the screen glows

The X rays may also be detected by producing photoelectric effects on metals and ionization of gas

Ultra violet radiation

Detected by photographic films and by the fluorescence they cause in some mineral salts. It can also be detected by photocells and light-dependent resistor

Visible light

When light dependent resistor (LED) an electric current flow in the circuit due to reduction of resistance in the circuit, hence a LED is also a good detector of visible light

Infrared radiation

It can be detected by a *thermopile,* a blackened bulb of a sensitive thermometer and a heat sensitive paper (thermochromics paper) and a phototransistor

Radio waves

These are detected by aerials, diodes and earphones in electric circuits. This is because they cause a small electric current to flow in electrical circuits containing such as detectors.it is micro waves of shorter wave length, infrared, visible light, ultra violet and X rays of longer wavelength all cause a heating effect. These are known as *thermal radiation* so they are detected by instruments that are sensitive to changes in temperature.

APPLICATION OF ELECTROMAGNETIC WAVES

a) *Gamma rays*
   - Tracers
     - ➢ Used in medicine to locate internal body organs that are not functioning as expected
   - Sterilizing
     - ➢ It kills bacteria, mould and insects or worms in food
     - ➢ Sterilize medical equipment's
     - ➢ It is used to kill cancerous cells
   - Thickness control
     - In the manufacture of sheets of steel the thickness can be controlled by monitoring it with gamma rays as they are passing through the sheets
   - Detecting flaws and cracks

     Gamma rays are used to check weak points eg welded joints in materials

b) *X rays*
   - They have high penetrating power so they used by doctors to check teeth and bones
   - They are used to check the welded metal joints
   - Used to check food manufacturing to check if there are any foreign objects like metals and stones
   - Used to study crystal structures (X ray crystallography)
   - Used in crime detection work e.g. forgery

c) *Ultra-violet radiation*
   - Used to produce needed vitamin D in our skin
   - Used to identify stolen items, where a security pen is used to mark the items, this pen use ink that shows up only under ultraviolet light
   - Used to detect forgery

d) *Infrared*

- Used to take photograph called *thermographs*, this uses special photographic films which are sensitive to infrared
- They are used in burglar alarms
- Infrared which are detected heaters are used to dry wet paint quickly on newly sprayed cars

e) *Radio waves*

- They are used in radio communication such as microwaves and radar

f) *Microwaves*

- Used for cooking in microwave ovens, satellite communications and for radar navigation
- Ultrahigh frequency waves(UHF) are used to transmit television programs
- Very high frequency (VHF) waves are used to transmit local radio programs and ambulances/police messages
- Medium waves are used to transmit messages over long distance since they have long wave lengths and are diffracted around the mountains, hills and curves of the earth.

EFFECTS OF ELECTROMAGNETIC WAVES

a) Greenhouse effect

- This is process of allowing in short wavelength radiation and protecting the radiated long wavelengths from escaping.

b) Global warming

- The atmosphere allows short half wave radiation from the sun to pass easily to the earth surface. This warms up the ground. The warmed ground radiates heat in form of infra-red radiation into the atmosphere. The atmospheric gases (carbon dioxide, water vapor) absorb the radiation from the earth they in turn give out heat. When more and more radiation is being directed back to the earth's surface.

c) Harmful effects of ultra violet radiation

- They cause sunburns that occurs when skin cells are damaged by absorption of energy. They cause damage to aquatic ecosystems

d) Harmful effects of gamma rays

- They can kill cells. When exposed to them they may kill body living cells.

e) Effects of x-rays

- They cause cell mutation i.e. DNA changes. They also can cause skin cancer
- They cause deformity in the infant. They cause baldness that's is cause loss of hair

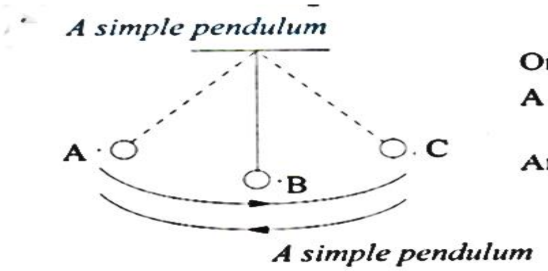
OSCILLATIONS

Oscillations are to and from or up and down movement of particle that repeats itself e.g. Pendulum, cantilever, Spiral spring

Cycle is anything that repeats itself at regular interval e.g. water cycle

Physical cycle
That show repeating movement and these cycles are

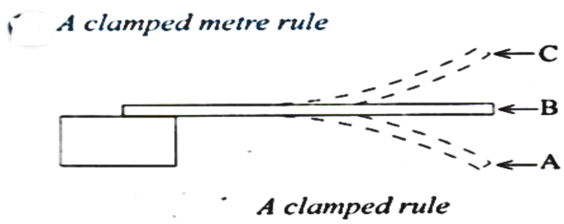
i. Pendulum (a string and mass at the end)



One oscillation is the movement
A → B → C → B → A

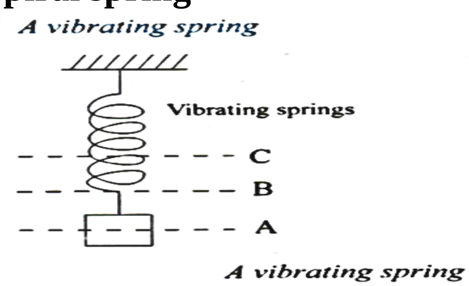
Amplitude is the distance BA or BC.

ii. Cantilever



One oscillation is the movement
A → B → C → B → A.
The amplitude is the distance BA or BC.

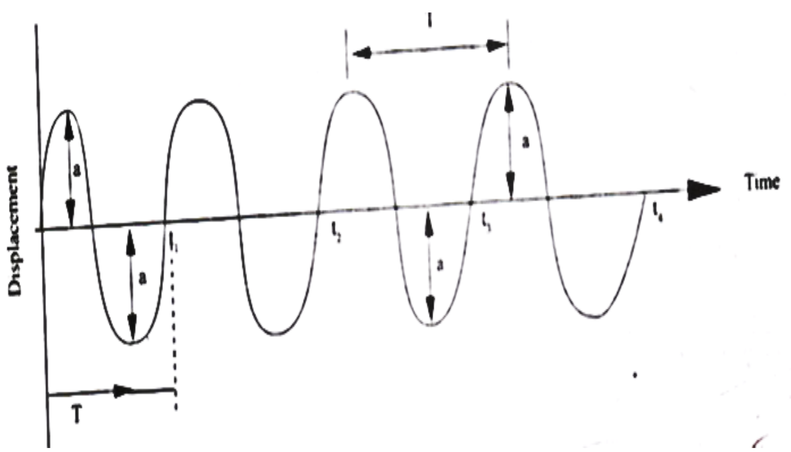
iii. Spiral spring



One oscillation is the movement
A → B → C → B → A.

The amplitude is the distance BA or BC.

CHARACTERISTICS OF AN OSCILLATING SYSTEM



1) Displacement d,
   This is the distance of the body from the mean/fixed position
2) Amplitude, a
   This is the maximum displacement of a vibrating object from equilibrium or resting position
3) Periodic time
   This is the time taken to complete one oscillations or cycle
   For example if there are 20 oscillations in 20 seconds then the period is equal to 1second
   P = time/number of full cycle
4) Frequency
   This is the number of complete cycles made in one 1 second
   F = vibrations/time
   Example
   If there are 10 oscillations in 5seconds.calculate the frequency
   F = 10/5
   =2Hz
   Frequency is measured in hertz (Hz).
   Relationship between frequency and period
   F =1/T or T = 1/F

   1hertz (1Hz) is one oscillation or cycle per second

FACTORS THAT AFFECT FREQUENCY OF OSCILLATING SYSTEM

	Factors affecting	Factors that do not affect
Pendulum	• Length of string • Type of string • Large amplitude	• Mass of the bob
Spring	• Mass of the ends • Type of spring • amplitude	• length of spring • changes in amplitude
Cantilever	• mass at the end • length of the ruler • type of the ruler • nature/material	• amplitude changes

WAVES

- This is the disturbance in a medium.
- Medium can be solid, liquid and gas

CHARACTERISTICS OF THE WAVES

(i) amplitude

(ii) period

(iii) frequency

(iv) displacement

(v) Velocity, this is the distance covered in a direction per unit time. The SI unit is m/s

(vi) Wave length, distance between two successive crest or troughs. The SI units is meter (M)

(vii) Wave speed

This is the distance covered by a wave per unit time. It is measured in meters per second (m/s)

V = frequency x wave length

Example 1

A water wave travels 480cm in 2minutes and has a wave length of 5cm.Work out the following

a) The speed of the wave
Speed = distance/time
= 480cm/100x2x60
=0.04m/s

b) The frequency of the wave
Frequency = velocity/wave length
0.04/0.05
=0.8Hz

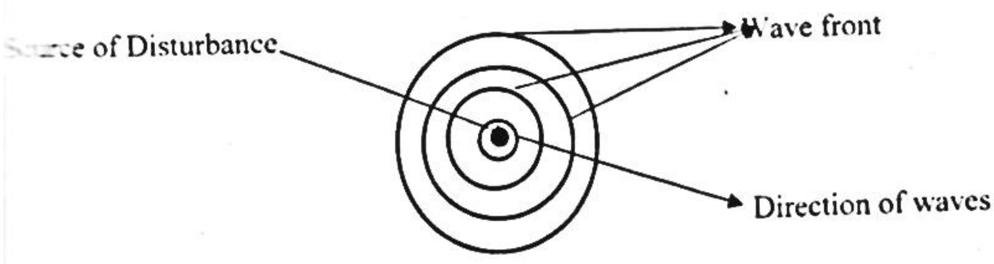
Example 2

The wave crests seen in a ripple tank are 5mm apart and the frequency of the vibrator is 10Hz.What is the wave speed

F = 10Hz
Wave length = 5mm
Change wave length to meters 5/1000 = 0.005
F = 10 x 0.005
=0.05Hz

WAVE FRONT

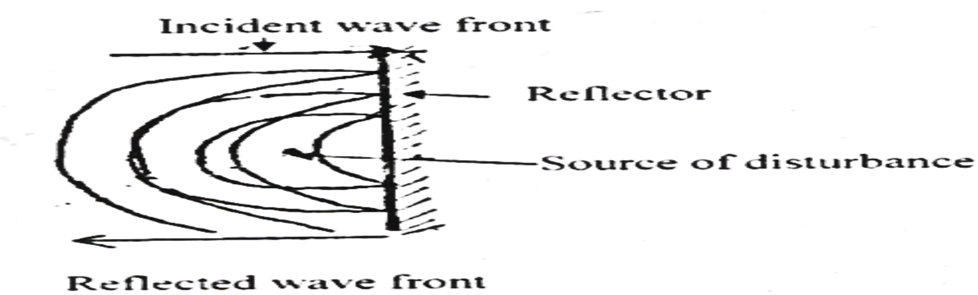
This refers to the common cycles of all particles, which vibrate in phase for example circular waves generated by dropping spherical object in water such that circular patterns are equidistant from the centre of disturbances



PROPERTIES OF THE WAVE

1. ***Reflection***

This is bouncing back of the waves when they met an obstacle
Sound, water and light waves reflect obeys laws of reflection



Laws of reflection

- The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane
- The angle of incidence is equal to the angle of reflection

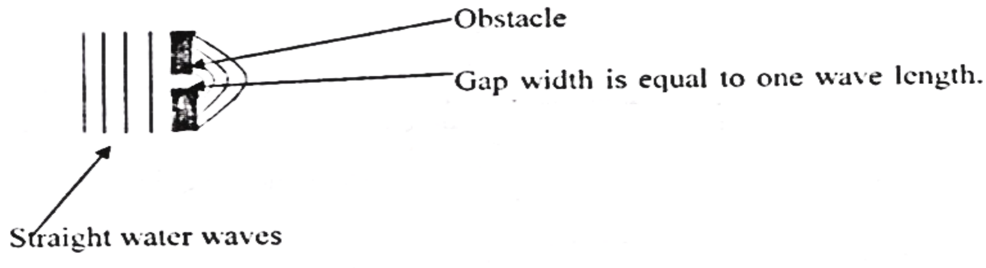
2. ***Refraction***

This is the bending or changing of the velocity of the waves when traveling in different mediums.
The wave change or bend direction when the speed or velocity changes
The wave length of the wave also changes. The deep waters the wavelength is longer as compared to the shallow waters. As the wavelength of the wave decreases in shallow water so the speed of the wave also decreases in shallow water than in deep water because in all cases frequency is the same.

3. ***Diffraction***

This is the spreading of the waves after passing through the narrow gap.

Diffraction is more pronounced when the gap is narrowed compared to wavelength of the waves. The gap acts like another source of waves.



4. *Interference of the wave*

This is the combination of the two waves to give a smaller or larger wave

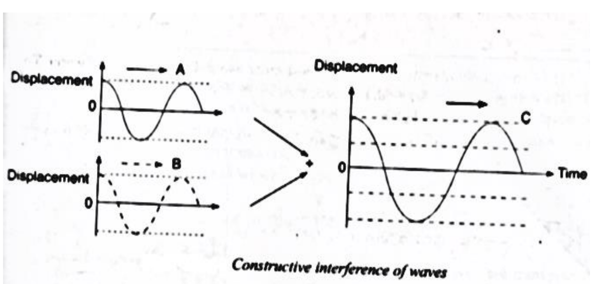
TYPES OF THE INTERFERENCE

I. Constructive interference

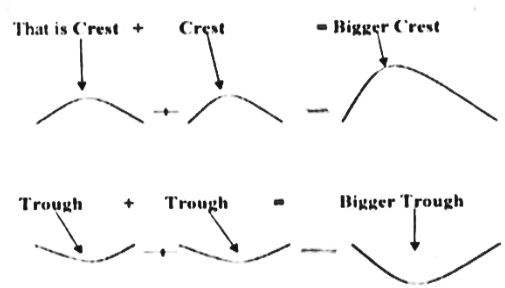
This is the combination of waves traveling in the same direction resulting in increased amplitude.

This forms when crest and crest meet to form larger crest, trough and trough meet forming larger trough.

If the wave has the same wavelength, amplitude and speed traveling in the same medium and in the same direction and are in the phase the resultant amplitude is higher.

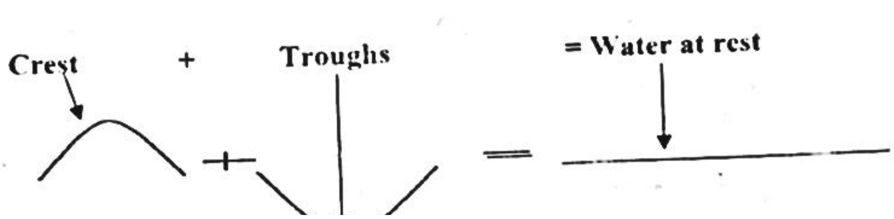


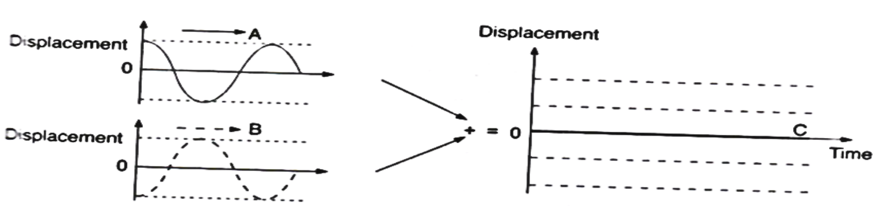
Constructive interference of waves



II.Destructive interference

This is formed when the crest meet the trough forming a straight line





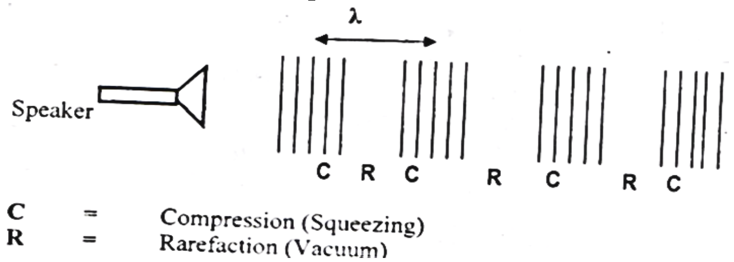
Destructive interference of waves

TYPES OF THE WAVES

a) Longitudinal waves

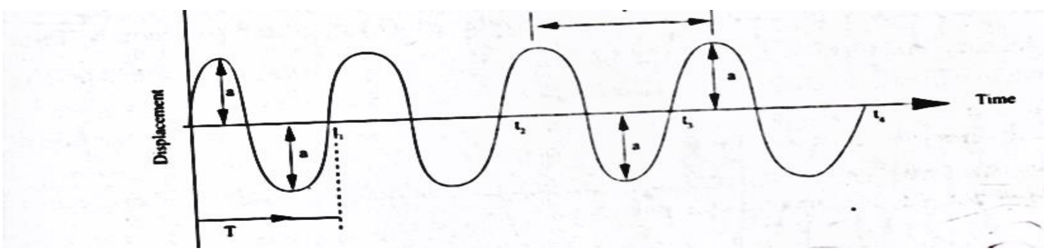
This is a wave in which the particle vibrates in the same direction as the wave. Example sound wave

It consist of rarefactions and compressions



b) Transverse waves

This is the wave in which particles vibrate at a right angle to the direction of the waves



DIFFERENCES BETWEEN LONGITUDINAL AND TRANSVERSE WAVES

Transverse	Longitudinal
Oscillations are at the right angle to the direction of the waves	Oscillations are in line with the direction of waves
Can travel through the vacuum	Cannot travel through a vacuum it needs a medium
Produces crest and troughs	Produces compression and rarefaction

Example

Fig below shows crest of straight ripples on water surface produced in a ripple tank by the wave generator.

i. What kind of the wave is represented by the crests?
   Transverse waves
ii. What is the wavelength of the ripples if there are 5complete waves in a distance of 60cm

Wavelength = 60cm/5 = 12cm 0.12m

iii. What is the frequency of the ripples if four crest pass through point **A** in one second

Frequency=4crest/1s = 4Hz

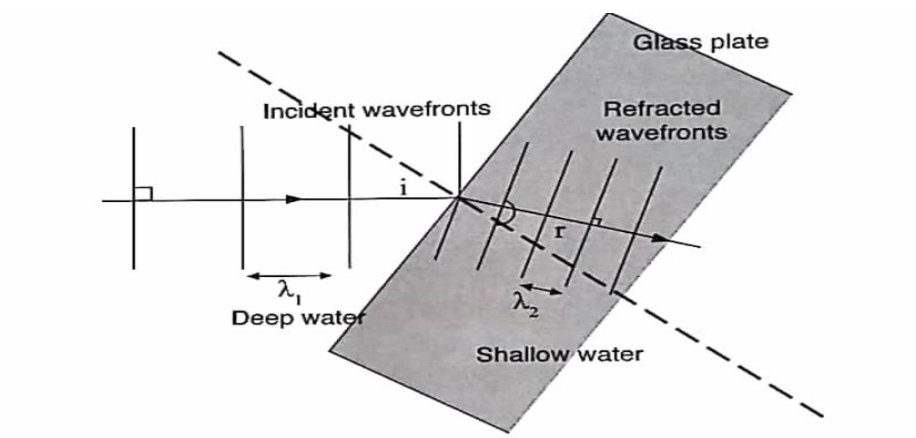
iv. Calculate the speed of the waves
Speed = frequency x wavelength
4 x 0.12 = 0.48m/s

v. What would happen to the wavelength if the waves moved from deep water to shallow water

When waves enter the shallow waters, there is no change in their frequency (as this depends on the frequency of the source/vibrator). The reduction in speed does however cause a reduction in wavelength with frequency kept constant. Refractive index of medium

Consider a wave front travelling from deep to shallow region

When the wave move from deep to shallow, the wavelength change



from h1 and h2.

From Snell's law = $\frac{\sin i}{\sin r}$=($\frac{\lambda 1}{xy}$ /$\frac{\lambda 2}{xy}$) x $\frac{\lambda 1}{xy}$ = $\frac{XY}{\lambda 2}$

$$\frac{\lambda_1}{\lambda_2}$$

Experiments proves that frequency f of the waves remains unaltered, using a wave equation v=fλ

Velocity in deep water= V= $f\lambda_1$

Velocity in shallow water = V = $f\lambda_2$

$_1\eta_2 = \frac{V_1}{V_2} = \frac{f\lambda_1}{f\lambda_2}$ therefore,

Refractive index = $_1\eta_2 = \frac{V_1}{V_2}$ = velocity in deep water/velocity in shallow

Where $_1\eta_2$ is the refractive index of a wave travelling from deep water to shallow water

Refractive index of a wave travelling from medium 1 to medium 2 is

$$_1\eta_2 = \frac{velocity\ of\ wave\ in\ medium\ 1}{velocity\ of\ wave\ in\ medium\ 2}$$

If the wave front are travelling from medium 2 to medium 1,the refractive index is

$$_2\eta_1 = \frac{velocity\ of\ wave\ in\ medium\ 1}{velocity\ of\ wave\ in\ medium\ 2}$$

$$= \frac{1}{_1\eta_2}$$

When a wave is travelling from air to a more optically dense medium, refractive index of the medium is given by

$$_a\eta_b = \frac{velocity\ of\ wave\ in\ air}{velocity\ of\ wave\ in\ a\ medium} = \frac{V\ air}{V\ medium}$$

The table below gives the refractive indices of some substances with respect to air (taking the refractive index of air as 1.00).The materials with higher refractive indices bend wave more than those with lower refractive indices.

Solid	Refractive index (η)	Liquid	Refractive index (η)
Ice	1.31	Water	1.33
Glass (crown)	1.50	alcohol	1.36
Ruby	1.65	Paraffin	1.44
Diamond	1.76	glycerine	1.47
Glass (flint)	2.40	turpentine	1.47

Example:

A light wave passing from air to glass is incident at an angle of 30^0. Calculate the angle of refraction in the glass,if the refractive index of glass is 1.50.

Refractive index of glass ${}_a\eta_b = \frac{\sin i}{\sin r}$

Sin r = $\frac{sin\ i}{\eta g} = \frac{\sin 30}{1.50} = 0.33$

r = $\sin^{-1} 0.33$

19.5^0

Example:

Calculate the refractive index of water, given that the velocity of a light wave in air is 3×10^8m/s and velocity of a light wave in water is 2.25×10^8 m/s

$\eta = \frac{velocity\ of\ light\ in\ air(c)}{velocity\ of\ light\ in\ water(v)} = \frac{3\ x\ 10^8}{2.25x10^8} = 1.33$

SOUND

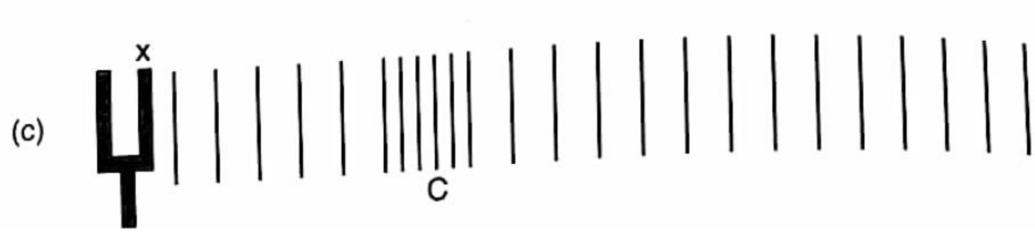
Sound is a form of wave caused by vibrating bodies.

Sound is a form of energy produced by vibrating objects.

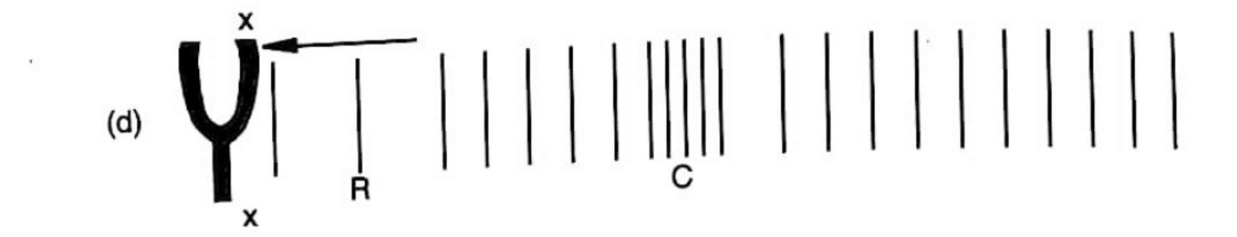
Nature of the sound waves

Consider a turning fork in a state of vibration. As prong X moves to the light, it compresses the layer of air in contact with it fig **b**.

The compressed layer passes the energy to the next layer of air molecules and returns to the original position. Thus the region of *compressions* moves to the right fig **c**.



AS prong X moves to the left, region of reduced pressure or a *rarefaction* is produced in the vicinity of fig **d**.



- The compressed air in the next layer, moves towards the left to 'equalize' the reduced pressure and hence produces another *rarefaction* to its right and so on. Thus a region of *rarefaction* moves to the right.
- As long as the vibrations are periodical, the number of times representing a compression must be equal to the number representing rarefaction and evenly spaced respectively.
- As the prong X vibrates to and fro, a series of compressions and rarefactions are produced. Each layer of air vibrates back and forth about its *mean* position along the direction in which propagation of energy takes place. Thus sound waves are *longitudinal waves.* The wavelength of sound waves is the distance between two successive compressions and rarefactions

HUMAN AUDIBLE FREQUENCY RANGES

The compressions and rarefactions produced in air by sound waves reach the eardrum of a person and force the eardrum into similar vibrations. The physical movements of the eardrum are transmitted to the brain and produce as mental sensational of hearing.

The human ear can detect sound waves of frequencies about 20 to 20000Hz (cycles per second).We cannot hear sound waves ,if the frequency is less than 20HZ or is above 20000Hz.The upper limit, however varies with persons and age ,it is higher in the case of children than in the old people. Sound waves obeys wave equation V=fλ

Therefore, the audible frequency ranges is given by:

$F_{max}=V/\lambda_{minimum}$

$F_{min}=V/\lambda_{max}$

Example

A certain animal can hear sound of wavelength in the range of 2M to 10 .Calculate its audible range of frequency. Take the speed of sound in air as 330m/s.

$F_{min}=V/\lambda_{max}$ $=\frac{330m/s}{10m}=$ 33 Hz

$F_{max}=V/\lambda_{minimum}$ $\frac{330m/s}{2M}$ = 165Hz

ULTRASONIC SOUND

Ultrasonic sound is a sound wave that have a frequency above the normal human audible frequency range. Very high frequency waves can penetrate deep sea-water without loss of energy by diffraction. Examples of sources of ultrasonic sound is ship siren and some factory sirens.

Therefore, ultrasonic sound has a fundamental frequency that is above the human hearing range i.e sound with fundamental frequency above 20 000 Hz.

The reverse of ultrasonic wave is the infrasonic. Infrasonic is a wave in which the fundamental frequency is lower than the human ear hearing range (audible range).

USES OF ULTRASONIC SOUND WAVES

Ultrasonic waves have many uses. The following are some of the uses:

1. **In medical and surgical diagnosis**
   - Ultrasonic waves are used in place of X –rays during X-radiography scanning parts of the body using an ultrasonic beam. Ultrasonic is also used to sterilize surgical instruments, jewelry and cleaning Medicare instruments. Ultrasonic waves are also used to monitor patient's heart beats, kidney, and growth of fetus (prenatal scanning) and destroy kidney stones.
2. **In industries**
- Ultrasonic waves is used in cleaning of the machine parts in industries. Objects or parts with dirt are placed in a fluid through which ultrasonic waves are passed. The waves are used in analyzing the uniformity and purity of liquids and solid particles.
3. **In fishing**
- Ultrasonic waves are is used to locate shoals of fish in deep sea by the process called **echolocation** i.e use of echo to locate an object. More interesting is that this method can detect different types of fish. This is because different fish reflect sound to different extents.
4. Ultrasonic waves are used in security system to detect even the slightest movement. Many buildings have ultrasonic motion sensors that detect motion.

Exercise 151

1. Define the term sound
2. Describe an experiment to show how sound is produced.
3. Explain the following terms in respect to sound wave:
(a) Compression
(b) Rarefaction
4. Distinguish between ultrasonic and infrasonic waves
5. An animal has audible frequency range of 40Hz to 20 000 Hz. Calculate the corresponding wavelengths of the frequencies.
6. Explain why a human being cannot hear sound above 20 000 Hz.

7. Explain how ultrasonic sound is used in:
(a) Industry
(b) Security

15.3 Characteristics of sound waves

The three main characteristics of musical sound are:

PITCH

- It is the characteristic of a musical sound which enables us to distinguish a sharp not from a hoarse one. For example, the voices of a women or of children, usually of high pitch than of men. Similarly, the noes produced by the buzzing of a bee or the humming of a mosquito is of much higher pitch than the roaring of a lion, though the latter is much louder.
- Pitch is purely qualitative and cannot be measured quantitatively. The greater the frequency of a vibrating body, the higher is the pitch of sound produced and vice versa. It should be noted that pitch is not frequency; it is a characteristic depend on the frequency. Frequency is a physical quantity and can be measured. Pitch cannot be measured.

THE PITCH OF SOUND DEPENDS ON THE FOLLOWING TWO FACTORS:

1. *Frequency of the sound produced*

Pitch is directly proportional to the frequency.

2. *Relative motion between the source and the observer*

When a source of sound is approaches the pitch of sound appears to become higher. On the other hand, if the source is moving away from the listener or the listener moves away from the source, the pitch appears to become lower. (This effect is known as the Doppler's effect).

Intensity and loudness sound

Intensity of sound at any point is the quantity of energy received per second on a surface area of 1 m^2 placed perpendicular to the direction of propagation at those points. Thus, the intensity of sound is purely a physical quantity, quite independent of the ear and can be measured quantitatively. It is measured in joule/second/m^2. ($Js^- m^{-2}$)

The loudness of sound is the degree of sensation of sound produced in the ear. It depends on the intensity of sound waves producing the sound and the response of the ear. In general, the sound waves of higher intensity are louder:

Intensity of sound depends on the following factors:

1. Amplitude of vibrating body.

The intensity or loudness 1, of sound is directly proportional to the square of the amplitude of the vibrating body.

If the amplitude of the vibrating body is doubled, the loudness of sound produced becomes two times greater.

2. Distance from the vibrating body

The intensity or loudness of sound 1, is inversely proportional to the square of the distance from the vibrating body.

Intensity $\alpha \frac{1}{d^2}$

If the distance from the source of sound is doubled, its intensity of sound becomes and so on.

3. Surface Area of the vibrating surface

Intensity directly surface area of the vibrating body

This is because the greater the area of the vibrating surface, the larger the energy transmitted to the medium and the greater is the loudness of the sound produced.

4. Density of the medium

   The intensity of sound is directly proportional to the density of the vibrating medium

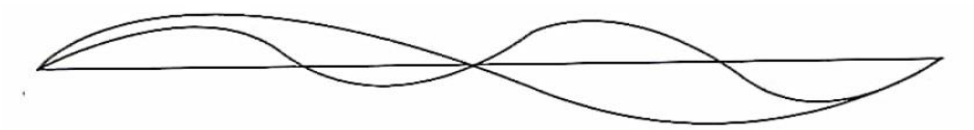
   For example, an electric bell ringing in a jar filled with oxygen produces a much louder sound than the jar filled with hydrogen. Similarly, the intensity sound of a tuning fork is much higher when the stem of the fork is placed on the table than in air.

5. Motion of the medium

If wind blows in the direction in which the sound is travelling, the intensity of sound at a point in the direction of the wind increases and vice versa. Thus, if we shout on a windy day, the sound heard is much louder at a certain distance in the direction of the wind than at the same distance in the opposite direction.

Quality (timbler) of sound

Quality is that characteristics of musical note which enables us to distinguish a note produced by one instrument from another one of the same pitch and intensity produced by a different instrument. For example two separate waves, one of which has the frequency twice that of the other. When the resultant of these two waves fall upon the ear, the ear is able to recognize the individual waves which have given rise to the resultant wave as they have different qualities (timbre)



Waves of two different frequencies

FREE, FORCED AND RESONANT VIBRATIONS

- The vibrations of the body undisturbed by the influence of any other body or system is called *free vibrations*
- The frequency of such vibrations undisturbed is called free frequency (f_0). Sometimes the body is made to vibrate with a frequency other than its own natural frequency this is called *forced vibrations*
- *Forced vibrations* is when a body is compelled to vibrate with a frequency other than its own natural frequency.
- Resonance is the phenomenon where one system in the vibrating state induces vibrations to another system both of which vibrate with the same natural frequency.

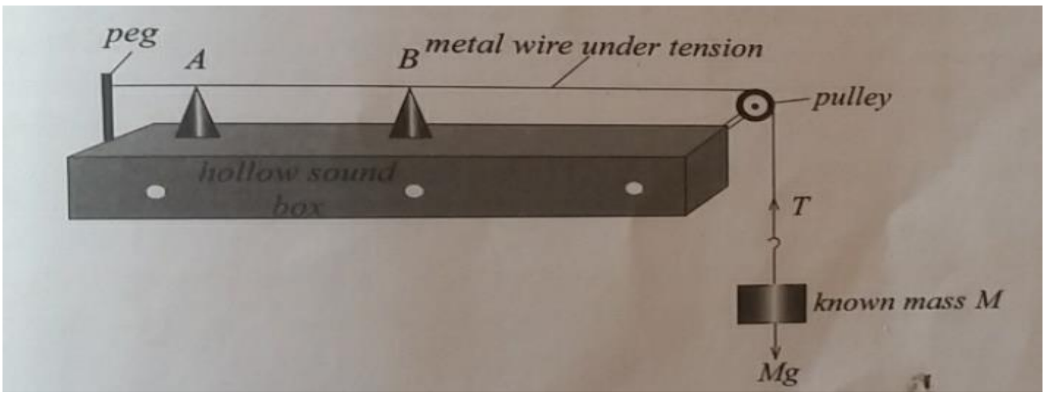
SOME REAL ILLUSTRATIONS OF RESONANCE

The following are real life situation that explain resonance.

1. Soldiers crossing a suspension bridge are warned to "break" their steps and not to march shows across the bridge in step. If they march in step, their frequency may coincide with the natural frequency of the bridge settling it into large amplitude resonant vibrations and may even come crashing down.
2. If we play a particular note on a piano, a glass bottle or a piece of china-wars placed on the top of the piano or a nearby shelf is set into resonant vibrations and may even break if the amplitude of vibration is large.
3. When a car is running at a particular speed, brisk rattling sound is heard, but the sound disappears if the speed changes. The sound is due to resonance taking place between the car engine and the rattling object.
4. Modern toys are constructed in a way that they are able to respond to a particular word command. This is due to the resonant vibrations of a "disc" placed inside them when sound of a particular frequency falls on them.
5. In a radio or a transistor receive set, a large current flows in a particular circuit called the "tuning" circuit, if the frequency of the electrical vibrations of the circuit coincides with the frequency of one of the radio waves in the atmosphere. Different radio stations in the world broadcast news at different frequencies.

SONOMETER

A sonometer or a monochord consists of a metal wire stretched across two wooden bridges A and B placed on a hollow wooden sound box, about a meter long. One end of the wire is tied to a peg one end of the box. The other end passes over a smooth pulley fixed at the other end of the sound box and carries a hanger or a pen on which the desired weights may be placed (fig below). The bridge B can slide along to have a suitable desired length of the wire between A and B. The tension, T in the wire (T=mg) keeps the wire taut.



Experiment 15.2: To demonstrate resonance with a sonometer

Apparatus

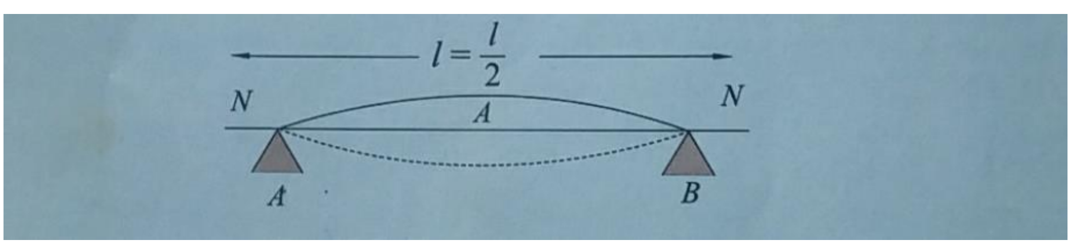
- A Sonometer
- A Tuning fork

Procedure

1. Set tuning fork of known frequency into vibration
2. Press the stem of vibration the tuning fork gently on the sonometer box.
3. Gradually alter the position of movable bridge and observe the vibrating wire.

OBSERVATION AND DISCUSSION

When resonance takes place for the first time, the length 1, of the wire as shown in Figure below



The positions of the bridges A and B act as nodes, (N,N) with an antinode (A) in the middle of the wire. Now the frequency of the wire is called the *fundamentalfrequency*.

Note Since $f_{wire}=f_{tuning\ fork,}$ and 1 $=\frac{l}{2}$, we can calculate the speed of sound waves v in the wire, v=f = f (2*l*).

MUSICAL SOUNDS

Musical sound and noises

In general, sound may be roughly classified as either (a) musical sounds (b) noises. If we pluck the string of a guitar or a stretched sonometer wire or set a tuning for into vibrations, the sound produced by thunder clouds or the rattling sound of some of some parts of a car, the sound produced have an unpleasant effect on the ears. A sound of which appears pleasant to the ear is called musical sound whereas that which produces an unpleasant or jarring effect on the ear is called a noise. The curves shown in Fig.15.10 (a) and (b) bring out the difference between noises and musical sounds.

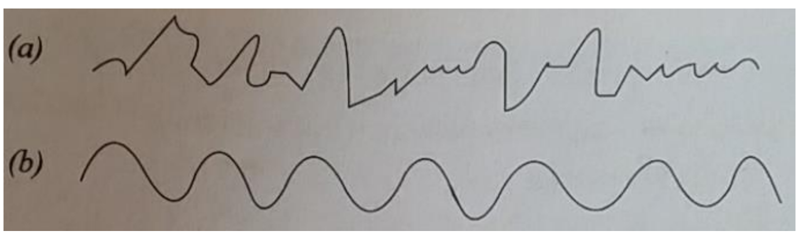


Fig.15.10 (a) Noise (b) Musical sound

Musical sound is *regular* and *periodic* with pulses following each other very rapidly produce the sensation of a continuous sound. Noises, on the other hand, are generally *sudden* and have no regular period; and are usually complex in nature.

15.5 propagation of sound

Sound waves cannot be transmitted through a vacuum. The transmission of sound waves requires at least a medium which can be a solid, liquid or a gas.

SPEED OF SOUND IN SOLID, LIQUID AND GAS

- The speed of sound is different in solids, liquids and gases. The arrangement of particles in matter determines how fast sound can travel in matter.
- The speed of sound in water is about 1 500 m/s and in steel about 5 500 m/s.
- Comparison of the speed of sound in solids, liquids and gases

  The speed of sound varies in solid, liquid and gas.

- The speed of sound is higher in liquids than in gases and slower than in solids
- The speed of sound is faster in solid than in liquid because the particles or atoms in solids are closely packed. This makes it easier for particles to transmit sound from one point to another
- The speed of sound in liquids is faster than in gas because the particles in liquids are relatively closer than those in gas
- Therefore the speed of sound is slowest in gases.

LIGHTNING AND THUNDER

- About the middle of the 18^{th} century, an American Scientist Benjamin Franklin demonstrated that charged thunder clouds in the atmosphere produce thunderstorms. These thunderstorms produce a lot of sound which we hear as thunder on the earth. Due to the spark discharge occurring between two charged clouds or between a cloud and the earth, electric spark discharge, called lightning occurs. Though the sound due to thunder is produced first, we see the flash of lightning first and after a few seconds we hear the sound of thunder. This is due to the fact that light travels much faster than sound in air. Experiments have proved that the speed of light in air (or vacuum) is 3.0×10^8m/s.

Example 15.2

The time interval between "seeing" the flash of lightning and "hearing" the sound of thunder clouds is 5 seconds.

(a) Calculate the distance between the thunder clouds and the observer on the earth.
(b) Explain why the calculated distance is only approximate. (speed of sound in air = 330 m/s)

Solution

(a) Speed of sound $= \frac{distance}{time}$

$$V = \frac{x}{T}$$

The distance between the thunder clouds and the observer is 1650 m

(b) The clouds may be moving

FACTORS AFFECTING THE SPEED OF SOUND IN GASES

Density

The higher the density of a gas, the higher the speed of sound. For example, the density of oxygen is 16 times higher than the density of hydrogen hence sound travels faster in hydrogen than in oxygen (speed of sound in hydrogen= 4 x speed of sound in oxygen).

Humidity

Moist air containing water vapor is less dense than dry air. The density of water vapour is about 0.6 times that of dry air under the same temperature conditions. If the humidity of air increases, density of air decreases hence the speed of sound in air increases.

Early in the morning the percentage of humidity of air is more and sound travels faster in the morning air.

Pressure

The speed of sound is not affected by any change in pressure provide temperature is constant. For example, on a day when the temperature and humidity of air is the same in Lilongwe and a city at the sea level, the speed of sound is the same in the two cities, although the air pressure in Lilongwe is lower than that at the city situated at the sea level.

Temperature

A change in the temperature of a gas changes its density and hence affects the speed of sound through it. If temperature increases, and hence the speed of sound increases. If temperature decrease the reverse is the effect.

Wind

Wind "drifts" air through which the sound waves travel. If air blows in the direction of sound, then the speed of sound increases. The speed of wind is added to the speed of sound in air, to get the resultant speed of sound. If wind blows in the opposite direction to that of sound, then the sound travels more slowly.

Table 15.1 summaries how the speed of sound in matter is related and their corresponding reasons.

Table 15.1

Matter	**Speed of sound**	**Reason**
Solid	Fastest	Particles are closely packed
Liquid	Medium	Particles loosely packed
Gas	Slowest	Particles are very far apart

Exercise 15.2

1. Explain why the speed of sound in solid is faster than the speed of sound in air.
2. Name two factors that affect the speed of sound in air
3. State the characteristic of sound waves
4. Explain why at night sound from a source is clear than during hot daytime.
5. Describe two factors that affect the affect the pitch of sound
6. Define the following terms
   (a) Resonance
   (b) Quality
7. Distinguish between music and noise
8. Explain the factors that affect the frequency of sound
9. During thunder and lightning, there are two types of waves produced.
   (a). Name the two waves
   (b). Which one reaches the ground first? Explain.
10. Sound is a longitudinal wave. How is it propagated? Describe an experiment to demonstrate the fact that sound is actually produced by vibrating body.

REFLECTION OF SOUND WAVES

- Just like light, sound waves undergo reflection on striking plane hard surface as well as curved surfaces.
- The angles of incidence and reflected rays are equal. Both incidence waves and the reflected waves lie in the same plane as the normal to the reflecting surface. We can then conclude that sound waves obey the laws of reflection as is the case with light wave.
- When sound waves meet a boundary between one medium and another a part of it is reflected, a part is refracted and the remaining part is absorbed. The relative amounts of these parts are determined by the size and the nature of the boundary under consideration. The proportion of energy reflected is greater in the case of hard substances such as stone and metal. An echo, a reflection of sound, is frequently heard in mountainous regions. There is very little reflection from cloth, wool and foam rubber. Sound which is incident on such soft materials is mainly transmitted through them or absorbed. In places where the effect of echo has to be illuminated, e.g musical recording room and concert halls, soft materials are used to line the walls of the hall.

Uses of Reflection of sound

1. Sound waves can be used to measure the speed of sound in air by reflecting sound at hard surfaces.
2. In public halls and churches, parabolic sound reflection is often placed behind the speaker. It reflects the sound waves back to the audience and thus increasing the loudness of the sound.

3. Sound waves undergo a total internal reflection just like light. Speaking metal tubes that are used to pass message on ships use total internal reflection of sound waves.

DETERMINING SPEED OF SOUND BY ECHO METHOD

Activity 15.7: To produce an echo

Stand about 100m away from a cliff or a large hard surface such as the wall of a building and clap your hands. What do you hear?

In Activity 15.7, you will hear two sounds; the one you produce and the reflected sound.

The reflected sound produced is called an echo. An echo is a reflection of sound from a large hard surface.

Activity 15.8

- Stand about 100 m from an isolated, large hard surface or a stone wall.
- Shout loudly and start a stop watch at the same time. Stop the watch on hearing the echo. Find the time interval between the production of the loud noise and hearing the echo.
- Repeat this a number of times and find the average time taken.

Note

For activity 15.8 to be more accurate:

1. A large obstacle, e.g. a cliff or a wall is needed. This is because the wavelength of sound waves is large.
2. A minimum distance between the source and the reflecting surface is required. This minimum distance, called Persistence of hearing is about 17m.

In Activity 15.8, you should have noticed that an echo is heard after some time interval. During this time, the sound travels to and from the hard surface covering twice the distance.

The speed of sound in air is given by the formula:

Speed= $\frac{total\ distance\ covered}{total\ time\ taken}$

Distance from the wall is *d*, meters.

Average time interval between the production of sound and hearing its echo is *t seconds.*

Total distance travelled by sound is *2d* meters.

Speed= $\frac{total\ distance\ covered}{total\ time\ taken}$

$= \frac{2d}{t}$

The speed of sound in air is given by $\frac{2d}{t}$

Example 15.3

A girl standing 100m from a tall wall and bangs two pieces of wood once. If it takes 0.60 s for the girl to hear the echo, calculate the speed of sound in air.

Solution

Speed of Sound, v = $\frac{total\ distance\ covered}{total\ time\ taken}$

$\frac{2x100}{0.6s}$ = 330m/s

The speed of sound in air is 330 m/s

Exercise 15.3

1. How is sound propagated?
2. Define the term echo.
3. A person stands infront of a wall and makes a loud sound. She hears the echo after 1.55. If the speed of sound is 333 m/s. Calculate the distance between the person and the cliff.
4. A person standing 150 m from the foot of a cliff claps and hears an echo after 0.9 s. What is the speed of sound in air?
5. Apupil, standing between two cliffs and 500m from the nearest cliff clapped his hand, and heard the first echo after 3 s and the second echo 2 s later. Calculate:
   (a) The speed of sound in air
   (b) The distance between the cliffs.
6. An echo of the sound produced by a whistle is heard after 0.50 s. If the speed of sound in air is 332 m/s, find the distance between the whistle and the reflecting surface.

15.6 Sound pollution

Sound is a very important form of energy. Human beings and animals use sound as a way of communication. But if sound is unorganized, it becomes noise. Any unwanted sound becomes a nuisance and leads to pollution in form of noise. Therefore, sound pollution is a type of pollution caused by undesirable or unwanted sound. Sound pollution can cause damages to eardrum or hinder communication. Sources of sound pollution are: very high music from discos, concerts, celebrations, factory sirens etc. Everybody is encouraged to minimize sound pollution at all cost. The government through some agencies must prohibit sound pollution by enacting some laws to govern this. The following are some of the ways used to minimize sound pollution.

1. Factories are encouraged to use sound sirens that are environmental friendly. Most of them use the normal fire alarms.
2. During construction of musical concert halls, the constructor should use materials that absorb most of incident waves of sound to avoid reverberation (reflected multiple sound).
3. Proper laws must be enacted by the government to reduce sound pollution
4. Proper education of the citizens on sound pollution should be done to sensitize them on the important of reducing sound pollution.

LIGHT

LENSES

This is the transparent medium bound between the two surfaces of definite geometrical shape. Lenses are made from different shapes and from different types of glasses.

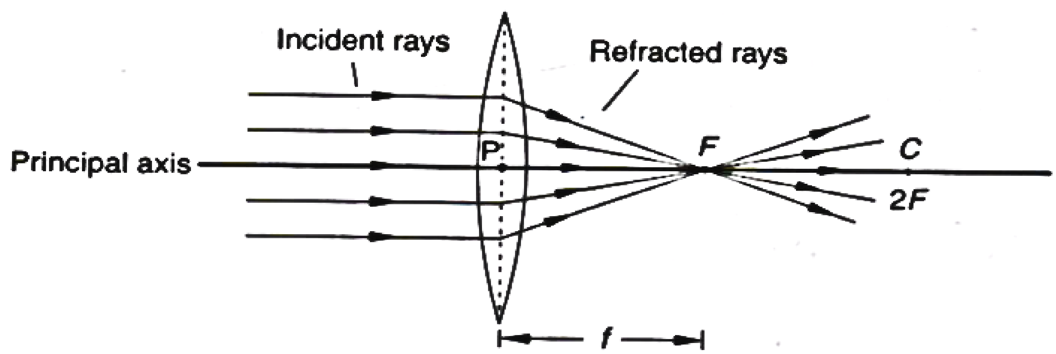
TYPES OF THE LENSES

- ***Converging (convex) lens***

  Convex lens is thicker at its centre than at its edges .It converge light rays incident on it. Examples of convex are Bi-convex, Plano-convex and concavo-convex.
- ***Diverging (concave) lens***

  Concave lens is thicker at its edges than at its centre and diverges the light ray's incident on it.

  Examples of concave are bi-concave or double concave, Plano-concave or convexo-concave.



PARTS AND TERMINOLOGY

- Optical centre is the centre of the lenses
- Principal axis (PA) is the line passing through the centre of the lenses perpendicular to the lens
- Principal focus or focal point is a point where the emergent light rays meet
- Focal length (F) is the distance from optical centre to the focal point

- Focal plane is an imaginary plane through the principal focus and perpendicular to the principal axis (PA)
- Beam of light is the collection of light rays all moving together and they are parallel to each other.
- Object distance it is the distance between lens and object
- Image distance is the distance between lens and image
- Object is the real thing
- Image it is the picture of the real thing

LOCATING IMAGES BY RAY DIAGRAM

- To locate the image of an object, we need a minimum of two incident rays from the object. From the three standards any two incident rays and their corresponding refracted rays can be drawn to locate the image.
- If the refracted rays converge ***areal image*** is formed
- If the refracted rays diverge a ***virtual image*** is formed

Characteristics of images

(i) Virtual or real

- A virtual image cannot be formed on a screen for example a mirror images
- A real image can be obtained on a screen for example projector

(ii) Magnified or Diminished or same size

- A magnified image has m>1: image is larger than object
- A diminished image has m<1: image is smaller than object
- Same size image has m=1

(iii) Upright (erect) or inverted (upside down)

- Upright/erect-image is in the same direction as object
- Inverted/upside down-image is in the opposite direction as object

HOW TO FIND MAGNIFICATION OF AN IMAGE

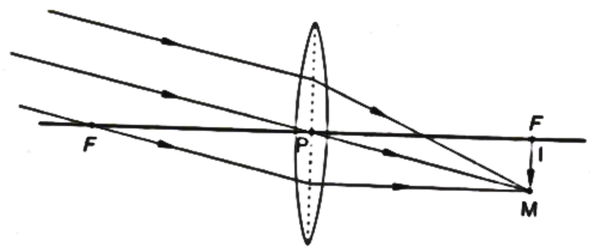
- Magnification = image height/object height $=h_2/h_1$
- Magnification = image distance/object distance = v/u

Object at infinity (object very far)

Since the object is at infinity, all the rays from the object, incident on the lens are almost parallel. The image is formed at **F**

Image characteristics

A *diminished, real, inverted* image is formed at *F*.



Characteristics of images

- Diminished
- Real
- Inverted
-

Object OB just beyond 2F

Image is formed between F and 2F

Object OB just beyond C (2F)

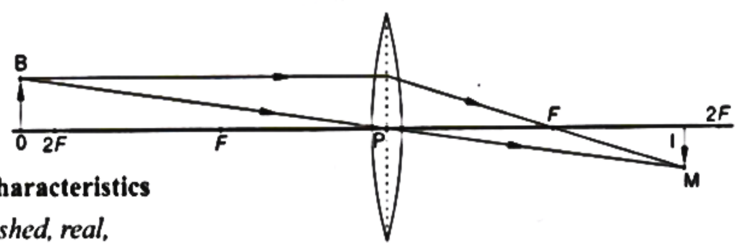


Image characteristics

A *diminished, real, inverted* image is formed between *F* and 2*F*.

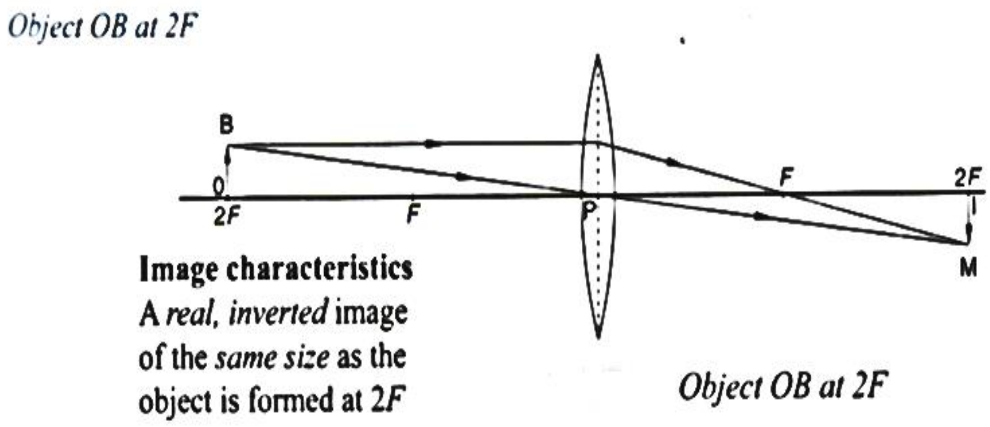
Fig. 2.13: Object OB just beyond 2F

Characteristics of images

- Diminished
- Real
- Inverted

Object OB at 2F

Image is formed at 2F



Characteristics of images

- Real
- Inverted
- Image is same size as object at 2F

Object OB between 2F and F
Image is formed beyond 2F

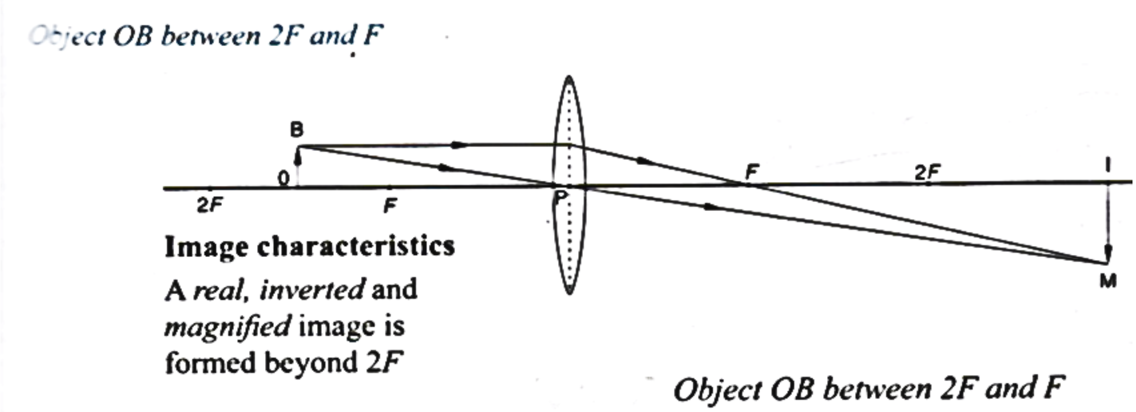
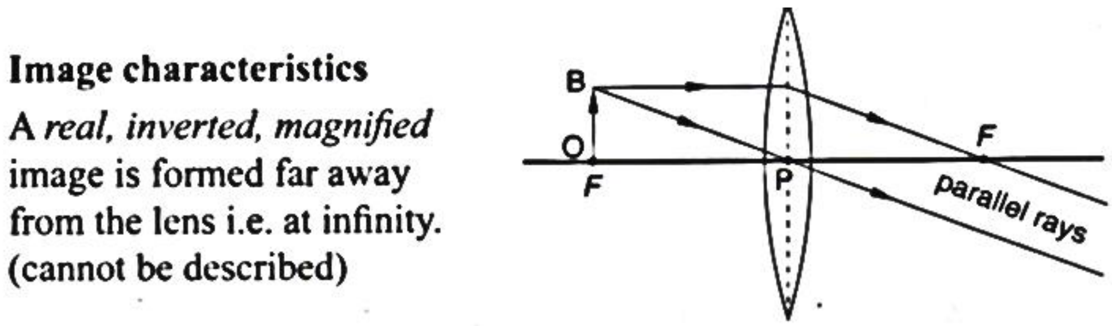


Image characteristics

- Real
- Inverted
- Magnified

Object OB at F
The refracted rays are nearly parallel and converge an infinity
Image is formed far away from the lens i.e. at infinity (cannot be described)



Object OB at F

Image characteristics
- ➢ Real
- ➢ Inverted
- ➢ Magnified

Object OB between F and the lens i.e. very close to the lens

The refracted rays diverge and when produced backwards a virtual image is formed.
This is formed on the same side as object.

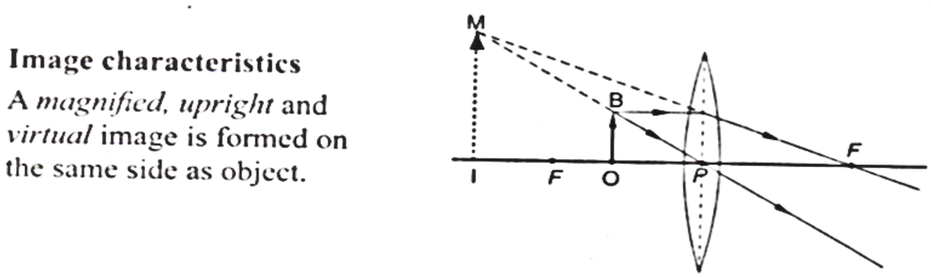
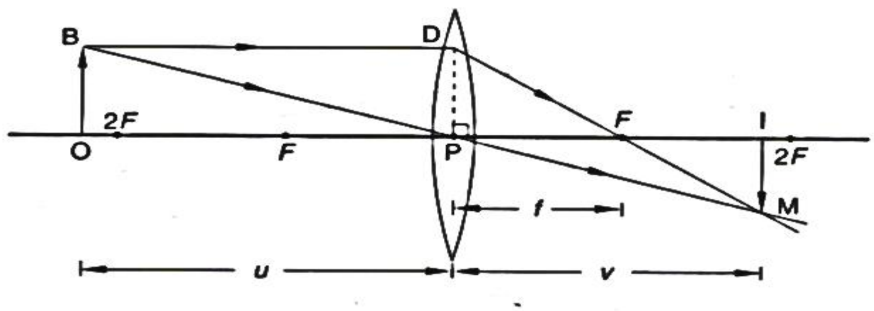


Image characteristics
- ➢ Magnified
- ➢ Upright
- ➢ Virtual image

DETERMINATION OF FOCAL LENGTH

- ➢ By lens Formula

  Convex lens of focal length f which forms a real image IM of an object OB as shown below



Triangles OBP and IMP are similar (3 are equal)

OM/IM = OP/IP…………….. (1)

Draw a line DP perpendicular to the Principal axis where DP = BO
Triangles DPF and IMF are similar (3 angles are equal)
DP/IM = PF/IF………….. (2)
Since DP = OB, from equations (1) and (2)
OP/IP = PF/IF
U/v = f/v-f
Cross multiplying
UV – uf = VF
Dividing both sides by uvf
Uv/uvf – uf/uvf = vf/uvf

1/f = 1/u + 1/v

1/f = 1/u + 1/v

Example
An object of height 1.2cm is placed 12cm from a convex lens and real image is formed at 36cm from the lens. Calculate (a) the focal length (b) magnification produced by the lens (c) the size of the image

- The focal length

    From the lens formula,1/u + 1/v = 1/f
    1/12 + 1/36 = 1/f
    3+1/36 = 1/f
    1/9 = 1/f
    F = 9cm
    Focal length of the lens 9cm

    - Magnification

$M = v/u = 36/12 = 3$

- The size of the image

$M = h_1/h_0$

$3 = h_1/1.2$

$h_1 = 3 \times 1.2$

$= 3.6$

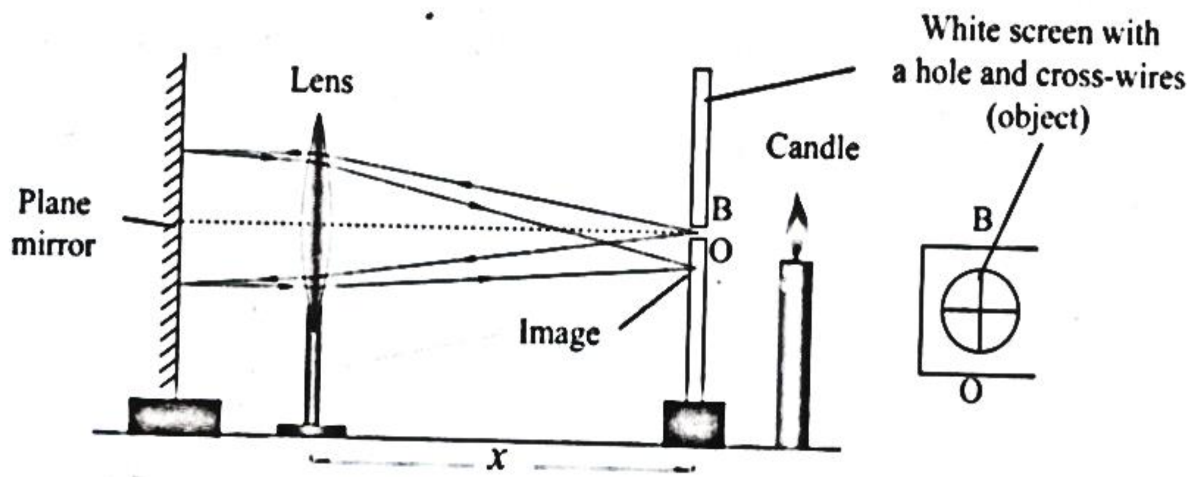
Size of the image is 3.6cm

- By experiment method
- Rough/estimation method

A distant object is focused on a screen

Measure the distance from the lens and the screen. This distance is the focal length

- Plane mirror method



The object, lens and the mirror are put in a straight line

The screen is placed beside the object

The light rays from the object passes through the lens and reach the mirror

The mirror reflects back the light rays which travel parallel to the PA and pass through the lens to form an image on the screen

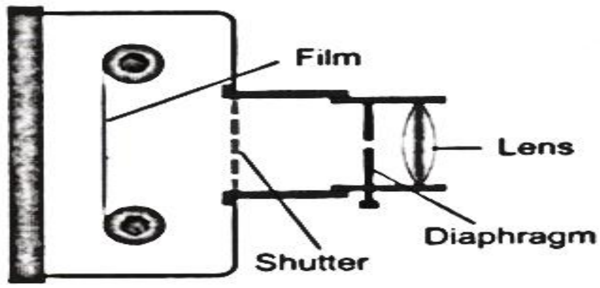
The focal length is the distance from the lens to the image i.e. F - U = V

- Graphical method

OPTICAL INSTRUMENT

1. The camera

A camera is a device used to take photographs.



A camera consists of a converging lens and the light sensitive film of plate enclosed in a light tight blackened from inside.
The lens focuses light from an object to form a real, diminished and inverted image on the film. Focusing of the objects is done by adjusting the distance between the lens and the film.

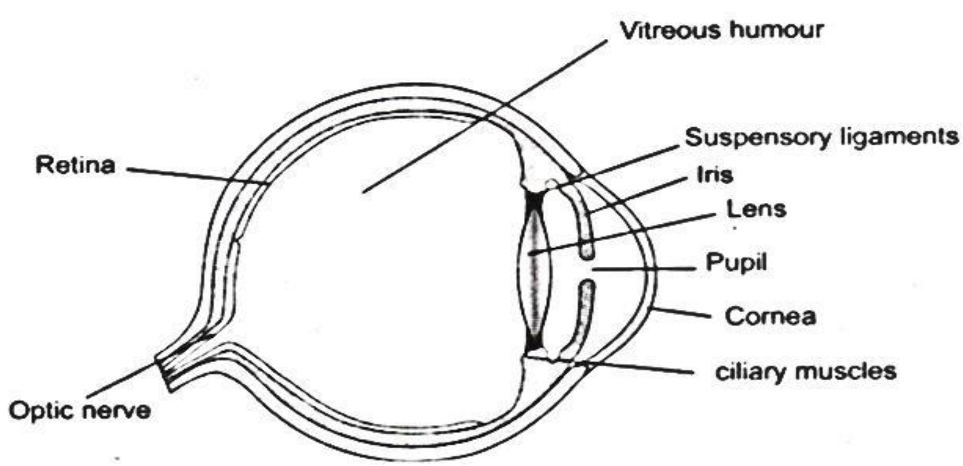
HOW CAMERA WORKS

Light is admitted by the shutter which opens for different required intervals of time and then closes automatically. During this interval of time, then film is exposed to light from the object. The film contains the light sensitive chemicals that change on exposure to light. The film is then developed to get what is called *negative* from the negative a photograph (positive) may be printed.

Functions of parts of the camera

- Aperture: allow light to pass through
- Lens: focuses the image on the film
  Converge light on to the film
- Shutter or diaphragm: controls the amount of light entering the camera
- Film: it is where the image is formed or produced.

2. The Human eye



Functions of parts of the human eye

- Iris: controls amount of light entering the eye

- Pupil: allow the light to enter
- Lens: converge light to retina or focus image on the retina
- Retina: where image is formed

Similarities between camera and the eye

- Both use converging lens
- Both produce a real, inverted, diminished images
- Both can control the amount of light entering the device
- Both are black inside

Differences between eye and camera

Eye	Camera
Focal length of the lens changes with the thickness of the lens	Focal length of the lens is constant
Distance between the lens and the retina is a constant	Distance between the lens and the film is altered
Focuses objects between 25cm from the lens	Focuses objects between a few centimeters from the lens to infinity
Form temporary images at the retina	Form permanent images at the film

Accommodation is the changing shape of lens to focus image.

Image formation in the eye

When one looks at far objects the eye lens become thinner and the focal length of the lens increases. The ciliary muscle is relaxed and the lens has the longest focal length, this enables it to focus rays from distant objects onto the retina.

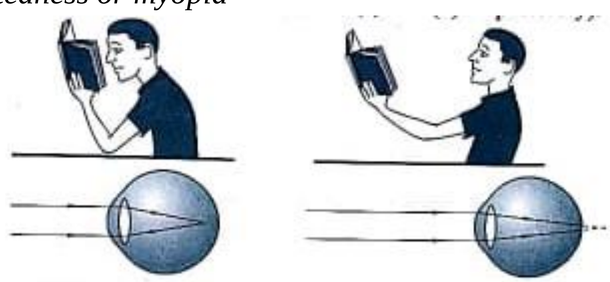
To view closer objects, the lens becomes thicker and the focal length of the lens decreases. The ciliary muscles contract to reduce tension in the lens and the lens becomes more curved with short focal length as more powerful. The lens focuses images of near objects into the retina

The accommodation

This is the process whereby the lens of the eye changes its focal length and produces focused images of both distant and near objects on the retina

Defects of vision

a) *Short-sightedness or myopia*



(a) Short-sightedness (b) Long-sightedness

This is ability to see nearby objects. The image of a distant object is formed in front of the retina

This arises due to the eye ball being too long or more refraction takes place at the cornea and hence the focal length of the eye lens becomes short

This is corrected by concave lens of appropriate focal length should be used. This lens diverges the rays from distant objects so that they appear to come from a virtual image formed at a point closer to the lens.

b) *Long sightedness*

This is ability to see the distant objects Cleary but cannot see clearly objects lying closer than a certain distance

This is caused by due to the eyeball being too short or due to the curvature of the cornea being defective and the focal length of the lens becoming longer.

This can be corrected by using convex lens of appropriate focal length. This lens converges the ray from near object so that they appear to come from virtual image formed at appoint far off from the lens.

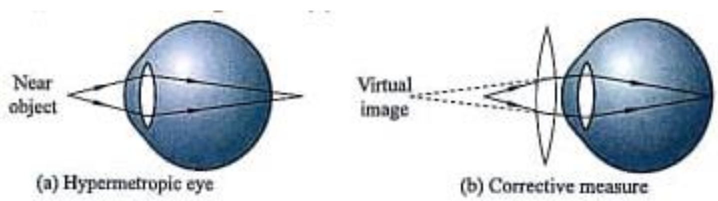
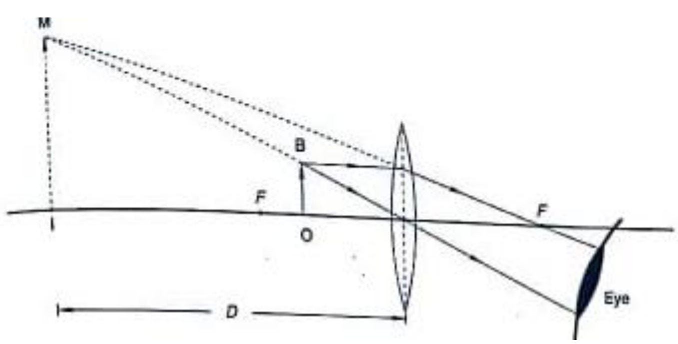


Fig. 12.36: Long-sightedness and the corrective measure.

3. Simple microscope

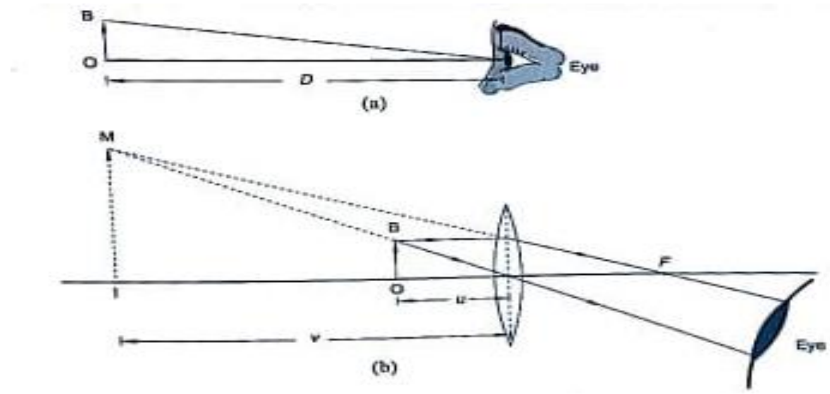
A magnifying glass also known as *simple microscope* is an instrument used to view details of every small objects.

It consists of a single converging lens of short focal length. When an object is placed within the focal length of such a lens, a magnified image which is virtual and upright is formed on the same side of the object. This image can be viewed by placing the eye close to the lens.



The action of a simple microscope

The object OB, when viewed by an unaided eye, cannot be brought closer to the eye, than distance Otherwise the image as seen by the eye will not be clearly visible. When the same object is viewed the magnifying glass, it moves nearer to the eye so that a magnified image is formed at the same distance. Therefore, a simple microscope enables us to bring an object very close to the eye making it appear magnified and clearly visible.



Magnifying power of a single microscope

Linear magnification m=$\frac{IM}{OB}$=$\frac{v}{u}$

Linear magnification of the lens is also *magnifying power* of the instrument. In a simple microscope, the v is negative as the image is virtual. Hence from the lens formula $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$ multiplying throughout by v and simplifying

$$M=1+\frac{v}{f}$$

From above expression, the shorter focal length of the lens, the greater is the magnifying power of the instrument therefore simple microscope uses converging of short focal length.

Example

Calculate the magnification produced by a lens of focal length 5 cm used in a simple microscope, the least distance o distinct vision being 25 cm

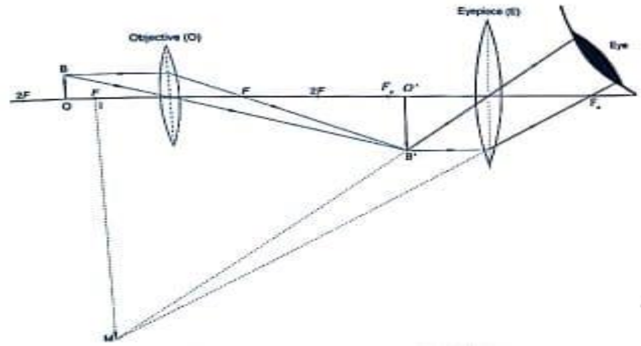
Image distance v=D=25cm

$$\mathbf{M=1+\frac{v}{f}}$$

$$\mathbf{1}+\frac{25}{5}=6$$

4. Compound microscope

A compound microscope uses two separate converging lens placed coaxially within two sliding tubes, to obtain a higher magnifying power. The lens O nearer the object is called *objective lens* and the lens E closer to the eye is called *eyepiece lens.* The eyepiece has longer focal length than the objective lens. The final image formed is magnified, virtual and inverted



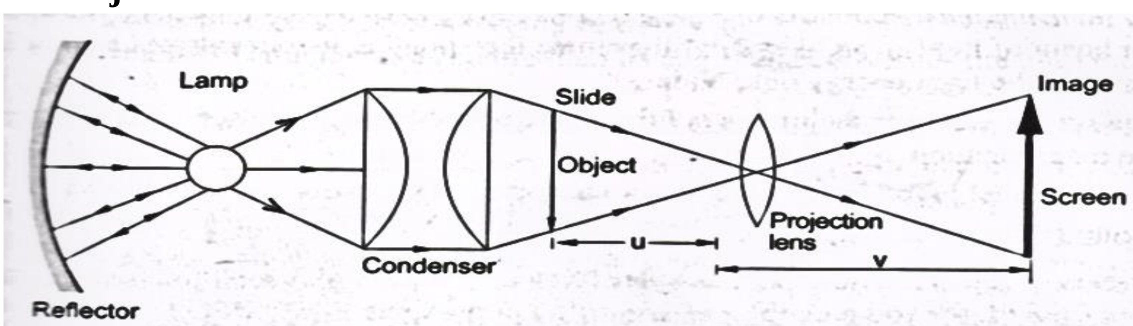
Action of compound microscope

The object OB is placed between F and 2F of the objective lens. A real, inverted, magnified image O'B' is formed beyond 2F of the objective lens. The position of the eyepiece lens is adjusted so that this image O'B' falls within its focal length. The eyepiece then acts as a magnifying glass and produces a final magnified, virtual and inverted image IM at a distance of distinct vision D from the eye, placed very to the eyepiece. If m_1 is the magnification produced by objective lens and m_2 is the magnification produced by the eyepiece lens, then the magnification produced by the system of lenses m is given by

$$M = m_1 \times m_2$$

A good compound microscope produces a very high magnification. The high magnification microscopes are usually used in research work in science.

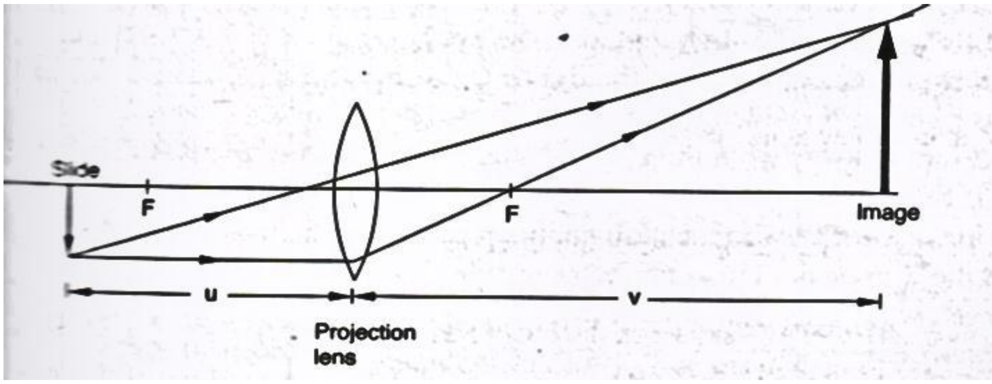
5. **Projector**



A quartz-halide Lamp: placed at the centre of curvature of a concave reflector. This is very bright source of light

- Reflector: reduces of the loss of light
- Condenser: consists of Plano-convex lens arrangement which concentrates the light energy from the lamp in the direction of the slide.

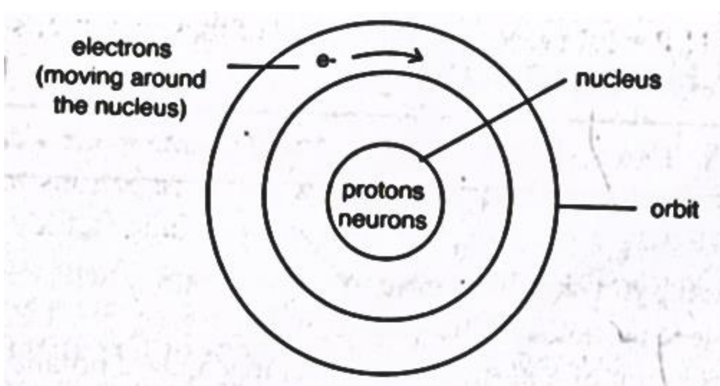
- The slide: contains pictures to be viewed on the screen. The slide is introduced in the projector upside down so that the images seen on the screen are the right way up. The slide is positioned such that 2f>u>f to form magnified real images.
- The projector lens: the projector uses one lens to form an image on the screen



The image produced is real, magnified and inverted. Since the distance v is large compared to the distance u, the image is highly magnified (m = u/v)
- Condensing lens: consists of a pair of the converging lens called condenser. It controls the beam of light so as to evenly illuminate the slide i.e. it concentrates as much as possible the light energy onto the slide.

The screen: this is where the image is formed.

NUCLEAR PHYSICS



This is the study of vast amount of energy that can be obtained from the nucleus of the atom and which can be released in nuclear reactions

NUCLEAR STRUCTURE OF THE ATOM

The atom is made up of protons, electrons and the neutrons. A nucleus is found inside the atom.
It is made up of neutrons and protons
A proton is positively charged particles
An electron is negatively charged particle that rotates around the nucleus at very high speed. An electron has negligible mass.

A neutron has equal number of positive charges and negative charges hence a neutron is considered to be neutral.

NUCLEAR NOTATION

The number of protons in the nucleus is called atomic number (Z)
Mass number (A) is the number of protons and neutrons (which collectively is called nucleons)
${}_Z^A X$

A is atomic MASS
Z Is atomic number
X is an element symbol
Examples
${}^{14}N_7$–means Nitrogen whose mass number is 14 and atomic number 7
${}_{-1}e^0$ represents an electron whose mass is negligible and the charge number is -1 i.e. equal but opposite to that proton
${}_0n^1$ represents a neutron whose mass is one atomic mass unit and charge 0 (neutral)

ISOTOPES

These are atoms of the same element with equal atomic number (Z) but different mass numbers (A)
The mass numbers are different due to difference in number of neutrons
Isotopes have identical chemical properties since they have the same number of electrons and they are in the same group.

Examples of the isotopes
${}_6^{12}C$ and ${}_6^{14}C$

${}^{23}{}_{11}Na$ and ${}_{11}^{24}Na$

${}^1{}_1H$,${}^2{}_1H$(deuterium) and ${}^3{}_1H$ (tritium)

Example

Chlorine isotopes exist in the ratio 3:1. That is the 3 atoms of mass number 35 and 1 atom of mass 37. Find the average atomic mass.
$\frac{3}{4}$x 35 + $\frac{1}{4}$ x 37 (Find the sum of the product of the ratios)

=35.5

TYPES OF THE ISOTOPES

Natural isotopes----- this occurs naturally e.g. carbon(c)=12 C = 14
Artificial isotopes-----this occurs artificially e.g. oxygen=17

RADIOACTIVITY

This is the random, spontaneous disintegration of certain atomic nucleus with the emission of different types of radiation such as alpha (α), beta (β) and/or gamma rays (γ)

STABILITY OF THE NUCLEUS

The nucleus will be unstable if it has

- Too many neutrons
- Too few neutrons
- Too many nucleons altogether i.e. it's too heavy
- Too much energy

WHAT CAUSES RADIOACTIVITY

When the atomic masses of the element become so large, the nucleus become unstable and breaks up producing two or more other elements or throw off energetic particles and emit energy in form of radiation.

As the atomic mass increases the neutrons also increases usually the increase in the neutrons (N) is more than the increase in the protons (P)
Atoms whose ratio of N: P=1:1 are very stable. Most of these are atoms of elements with atomic numbers between 1 and 20. When the ratio N: P is much greater than certain range, and then the atoms become unstable and emit some particles and/or radiations to become stable.
The energy required to break the nucleus is called the **Binding energy**

RADIOACTIVE DECAY

This is disintegration and emission of particles and/or radiations to form more stable elements.

WHY IS RADIOACTIVITY RANDOM PROCESS?

It is not possible to predict which atoms are going to decay and when they are likely to decay

WHY IS RADIOACTIVITY SPONTANEOUS IN NATURE?

It is not affected by environmental factors such as temperature, pressure and rainfall

TYPES OF RADIATION

Alpha (α) particles

Nature: it is a positive nucleus of helium atom ($^{4}_{2}He$) having two protons and two neutrons
When atomic mass of radioactive substance is greater than 210, alpha particles are emitted

PROPERTIES OF ALPHA PARTICLE

i. They are deflected by magnetic and electric field and are attracted to the negative side
ii. They travel in a straight line in a free space
iii. They have less penetration power, they are blocked by the paper
iv. They have high ionization power
v. They are big and heavy with slow movement

Beta (β) particle

Nature: it is a fast-moving electron

They are streams of high energy electrons

Beta particles have no mass and are negatively charged. Lack of mass it makes beta to be light

In a beta emission, a neutron decays (changes) to a proton and an electron. The electron is emitted and the proton remains in the nucleus but the electron is emitted

neutron→proton+electron

The atomic number of the new element is increased by 1 but the mass number does not change.

When the atomic number of the radioactive material is less than 210 beta particles is emitted

PROPERTIES OF BETA PARTICLE

i. Has less ionizing power than that of alpha (α) but more ionizing power than gamma rays
ii. It has more penetrating power than alpha (α) but less than of gamma rays(γ)
iii. It is easily deflected by magnetic field and electricity field because it has a negative charge.
iv. They have varying velocities and ranges in air

GAMMA RADIATION

Nature: Gamma ray's electromagnetic waves with shorter wave length

These are electromagnetic radiation traveling at the speed of light

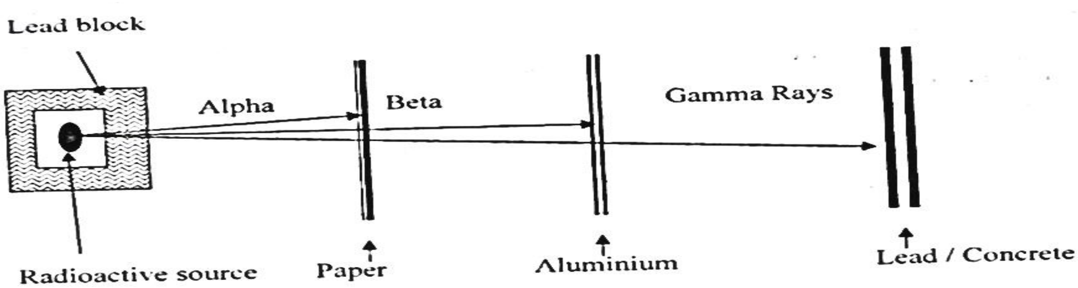
HOW GAMMA IS EMITTED

After emission of alpha or beta particles from the atom. The particles inside the atom is left in an excited way so as they are trying to re arrange themselves high amount of energy is emitted inform of gamma rays

PROPERTIES OF GAMMA RAYS

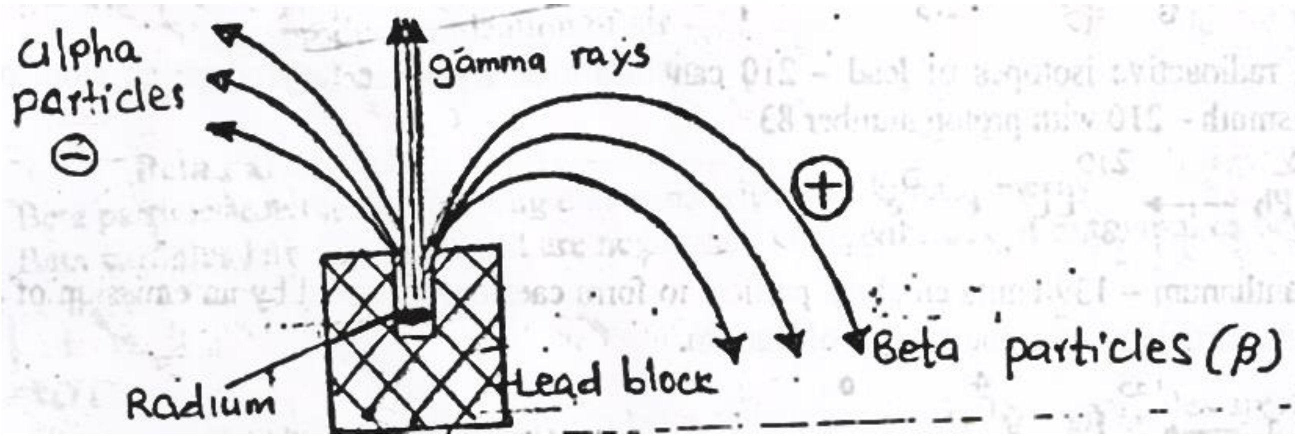
i. They have greatest penetration power
ii. They are not deflected by magnetic field and electric field because they have no charge.
iii. They have least ionizing power of the three radiations

PENETRATION POWER OF ALPHA, BETA AND GAMMA RAYS IN DIFFERENT MATERIALS



Alpha is blocked by sheet of paper, beta penetrates the sheet of paper but it is blocked by aluminium foil and gamma rays are blocked by lead but it penetrates sheet of paper and aluminium foil.

DEFLECTION IN MAGNETIC FIELD



Alpha particle is attracted to the negative because it is positively charged Helium atom
Beta particle is attracted to the positive plate because it is a negatively charged
Gamma is not deflected because it is neutral

NUCLEAR EQUATIONS

Alpha emission

During an alpha particle emission, 2protons and 2neutrons are emitted spontaneously from the nucleus of an atom of the radioactive element i.e. positively charged Helium atom ($^{4}_{2}He$). Hence during alpha emission, atomic number (Z) of the atom decreases by 2 and mass number (A) decreases by 4.

Example

$^{210}_{84}Po \rightarrow ^{4}_{2}He + ^{206}_{82}Pb$

Po is Polonium and Pb is a lead element. Po is called the parent nuclide while the lead is called the daughter nuclide. This is called the nuclear equation

Example

$^{241}_{95}Am \rightarrow ^{4}_{2}He + ^{237}_{93}Np$ (Np is Neptunium)

In general

$^{A}_{Z}X \rightarrow ^{A-4}_{Z-2}Y + ^{4}_{2}He$

Beta emission

It is a fast-moving electron emitted from the nucleus of an atom. During a beta emission, neutron is changed into a proton and electron so electron is ejected out, i.e. the atomic number increases by 1 whereas the mass number remains the same.

Example

$^{14}_{6}C \rightarrow ^{0}_{-1}e + ^{14}_{7}N$

Example

An isotope of strontium $^{88}_{38}Sr$ decays into isotope of Yttrium by emitting a beta particle

$^{88}_{38}Sr \rightarrow ^{0}_{-1}\beta + ^{88}_{39}Y$

In general

${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta$

Gamma ray emission

Gamma rays are represented by ${}^{0}_{0}Y$.They have no charge and no mass. If the element decays emitting gamma rays only it's mass and atomic number does not change.

Example

Cobalt 60 emit gamma radiation

${}^{60}_{27}Co \rightarrow {}^{60}_{27}Co + {}^{0}_{0}Y$

In general

${}^{A}_{Z}X \rightarrow {}^{A}_{Z}X + {}_{0}^{0}Y$

RADIATION DETECTORS

1. ***Photographic plates***

When plates are exposed to radiation they blacken. Alpha (α) is maximum.

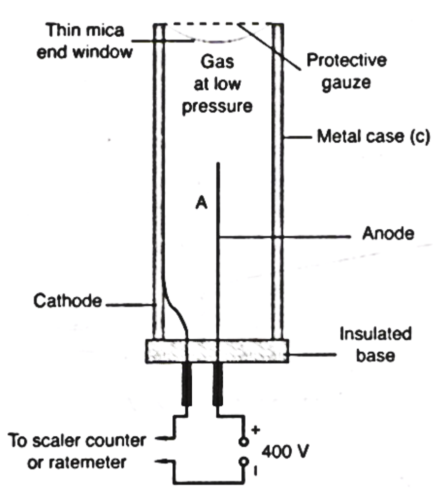
2. ***Scintillation counter***

This involves the use of fluorescent screen together with a photo multiplier together with a microscope of the fruoscent crystal placed in contact with a photomultiplier. As the radioactive rays strikes the crystal light rays (scintillations) are produced. This light rays (scintillations) are detected by photo multiplier.

3. ***THE GEIRGER MULLER TUBE (G-M TUBE)***

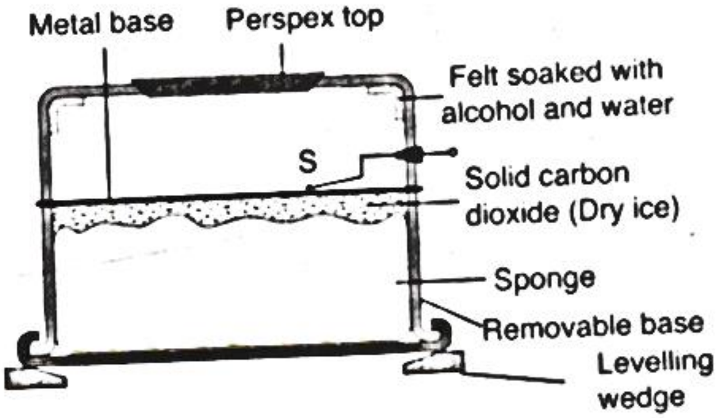
   Ionizing effect is what mainly used to detect the radiation. When radiation enters G-M tube it ionizes argon gas and this creates argon ions and electrons. The argon ions are attracted to the cathode and the electrons are attracted to the anode and cause more ionization by colliding with other argon atoms.

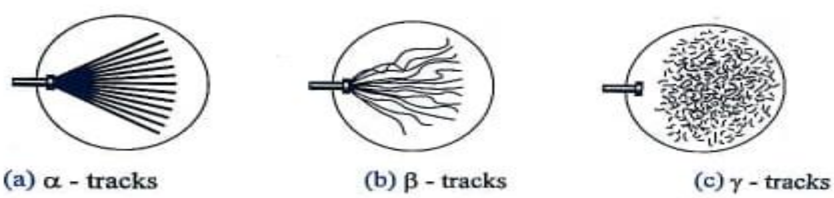
   On reaching the electrodes the ions produce sound and is fed to scaler or rate meter which show the current. This is also used to detect rate of disintegration of the source.



4. CLOUD CHAMBER

Saturated alcohol vapor is made to condense on ions created by radiation. The result is a white line of the tiny drops shows up as a trail in the chamber when illuminated the cloud chamber

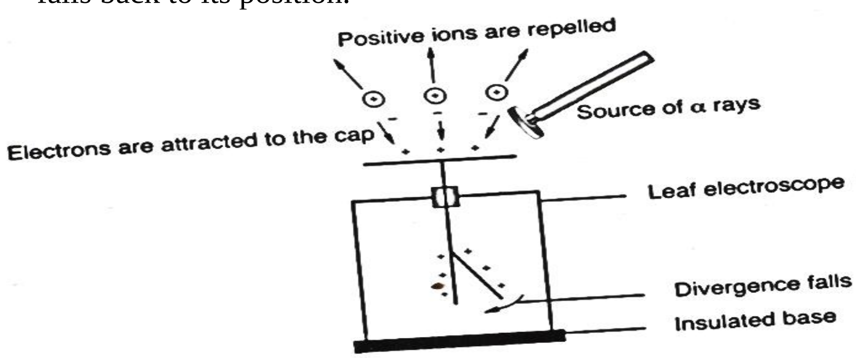




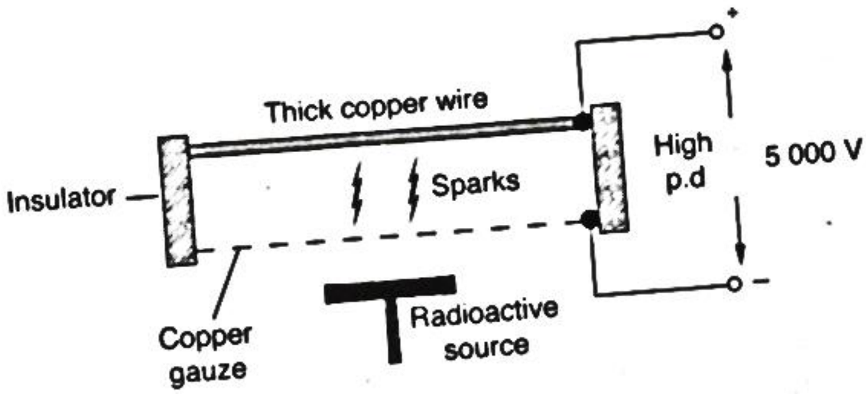
The tracks of alpha, beta and gamma as seen in a cloud chamber

5. ELECTROSCOPE (IONIZATION DETECTORS)

The alpha particle from the source (radium) ionizes gas round metal cap. The ionized gas split into ions and electrons. The metal cap of electroscope has positive charge. The charge of the metal rod and the gold leaf repels and makes the leaf to rise. The positive cap attracts the electrons around the cap. The attraction of negative charge neutrises the gold leaf which falls back to its position.

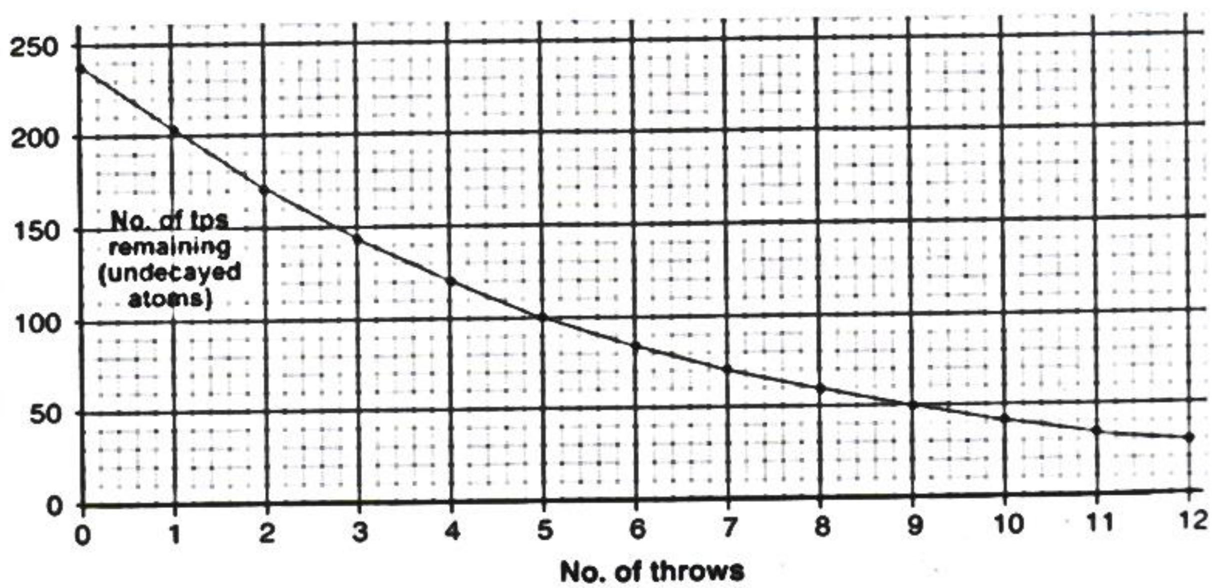


6. THE SPARK COUNTER



The high voltage applied makes air to conduct electricity. When air between gauze and the metal wire is ionized by radiations from the source, spark occurs. This detector provides useful means of detecting alpha rays because it causes more ionization of air molecules. If the source is weak the individual sparks produced can be counted and is used as a measure of radioactivity of the source.
This method is not suitable for beta and gamma rays because they cause weak ionizing of air.

RADIOACTIVE DECAY
This is the breakdown of nuclei of radioactive elements. It starts with unstable nucleus of an element and decreases exponetiary with time



HALF-LIFE
It is the time taken for half of the atoms in a given sample to decay

For example
Radium has half-life of 1600years

Uranium has half-life of 5.7×10^9 years

ACTIVITY

This is the rate of disintegrations or the number of disintegrations per second of the radioactive substance.
It is measured in Becquerel (Bq)
1Bq is equal to 1decay or one disintegration per second

In general

If the original activity is A_0, it reduces to $A_0/2$ in one half-life period; $A_0/2$ reduces to $A_0/4$ in another half-life as shown below

$$A_0 \xrightarrow{T_{1/2}} A_0/2 \xrightarrow{T_{1/2}} A_0/4 \xrightarrow{T_{1/2}} A_0/8 \xrightarrow{T_{1/2}} A_0/16 \xrightarrow{T_{1/2}} A_0/32$$

Hence, the activity reduces to 1/32 of the original value after 5 half-life.

If the original nucleic (mass) in a sample is N_0 it reduces to $N_0/2$ in one half-life as shown below

$N_0 \rightarrow N_o/2 \rightarrow N_0/4 \rightarrow N_0/8 \rightarrow N_0/16$

Example 1

A radioactive source has a half life of 20minutes.What fraction is left after 1hour (60minutes)

Solution

After 20min =1/2

After 40min $=\frac{1}{2} x \frac{1}{2} = \frac{1}{4}$

After 60min = ½ x ½ x ½ =1/8

Example 2

When a source of radiation is placed in front of Geiger Muller counter the initial count rate is 128.After 16 minutes the count rate is 8.Calculate the half life of the source

Solution

$A_0=128$ $t=16$

$A_n=8$

$A_o/A_n = 2^n$ where n is the number of half lives

$128/8=2^n$

$2^n=16$

$2^n=2^4$ and n=4

Number of half lives is 4
Half life 16min/4 = 4min
The half life is 4min

Another method
1^{st}half life count rate reduced from 128 to 64
2^{nd}half life count rate reduced from 64 to 32
3^{rd}half life count rate reduced from 32 to 16
4^{th}half life count rate reduced from 16 to 8

This means there are 4half lives
Half life=total time taken/number of half lives
16mins/4=4mins
The half life is 4mins

Example
A radioactive source has half life of 30minutes.Calculate the fraction left after 2hours.
Solution

After 30minutes fraction left = ½
After 60minutes fraction left =1/2x1/2=1/4
After 90minutes fraction left =1/2 x 1/2 x 1/8=1/8
After 120mins fraction left = ½ x ½ x ½ x ½ =1/16

Another method
T=2hrs=120mins $t_{1/2}$=30min N_0=1

$N_t=(1/2)^{\frac{t}{t1}/2}N_0$

$= (1/2)^{120/30} x1$

$= (1/2)^4 \times 1$
=1/16

The fraction left is 1/16

COUNT RATE AND DECAYING CURVE

The isotopes used in scientific research must have short half lives so that it takes short time to decay and take short to detect
The activity of the source is then low after it has been used and so will not pose an on going radiation threat.

BACK GROUND RADIATION

This is the ‘stray’ radiation present in the atmosphere and is not due to any particular radioactive material.

SOURCES OF BACK GROUND RADIATION

i. Cosmic radiation which originates outside the earth (from the sun)
ii. The presence of natural radioactive materials in the rocks

TYPES OF RADIOACTIVITY

A. NATURAL RADIOACTIVITY

These are nuclei that occur naturally.

Element that disintegrate in order to attain stability. The elements that undergo natural radioactivity have extremely long half life and these are not used in scientific research because of their long half lives.

Natural Radioactive	Half life
Uranium-283	4.5×10^{9}
Carbon -14	5.7×10^{3}
Radium-226	1.6×10^{5}

B. INDUCED OR ARTIFICIAL RADIOACTIVITY

Is induced radiation with other particles such as neutron

The changing of one radioactive substance into different elements is called ***transmutation***

These isotopes are created by colliding or bombarding the stable nucleus with neutron or charged particle.

The types of atoms which can be induced are those with *stable nucleus*

The main products of induced radioactivity are *radioisotopes*

WHY BOMBARDING WITH NEUTRON

They are neutral and they cannot be repelled by the nucleus of an atom.

Example

i. Radioactive ${}^{32}_{15}P$ is obtained by bombarding a stable ${}^{31}_{15}P$ with neutron

$${}^{1}_{0}n + {}^{31}_{15}P \rightarrow {}^{32}_{15}P$$

(Stable) (Unstable)

${}^{32}_{15}P$ being heavier than the stable isotope, undergoes beta decay to ${}^{32}_{16}S$

***Most artificial radioactive isotopes have very short half lives. Their short half life makes them suitable in live scientific work. The shorter the half life the faster the isotope decays and the more unstable it is. The intensity of its radiations soon flashes below lethal level.*

Artificial radioactive isotopes and their

Artificial isotopes	Half life
Iodine -131	8.1 days
Phosphorous-32	14 days
Bismuth-214	19.7 minutes

CIRCUMSTANCES WHERE INDUCED (ARTIFICIAL) RADIOACTIVITY CAN BE USED

a. *Used in scientific research as tracers because they have short half life*

Example:

i. As biochemical tracers in tracing brain tumors, goiter
ii. Tracing fertilizer uptake in plants

b. *Industrial use*

i. Radio sodium 24,for detecting leakages in the water pipes
ii. Detection of faults in welded steam and boilers

c. *Radiotherapy*

i. Radio cobalt 60 used as treatment of goiter

NUCLEAR ENERGY

When nucleons i.e. protons and neutrons are bound together or separated a part, the resulting nucleus has a mass slightly less than that of the total initial nucleus. This difference of mass is radiated as enormous energy according to Einstein equation

$E = MC^2$ where m is the mass an c is the speed of light
This mass difference is known as ***mass defect***
NUCLEAR FISSION
Nuclear fission is the splitting of heavy nucleus into lighter nuclei. For instance, the fission of uranium

$$^{1}_{0}n + ^{235}_{92}U \rightarrow ^{236}_{92}U \longrightarrow ^{144}_{56}Ba + ^{90}_{36}Kr + 2^{1}_{0}n$$

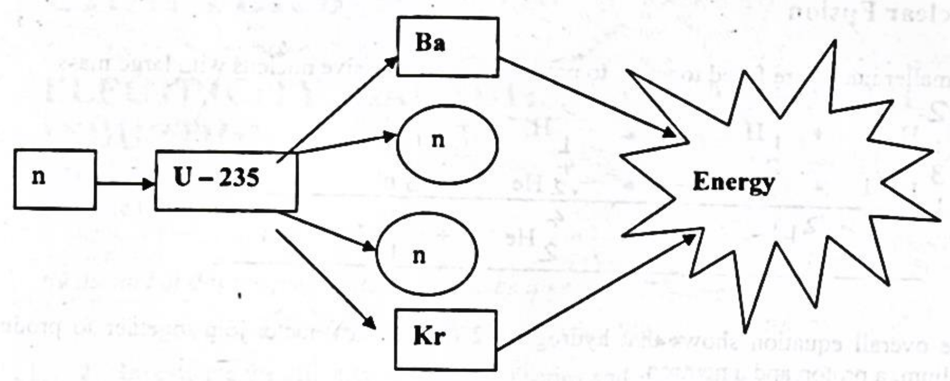
When Uranium-235 is bombarded with slow moving neutron it becomes unstable and split into two. When two neutrons released on the right bombarded another Uranium-235 the process continues as before continuously hence amount of energy is released. This is called chain-reaction. If this is not controlled, it results in atomic bomb

NOTE: The chain reaction process is controlled by neutron absorbing

- Boron steel rods
- Graphite is also used to slow down the chain reaction

CONTROLLED NUCLEAR FISSION

Controlled Nuclear Fission



UNCONTROLLED NUCLEAR FISSION

NUCLEAR FUSSION

It is the combination (joining together) of lighter nuclei to form heavy nucleus.
This releases energy inform of heat energy.
For instance; solar energy from the sun is produced by the combination of Deuterium to form Helium

$^{2}_{1}H + ^{2}_{1}H \rightarrow ^{3}_{2}He + ^{1}_{0}n$

$^{3}_{1}H + ^{2}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$

Overall equation: $3\ ^{2}_{1}H \rightarrow ^{4}_{1}He + ^{1}_{1}H + ^{1}_{0}n$

This reaction takes place at high temperature to overcome repulsive forces. Nuclear fusion releases heat light and gamma radiation e.g. energy from the sun

CHARACTERISTICS OF RADIOACTIVE SUBSTANCES

i. The atoms of radioactive substances are continually decaying (breaking down into different type of atoms after emitting radiation)
ii. The radiation from radioactive substance produce light flashes of light (fluoresces) when they strike certain compounds e.g. Zinc Sulphide
iii. They cause ionization of air molecules
iv. Radiation from radioactive substance can blacken photographic film.
v. Radiation from radioactive material can kill bacteria, burn or kill animals and plants

APPLICATION OF RADIOCTIVITY

1) ***Used in medicine***
   a) Radioactive isotopes can be used as tracers; radioisotopes are injected into a body of people or swallowed. The progress around the body can be followed using the detector.

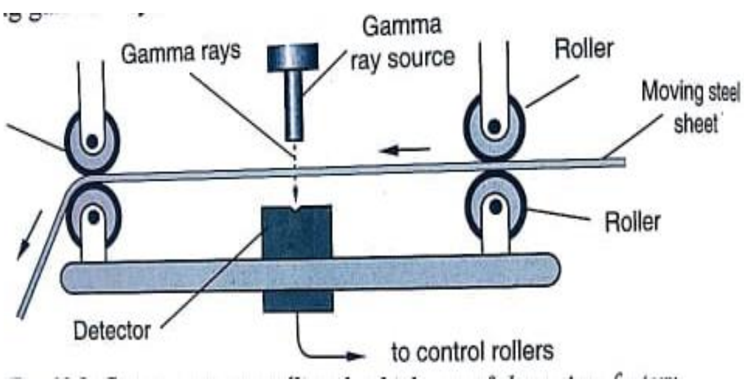
Example

Iodine-131 which is absorbed by the thyroid gland and gives out radiation which is detected by Geiger Muller tube (GM – tube) to indicate whether the gland is functioning normally or abnormally. At high concentration in the gland may indicate the presence of cancer

b) Medical instruments are also exposed to high dose of gamma rays which kills bacteria.
c) Radiation from radioisotopes are used to kill cancerous cells in the body

2) Used in industry

a) Radioisotopes can be used to detect leakages in pipes. The radioisotopes are placed inside the pipe and inspection is done outside the pipe with the detector to find areas of high concentration which indicate the pipe is leaking out. The isotopes must have short half-life. The isotope must be a gamma source so that the radiation can be detected even through metal.
b) Food can be exposed to a high dose of gamma rays which kill all bacteria. This keeps the food fresh for longer time.
c) Quality control



Sheet materials such as paper or metal needs to be produced with constant thickness, for example paper production

Beta-emitting source is placed above the paper and beta detector is placed directly below it. If the paper becomes thinner, more radiation reaches the detector. This makes the control unit to open the rollers out to make thick paper

If the paper becomes thicker, less radiation is detected. This makes the control unit to increase pressure in rollers to make thin paper

3) Uses in archaeology (Carbon dating)

Living plants absorb carbon-14 ($^{14}_{6}C$) by photosynthesis. The amount of carbon in the tree goes on increasing as long as the tree is alive. When the tree is cut down, it no longer absorbs carbon-14 and the radioactive atoms already absorbed start to decay by emitting beta particle together with nitrogen atoms as shown below

$^{14}_{6}C \rightarrow ^{14}_{5}N + ^{0}_{-1}e$

The half life of carbon-14 is 5600years .If freshly cut piece of wood gives out say 64counns/minute and sample of wood dug gives 8counts/minute, then age of sample is

3half lives i.e. 16800years.This process of finding the age of fossils is called ***carbon-dating***

4) ***Source of electrical energy***

The energy released in the fission or fusion process could be used to drive a turbine of a generator to generate hydro electric energy

5) *Uses in biology and agriculture*

a) To sterilize male insects thus reducing insect population
b) Tracer technique being used to monitor how plants take up fertilizers.
c) Wheat, maize etc when irradiated with mild gamma rays can be stored for long time without damage.

DANGERS OF RADIOACTIVE SUBSTANCES

a) Radiation from radioactive substances causes skin burns
b) Production of cancerous cells or blood defects

HOW TO DISPOSE OF RADIOACTIVE SUBSTANCES

a) *Reprocessing*

The unwanted materials undergo new carefully controlled nuclear to make it suitable for re-use.

b) *Dumping in containers made of thick concrete or lead and sinks them in deep oceans or earth*.

SAFETY PRECAUTIONS AND STORAGE OF RADIOACTIVE MATERIALS

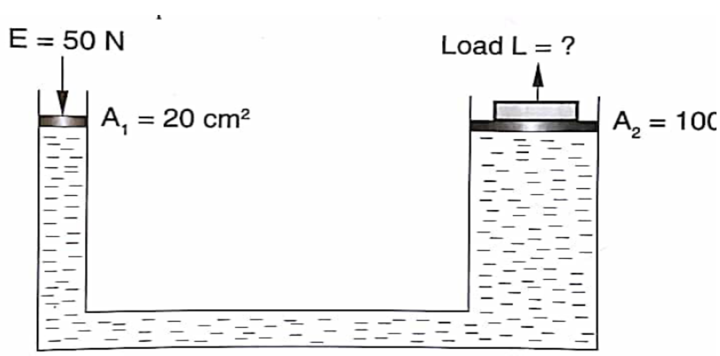
i. Never allow skin contact with the source. Always handle the radioactive isotopes with tongs
ii. Keep the source at arm's length to keep it as far from the body as possible
iii. Wear full protective suit in industry
iv. Always keep the source in lead box.

PHYSICS, MODEL EXAMINATION

PAPER I

1. (a) Mention two uses of liquid pressure.**(2 marks)**

(b) Figure 1 is a hydraulic system being used to raise a load. A force of 50N is applied on piston A_1.



i. Calculate the pressure piston A_1 exerts on the liquid. **(3 marks)**
ii. How much pressure does the liquid exert on piston A_2?
iii. Calculate the value of the output force labeled F in the diagram in Figure 1. **(3 marks)**
iv. Explain why the hydraulic system in figure 1 is a force multiplier. **(3marks)**

(c) Derive a formula to show that the pressure of a liquid depends on its density and depth. **(4 marks)**

2. (a) i. Explain why mass is a scalar quantity while momentum is a vector quantity **(1mark)**

ii. An object is pulled by two forces whose magnitudes are 250N and 320N. The angle between the two forces is 60°. Draw a scale diagram to show the size of the resultant force. **(3marks)**

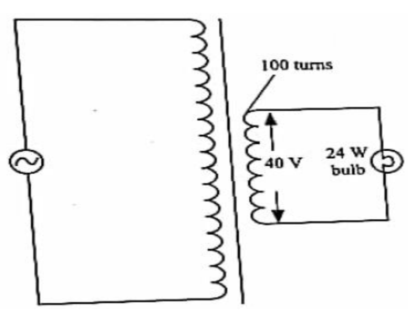
(b) i. State Newton's second law of motion **(3marks)**

ii. A car weighing 500kg moves from rest and reaches a speed of 15m/s in 5 seconds.

(c) A cyclist starts from rest and accelerates uniformly at $1m/s^2$ for 20 seconds. He then travels at a constant speed for 1 minute and finally decelerates uniformly at $2m/s^2$ until he stops. Draw a velocity time graph paper in figure 2 to represent the motion of the cyclist. **(6marks)**

3. (a) Explain each of the following
i. A transformer will not on direct current (D.C) **(2marks)**
ii. If a transformer increases voltage, it reduces current. **(2 marks)**

(b) Figure 3 is a diagram of a transformer.



i. Explain the reason why this transformer can never be practically 100% efficient. **(2marks)**

ii. Assuming this transformer is 100% efficient, calculate the current through the input coil. **(3marks)**

4. (a) Define the following terms as applied in thin lenses:

i. Principal focus **(1mark)**

ii. Focal length **(1 mark)**

(b) An object 2cm high is 4cm in front of a converging lens of focal length 5cm.

i. Draw a ray diagram and find the position of the image formed. (Use a scale of 1cm: 2cm on the vertical and horizontal axes). **(3marks)**

ii. Describe the nature of the image formed.

(c) Calculate the magnification of the image formed **(1mark)**

(d) Explain how a magnifying glass works. **(2marks)**

5. (a) Define 'linear momentum'**(2marks)**

(b) State the principal of conservation of momentum. **(2marks)**

(c) A perfectly elastic collision takes place between balls A and B with Masses 4kg and 2kg respectively. The initial speed of A is 5m/s while B is initially at rest. Given that the final speed of B is 2m/determine the Speed of A after collision. **(4marks)**

6. (a) Define the following terms

(i) Circular motion **(2marks)**

(ii) Angular velocity **(2marks)**

(b) A wheel starts from rest and accelerates uniformly with an angular Acceleration of 4rad/s^2 what will be its angular velocity after 4 seconds? **(3marks)**

7. (a) Define 'half-life' **(1mark)**

(b) Table 1 shows the decay process of iodine -131

Time (days)	0	7	14	21	28	35
Activity (units per litre)	1600	875	470	260	140	77

(i) Using the graph paper in figure 4, draw a graph of activity against time **(5 marks)**

(ii) Estimate the half-life of iodine -131 and show on the graph how you arrived at the answer. **(1mark)**

(c) State any three safety precautions to be observed when using radioactive sources in a school laboratory. **(3marks)**

(d) Complete and balance the following nuclear equations.

(i) __________ + $^{16}_{8}0 \longrightarrow ^{17}_{8}X$ **(1mark)**

(ii) $^{226}_{88}Ra \longrightarrow$ Rn+ _____ **(1 mark)**

8. (a) Define "terminal velocity". **(2 marks)**

(b) Figure 5 shows a metal ball bearing falling in oil.

Figure 5

(i) Using forces A, B and C describe the motion of the ball bearing through the oil until it reaches the bottom of the container. (Assume the ball bearing reaches terminal velocity before reaching the bottom of the container). **(8 marks)**

(ii) Mention **two** forces that affect terminal velocity. **(2 marks)**

(C) (i) What are semiconductors? **(1 mark)**

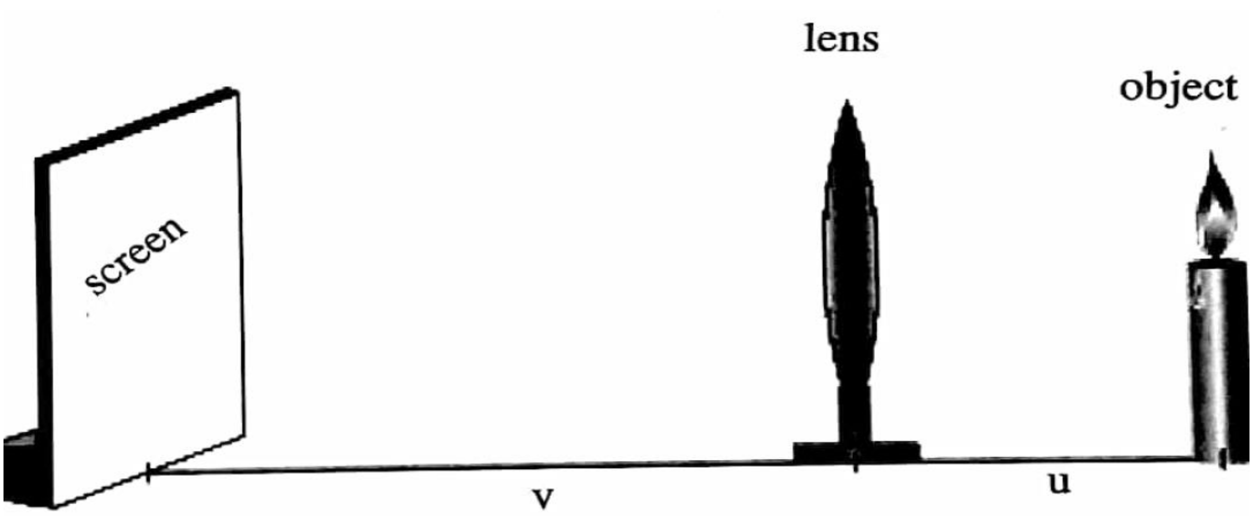
(ii) Explain how raising the temperature of a semiconductor affects its electrical conductivity. **(3 marks)**

(iii) With the aid of a diagram, explain how n-type semiconductors are made. **(4 marks)**

Paper II

1. You are provided with a candle, a match box, a lens holder, convex lens, white screen and a meter ruler.

(a) Arrange the candle, convex lens and screen as shown in **Figure 1.**



(b) Light the candle.

(C) With the candle at 20cm from the lens, produce a well-focused image of the flame on the screen.

(d) Measure and record the image distance in the table of results **(Table 1)**

(e) Repeat steps (c) and (d) for object distance shown in **Table 1**.

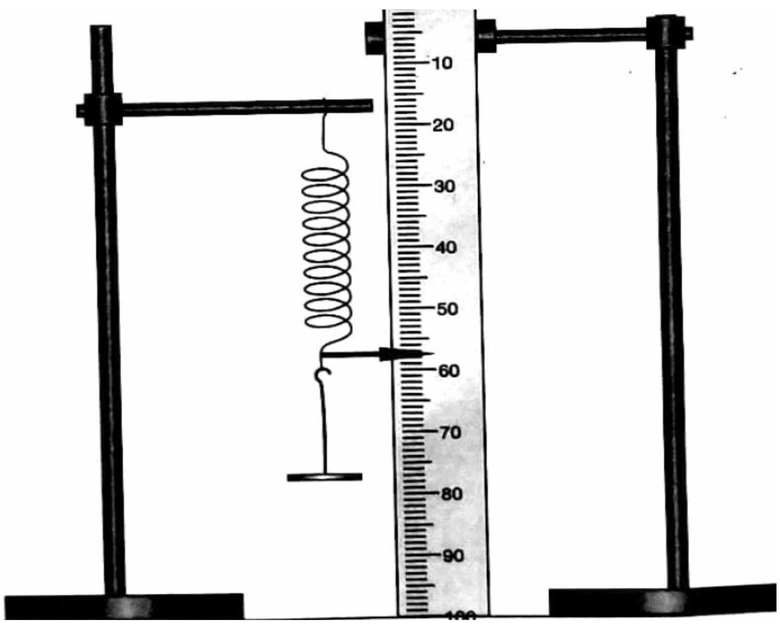
Object distance, u(cm)	Image distance, v(cm)	U + v(cm)
20		
30		
40		
50		
60		

(f) Plot a graph of u + v against u. **(5 marks)**

(g) From the graph, write down the coordinates of the minimum point**. (1mark)**

(h) Using the coordinates of minimum point, find the focal length of the lens.**(1 mark)**

2. You are provided with a clamp stand, a meter ruler, a spring and masses of 100g, 200g, 300g, 400g, 500g, 600g and 700g.



(a) Arrange the clamp stand and the spring as shown in figure 2.

(b) Use the ruler to find the length of the upstretched spring and record the result in **table**

(c) Hand a 100g mass on the spring.

(d) Calculate the extension in the spring caused by the 100g mass.

(e) Record the result in table 2.

(f) Repeat steps (c), (d) and (e) using the other masses and records all the results in table

Mass (g)	**Initial length (cm)**	**Final length (cm)**	**Extension (cm)**
0			
100			
200			
300			
400			

(4 marks)

3. With the aid of a well labeled diagram, explain how a manometer works to measure gas pressure. **(13 marks)**

4. Suppose you are provided with materials labeled P,Q and R which are a diode, conductor and an insulator but not necessarily in that order, describe an experiment you would perform to identify these materials.**(12 marks)**