MUSTAFA ASIF

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O Level Physics Flash Cards

Compiled By:

Abdul Hakeem

Lahore Grammar School
Beaconhouse School System
The Lahore Alma
0300-4810 136

Measurement

1.1 Units Of Measurement.

1. In Physics, there are three fundamentals or basic quantities which are very important.
2. The three quantities are length, mass and time.
3. We use a metric system of measurement called the International System of Units (S.I) to express these quantities as shown in the following table:

Quantity	S.I Unit	Symbol
Length	Metre	M
Mass	Kilogram	Kg
Time	Second	S

1.2 Length

Besides the metre, other units used in measuring length are the kilometer (km), centimetre (cm) and millimetre (mm). They are related in the following way:

$$1\ m = 0.001\ km$$
$$1\ m = 100\ cm$$
$$1 m = 1\ 000\ mm$$

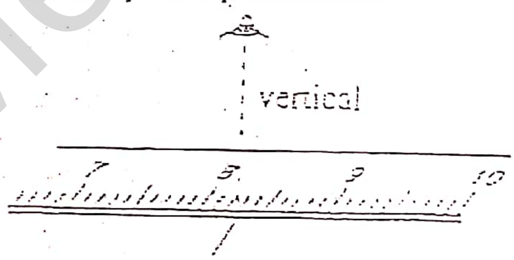
$$1\ km = 1\ 000\ m$$
$$1\ cm = 0.01\ m$$
$$1\ mm = 0.001\ m$$

The instruments used in measuring length with the smallest possible reading they can make are shown in the following table:

Instrument	Smallest reading
Ruler	0.1 cm
vernier calipers	0.01 cm
micrometer screwgauge	0.01 mm

(a) Ruler

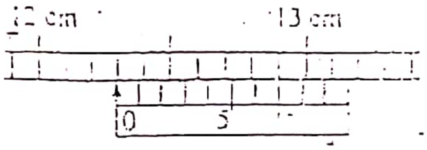
The correct way to read a ruler is to position the eye vertically above the mark on the scale that is to be read. This is to prevent parallax error.

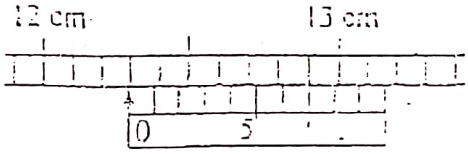


(b) Vernier Calipers

Example

First, read the main scale reading just before the zero division of the vernier scale. Here, it is 12.2 cm. Then look for the vernier division which coincides with the main scale. In this case, it is the 7th division or 0.07 cm. The final reading is (12.2 + 0.07) cm = 12.27 cm.





(c) Micrometer Screwgauge

The divisions above the main axis of the micrometer screwgauge correspond to millimetres (1.0 mm, 2.0 mm, 3.0 mm, ...) while those below correspond to half-millimetres (0.5 mm, 1.5 mm, 2.5 mm, ...).

Example 1

Get the approximate reading on the main axis, i.e. 3.0 mm. Read the thimble reading, i.e. the 47th division or 0.47 mm. Therefore, the final reading is (3.0 + 0.47) mm = 3.47 mm.

Example 2

Get the approximate reading on the main axis, i.e. 7.5 mm. Read the thimble reading, i.e. the 24th division or 0.24 mm. Therefore, the final reading is (7.5 + 0.24) mm = 7.74 mm.

1.3 Area And Volume

- The S.I. unit for area is the square metre m^2.
- Another unit for area is the square centimeter cm^2.

The area of regular figures can be calculated by using the following formulae:

Area of	Formula
square	length x length
Rectangle	length x breadth
Circle	π (radius)?

- The S.I unit for volume is the cubic metre (m^3).
- Other units include the cubic centimetre (crrr'), the milliliter (mt) and the litre *(l)*.

$1 m^3 = 1\ 000\ 000 cm^3$ or $1 cm^3 = 0.000\ 001\ m^3$
$1 m^3 = 1\ 000\ l$ or $1 l = 0.001\ m^3$
$1 cm^3 = 1\ l$

- The volume of a liquid is obtained by using a measuring cylinder.
- The volume of a regular solid can be obtained by calculation using the following formulae:

Volume of	Formula
cube	length x length x length
rectangular block	length x breadth x height
Sphere	$\frac{3}{4} \times \pi(radius)^3$

The volume of an irregular solid can be obtained by the displacement method. First, pour some water into a measuring cylinder and note the volume, *VI*. Lower the solid into the water and read off the new volume, V_2. The volume of the solid will then be $(V_2 - V_1)$.

1.4 Mass

The mass of an object is the measure of the amount of matter in it. It remains constant regardless of where the object is.

It can be measured by using a lever balance or a beam balance. Besides the kilogram (kg), another unit is the gram (g).

$1\ kg = 1\ 000\ g$ or $1\ g = 0.001\ kg$

1.5 Density

Density of a substance is defined as its mass per unit volume.

$$Density = \frac{mss}{volume}$$

The S.I. unit is kilogram per cubic metre (kg m''). Anomer unit is gram per cubic centimetre (g cm''').

1 min = 60 s	or	1 s	=	$\frac{1}{3600}$ h		
	or	1 s	=	$\frac{1}{60}$ min		
1 h = 60 min	or	1 min	=	$\frac{1}{60}$ h		

1 kg m^{-3}=0.01cm-3 or 1 g cm^{-3} = 100kg m^{-3}

- To find the density of a solid, y.'e do the following:
  (a) Find the mass of the solid using a beam balance
  (b) Obtain its volume.
  (i) If it is a regular solid, find its volume from calculation using the formulae stated in Section 1.3.
  (ii) If it is an irregular solid, find its volume using the displacement method.
  (c) Calculate the density using the formula

$$Density = \frac{mass}{volume}$$

1.6 Time

Besides the second (s), other units for time are the hour (h) and the minute (min).

1h	=	3600 s	or	1s	=	$\frac{1}{3600}$h
1 min	=	60 s	or	1s	=	$\frac{1}{60}$ min
1 h	=	60 min	or	1min	=	$\frac{1}{60}$h

Devices for measuring time include clocks. Stopwatches. Ticker-tape timers and the pendulum.

The ticker-tape timer makes 50 dots in one second on a paper tape. Thus the time interval between two consecutive dots is 1/50 s or 0.02s.

The period of a pendulum is the time taken for it to rnake one complete oscillation. This period is dependent on the length of the pendulum and not on the mass of the bob. The longer the pendulum. the longer is its period.

Speed, Velocity and Acceleration (2)

- Speed is defined as the distance travelled per unit time.
- Velocity is defined as the distance travelled per unit time in' a given direction
- The S.I unit for both speed and velocity is metre per second (m S^{-1}).

Another unit is kilometer per hour (km h^{-1}).

- **Acceleration** is defined as the rate of change of velocity.
- The S.I unit for acceleration is meter per second squared (m s^{-2}).
- Acceleration can be positive or negative. If the velocity of an object is increasing, its acceleration will be a positive value. If its velocity is decreasing, its acceleration will be a negative value.
- A negative acceleration is also known as deceleration or retardation..

2.2 Calculations

(a) Boy cycles 300 meters in 40 seconds.

Speed of the boy $= \frac{distance}{time}$

$= \frac{300}{40}$

$= 7.5 \text{ ms}^{-1}$

(b) The boy accelerates uniformly from 4 ms^{-1} to 10 ms^{-1} in 3 seconds

His acceleration $= \frac{Final\ velocity - intial\ velocity}{Time\ taken}$

$= \frac{10-4}{3}$

$= 2ms^{-2}$

(c) He then decelerates uniformly from toill 5^{-1} to a stop in 8 seconds.

His acceleration $= \frac{Final\ velocity - Initial\ velocity}{Time\ taken}$

$= \frac{0-10}{8}$

$= 1.25 \text{ ms}^{-2}$

$\therefore = 1.25 \text{ ms}^{-2}$

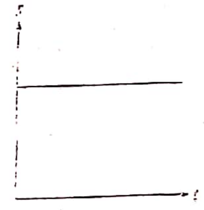
2.3 Speeds-Time Graph

- A speed-time graph plots the speed of an object (y-axis) against time (x-axis).
- The following show the different types of motion as represented on a speed-time graph.

(a)

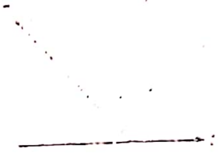
Object is at rest.

(b)

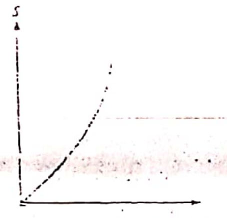


Object is moving with uniform velocity.

Object is moving with uniform acceleration



Object is moving with uniform retardation



Object is moving with non-uniform acceleration (increasing rate).

Object is moving with non-uniform acceleration (decreasing rate).

From a speed-time graph, the following quantities can be determined.

(a) The speed of an object at any time can be read off the graph.

(b) The acceleration of an object at any time can be found by calculating the gradient of the graph at that point in time.

(c) The distance covered by an object can be found by calculating the area under the graph.

Worked Example

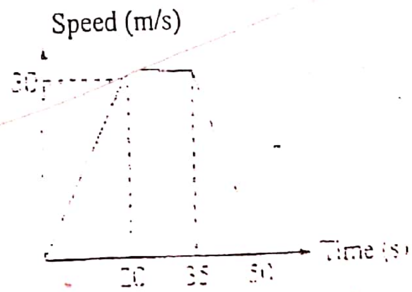
The speed-time graph of a sports car is shown on the right.

Find

(a) the acceleration of the car in the first 20 seconds,

(b) the deceleration of the car in the last [5 seconds,

(c) the total distance travelled by the car.



Solution:

(a) Acceleration = Gradient of graph for first 20 seconds

$$= \frac{30 - 0}{20}$$

$= 1.5ms^{-2}$

b) Acceleration $= \frac{0-30}{15}$

$= -2.0\ ms^{-2}$

$\therefore Decleration = 2.0ms = 2$

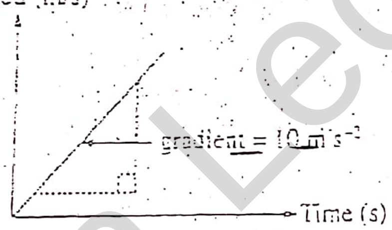
Deceleration

(c) Distance =Area under the graph (which is a trapezium)

Note: The last answer is in meters because in {he graph, the speed is plotted in m s:' and the time in seconds.

2.4 Gravitational Acceleration (*g*)

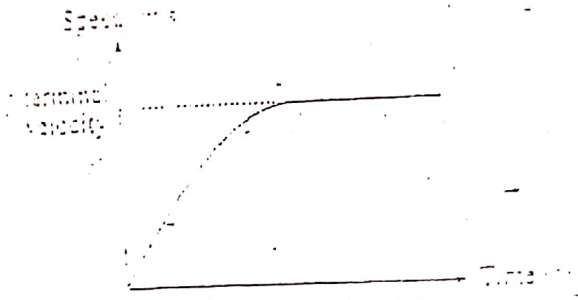
- This is the - acceleration with which all objects fall when unsupported. Such a motion is also known as free fall. This acceleration is the same for all falling objects regardless of their masses.
- It is a constant near the surface of the Earth and has a value of approximately 10 m S^{-2}.
- A falling object, not subjected to air resistance, will increase its speed by [0 m S^{-1} every second. The diagram on the right is a speed-time graph for such a falling object.



Object falling with no air resistance

2.5 Terminal Velocity

- When objects fall through air, they are always subjected to air resistance which slows down their acceleration.
- Air resistance is dependent on two factors:
  (a) The surface area of the object; the larger the surface area, the greater the air resistance.
  (b) The speed of [he object; the faster the object, the greater the air resistance.
  As an object falls through air, it is accelerated by gravity and its speed increases. This implies that the air resistance acting on it also increases. When the air resistance becomes equal to the object's weight, the net force on the object is zero and it will then fall with a constant velocity known as terminal velocity. The following graph shows how the speed of such a falling object varies with time. (Read also Section' 4.3.)



Object falling with air resistance

(3) Mass, Weight And Centre Of Gravity

3.1 Mass And Inertia

- In Section IA, it is stated that mass is a measure of the amount of matter in an object and is a constant, that is, it does not vary from place to place.
- Anything with mass will possess inertia. Inertia of an object is the tendency of the object to remain at rest if it is stationary or to maintain constant speed along a straight line if it is moving.
- The greater the mass, the greater is the inertia.

3.2 Weight

The weight of an object measures the force of gravity acting on it. The S.L unit for weight is the Newton (N).

The spring balance is used to find the weights of objects.
The weight of a body is obtained from its mass using the following

Equation

Weight (W) =mg

Where *m* is the mass of the object in kg and *g* is the gravitational acceleration in m s^{-2},

Worked Example

Find the weight of a book of mass 1-5 kg on the Earth's surface and on the Moon's surface.

Solution:

On Earth's surface, $g = 10\ m\ S^{-2}$

:. Weight of book =1.5 x 10:: 15 N

On Moon's surface, $g = 1.6\ m\ S^{-1}$

:. Weight of book = 1.5 x 1.6 = 2.4 N

3.3 Centre Of Gravity (Centre Of Mass)

- The centre of gravity of a body is defined as the point at which the whole weight of the body seems to act.
- For a regular object, this point is at the centre of the object.
- If the object is not too large, the centre of gravity is also the centre of mass.

3.4 Stability

- Stability refers to an object's ability to maintain its original position.
- An object is stable if when it is displaced slightly, it returns to its initial position.

This usually means that its centre of gravity is at the lowest point.

- An object is unstable if at the slightest tilting, it topples over. This usually implies that its centre of gravity is too high.
- The stability of an object can be increased by
  (a) lowering its centre of gravity,
  (b) increasing its base area.

(4) FORCES

4.1 What Is A Force?

- A force is a push or a pull.
- Forces can do the following:
  (a) They can change the shape and size of a object.
  (b) They can cause an object to accelerate.
  (c) They can change the direction of an object's motion.
- The S.I unit for force is the Newton (N).

4.2 Hooke's Law

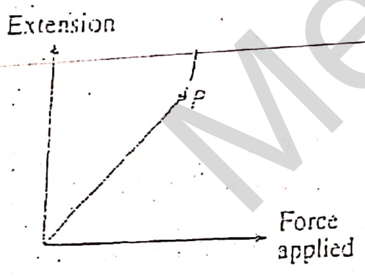
For any elastic material that obeys **Hooke's Law**, the extension produced in the material *(e)* is directly proportional to the force applied *(F)*, provided the limit of proportionality is not exceeded. Mathematically, this means $F \propto e$.

Written in equation form; this is:

$$F = ke$$

Where k is a constant

The graph for a material obeying Hooke's Law is shown on the right The limit of proportionality is the point beyond which the extension produced is no longer proportional to the applied force. It is shown on the graph as point P.



- An important application of Hooke's Law is the spring balance

Worked Example

A spring extends by 2 em when a load of : 0 . is hung on it. Calculate the extension produced when a 15 N load is suspended on it.

Sol l.it ion: –

For a force of 10 N, the extension is 2 cm.

$$F = ke$$

$$10 = k(2)$$

$$\Rightarrow k = 5\ N/cm$$

∴ For a force of 15 N, extension, $e = \frac{F}{k}$

$$= \frac{15}{5}$$

$$= 3cm$$

26

4.3 Newton's Second Law

Newton's Second Law states that whenever there is a resultant force F acting on a mass, the mass will accelerate. In equation form, it reads:

$$F = ma$$

Where m is mass in kg and a is its acceleration in m S-2.

- From the above equation, it can be seen that when there is no resultant force acting on an object, there will be no acceleration. This means the object will either remain at rest or move with a constant velocity.
- If mass is kept constant, then the acceleration produced IS directly proportional to the resultant force acting on the body.

Worked Example

Find the acceleration on a 5 kg mass while it is subjected to a force of 24

Solution:

$$F = ma$$

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

$$= \frac{24}{5}$$

$$4.8\ ms^{-2}$$

When an object moves in a circle with a constant speed, its direction of motion is always changing. This means that its velocity is always changing which implies that there must be an acceleration. By Newton's Second Law, a force is required for an acceleration. This force which keeps objects in circular motion is called centripetal force. It always acts the towards

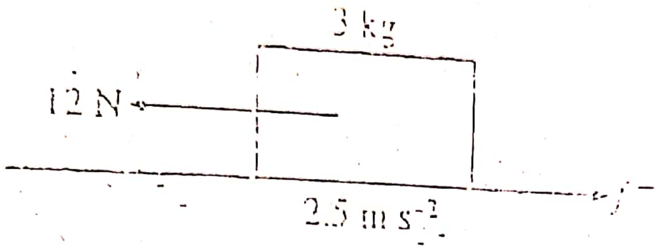
centre of the circle.

4.4 Resistive Forces

Friction and air resistance are resistive forces and they act in such a way as to oppose the motion of objects.

Worked Example

Find the frictional force f acting on an object of mass 3 kg when it is pulled with a force of 12 N and accelerates at 2.5 m S^{-2}.



Solution:

From the diagram, the resultant force on the object is (12 - f).
By Newton's Second Law, the resultant force $=ma$

$$12 - f = 3 \times 2.5$$

$f=12-7.5$

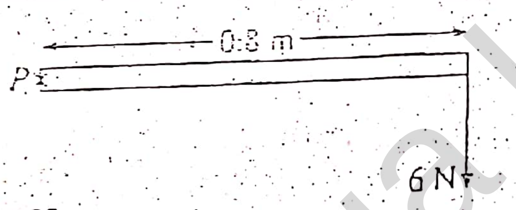
$$\therefore f = 4.5N$$

(5) Moments

5.1 Definitions And Units

The moment of a force about a pivot is the product of the force and the perpendicular distance between the pivot and the line of action of the force.

Moment= Force x Perpendicular distance



The S.I unit for moments is the Newton-metre (Nm).

Worked Example

Find the moment about P from the given Diagram

Solution:

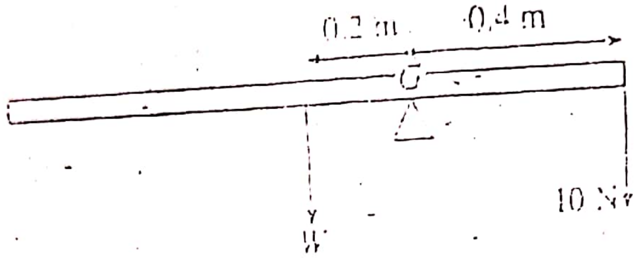
Moment about P = Force x Perpendicular distance
=6 x 0.8 =4.8 Nm

5.2 Principle Of Moments

The principle of moments stares that for a body to be in equilibrium, the sum of all clockwise moments must be equal [Q the sum of all anti- clockwise moments.

Worked Example

A ruler is balanced under two forces as shown if the diagram on the right. Find W, the weight of the ruler.



Solution:

Taking moment about G, clockwise moments = anti-clockwise moments

10 x 0.4=

$$W = \frac{4}{0.2} = 20N$$

Work, Energy And Power (6)

6.1 Work

Work is defined as the product of a force and the distance moved in the direction of the force.

In equation form, it reads:

Work = *F* x *d*

Where *F* is the force In Newton's and *d* is the distance moved in the direction of the force in metres. (Do not confuse this equation with that for moments!)

The S1. unit for work *is* the Joule (1).

Worked Example

A girl uses a force of 80 N 'O carry a pail of water up 2 metres. Find the work done.

Solution:

Work done = *F* x *d*

= 80 x 2

= 160 J

6.2 Energy

- Energy is defined as the capacity to do work.
- The S.I. unit for energy is the Joule (1), similar to that for work.
- When work is done on an object, it will gain energy. When the object does work, it will lose energy.
- The Law of Conservation of Energy states that energy cannot be created or destroyed. It can only be converted from one form to another.
- The various forms of energy are': heat, light, sound, electrical, solar, wind, geothermal, nuclear, kinetic and potential energy.

6.3 Nuclear Energy

- Nuclear energy can be obtained through two processes: nuclear fusion and nuclear fission.

 (a) Nuclear fusion

This is the process whereby the nuclei of lighter atoms are fused together to form a larger nucleus and in the process releases energy (in the form of heat and light).

(b) Nuclear fission

This is the process in which the nuclei of heavy atoms break up into smaller nuclei, thereby releasing energy.

- For both processes, there will be a loss in mass in the final nuclear products and this 'lost mass' will be converted into nuclear energy. This energy (E) can be calculated using the following formula: –

  $E = mc^2$

  Where m is the 'lost mass' in kg and c is the speed of light in ms^{-1}

Worked Example

Calculate the energy produced by converting 1 g of matter *into* energy.

Solution:

1 g = 0.001 kg

Energy = mc^2

= 0.001 X (3 X 10!)2

= 9×10^{13} J

6.4 Kinetic And Potential Energy

Kinetic energy (K.E.) is the energy possessed by a moving object and can be found by using the equation:

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

Where m *is* the mass of object in kg and v is its velocity in $m\,S^{-1}$,

Worked Example

Find the kinetic energy of a 2-kg mass moving at 5 $m\,S^{-1}$.

Solution:

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

$= \frac{1}{2} \times 2 \times 5^2$

$= 25J$

Potential energy (P.E.) is the energy an object has because of its position or height above a reference point in a gravitational field. It can be calculated from the equation:

P.E. = mgh

Where m is the mass in kg, g is the gravitational acceleration in $m\,S^{-2}$ and h is the height in meters.

A second equation for potential energy is:

P.E. = weight x h because weight = mg

Worked Example

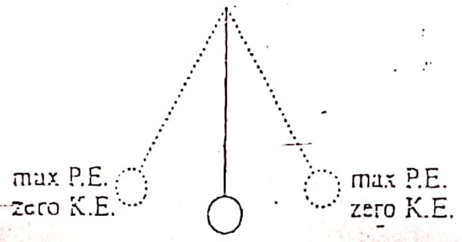
Find the potential energy of a 2-kg mass 10 metres above the ground.

Solution:- = *mgh*

P.E.
=2x10x10
=200 J

In a swinging pendulum, there is a constant interchange of potential and kinetic energy

$P.E \rightarrow K.E \rightarrow P.E.$



6.5 Power

Power is defined as the rate of doing work. In equation form, it reads:

$$Powr = \frac{Work\ done}{Time}$$

The SJ. unit for power is the Watt (W).

Worked Example

A boy uses up 200 J of energy in 5 seconds. Find his power output.

Solution:

200 J of energy used = 200 J of work done

$$Powr = \frac{Work\ done}{Time}$$

$$= \frac{200}{5} = 40W$$

6.6 Efficiency

The efficiency of a system can be calculated using either of the following equations:

$$\text{Efficiency} = \frac{\text{Energy output}}{\text{Energy imput}} \times 100\% \text{or}$$

$$\text{Efficiency} = \frac{\text{Power output}}{\text{Power imput}} \times 100\% \text{or}$$

Pressure (7)

7.1 Definitions And Units

- Pressure is defined as the force acting normally per unit area. In equation form, it reads:

$$Pressure = \frac{Force}{Area}$$

- The S.I. unit for pressure is Newton per metre squared (N m"). Another name for this unit is the Pascal (Pa).

1 Pa = 1 Nm^{-2}

- The other units for pressure include mm Hg, cm Hg, bars, millibars and atmospheres.

- The pressure due to a solid depends on the magnitude of the acting force and the area on which it acts. The smaller the area, the larger is the pressure.

- The pressure due to a liquid at rest depends only on the depth and the density of the liquid. The equation for liquid pressure is:

$$Pressure = h\rho g$$

where h is depth of liquid in m, ρ is density of liquid in kg m? and S^{l} is gravitational acceleration in m S^{-2}.

Worked Example

Calculate the pressure at the base of a 5-m deep swimming pool.

Solution:

Assuming that the water has a density of 1 000 kg m " and g = 10 m S^{l},

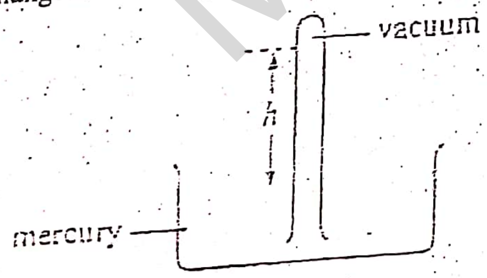
pressure = $h\rho g$

= 5 × 1 000 × 10 = 50 000 Pa

The devices that can measure pressure are (he barometer and the manometer.

7.2 Barometers

The simple mercury barometer is an instrument for measuring atmospheric pressure. It consists of an inverted thick-walled glass tube filled with mercury placed vertically with its open end below the surface of mercury in a dish. The height of the mercury, column in the tube *(h)* gives the atmospheric pressure. If the tube is slightly tilted, this height remains unchanged.



h - barometric height

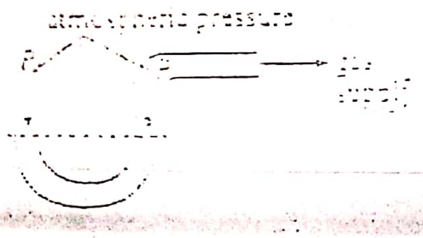
The normal atmospheric pressure is about 760 mm Hg.

7.3 Manometers

- The U-tube manometer is an instrument used to measure gas pressure.
- One arm of the manometer is exposed [Q air while the other is connected to the gas supply whose gas pressure is to be determined.

Case-1

If the mercury columns in both arms are at the same horizontal level, then the gas is at atmospheric pressure.



Case 2

If the mercury column in the arm connected to the gas supply is at a lower level, then the gas pressure is given by:

Pressure =Atmospheric pressure + Height difference between the two columns

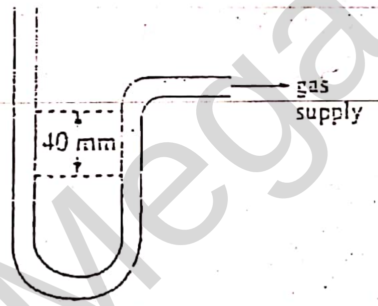
Worked Example

Determine the pressure of the gas supply in the diagram on the right.

Solution:

Pressure =760 + 40

=800 mm Hg



Case 3

If the mercury column in the arm attached to the gas supply is at a higher level, then the gas pressure is given by:

Pressure = Atmospheric pressure - Height difference between the two columns

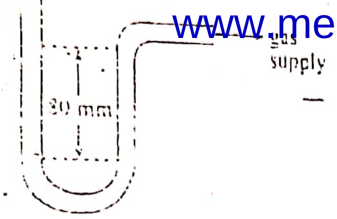
Worked Example

Determine the pressure of the gas supply in the diagram on the right.

Solution:

Pressure =760 - 80

=680 mm Hg



7.4 Isobars And "Wind

- Weather maps show the air pressure on the Earth's surface.
- Isobars are lines on the weather map joining places on the Earth's surface having equal air pressure.
- Pressure gradient measures the difference in pressures across two regions. If the difference is very large, the pressure gradient is high.
- Winds blow from a region of high pressure to one of low pressure. When the pressure gradient is high, strong winds will occur.

Scalars And Vector-s (8)

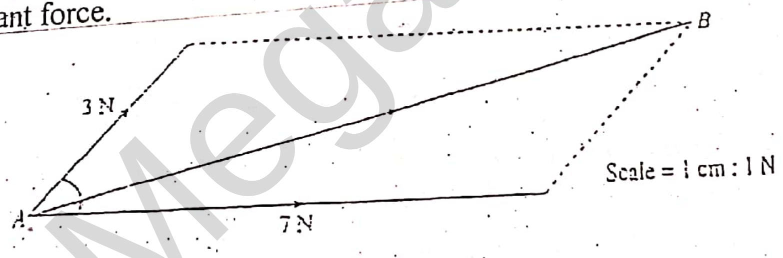
- Scalars are quantities with magnitude only.
- Examples of scalars are mass, distance. speed, energy and power.
- Vectors are quantities which have both magnitude and direction.
- Examples of vector are velocity, acceleration, force and weight.
- Addition of vectors is performed through the use of a scale diagram.

Worked Example

Find the resultant of two forces 7 N and 3 N acting at 45° to each other.

Solution:

Choose a suitable scale. Draw the two component forces 45° apart. using the chosen scale such that they form two sides of a parallelogram. Complete the parallelogram by means of dotted lines. Measure the diagonal *AS* of the parallelogram to obtain the magnitude of the resultant force.



By measurement, length of AB = 9.35 cm.
Thus, resultant force is 9.35 N.

By measurement, length or-AS = 9.35 cm.
Thus, resultant force is 9.35

The Kinetic Theory Of Matter (48)

9.1 Introduction

- The kinetic theory of matter proposes that all matter is made up of tiny particles (atoms, molecules or ions) which are in constant random motion.
- The evidence to support this theory are:

(a) Diffusion

This is the movement of molecules of a substance from a region of higher concentration to one of lower concentration. This can be observed from the diffusion of gases to fill up an entire container.

(b) Brownian motion

This is the random, haphazard motion of smoke particles observed in a smoke cell. It can be explained by imagining that air molecules, which are moving randomly with different speeds, are colliding with the smoke particles.

9.2 The Three States Of Matter

The following table highlights the main differences between solids, liquids and gases:

Solid	Liquids	Gasess
Definite shape and volume	Definite volume, no definite shape	No definite shape and volume
Molecules vibrate about a fixed mean position	Molecules vibrate and also move freely in the liquid	Molecules move freely and randomly at high speeds.
Intermolecular forces are very strong	Intermolecular forces are is lightly weaker than that in solids	Intermolecular forces are very weak
Separation between molecules is small	Separation is about the same as that in solids.	Separation is about 10 times further than that in the other two states.

Heat And Temperature (10)

10.1 Introduction

- **Heat** *is* energy which flows from a hotter body to a celder one.
- **Temperature** *is* the degree of hotness or coldness as measured on a chosen scale.

10.2 Measurement Of Temperature

- The instrument used for measuring temperature is the thermometer.
- A thermometer requires three things:

a) a thermometric property, i.e. a property that varies uniformly with temperature.
b) a temperature scale.
c) two fixed points on the chosen temperature scale.

Some thermometric properties involve:

(a) expansion of a fixed mass of liquid, e.g. mercury.

(b) expansion of a fixed mass of gas at constant pressure.

(c) electrical resistance of a platinium wire.

(d) voltage of a thermocouple.

Two temperature scales, the Celsius scale and the thermodynamic scale, are most commonly used. The differences are shown in the following table:

	Celsius scale	Thermodynamic scale
Unit	Degree Celsius (°C)	Kelvin (K)
Fixed Point	(a) The lower fixed point is the melting point of pure water (Goe).	a) The lower fixed point is the absolute zero of temperature (0 K). This is the lowest possible temperature of a substance.

	Celsius scale	Thermodynamic scale
Fixed Point	(b) The upper fixed point is the boiling point of pure water at atmospheric pressure (100°C)	(b) The upper fixed point is the triple point of water (273.16k)

- Temperature in K = Temperature in °C + 273
- 0K =-273°C

Worked Example

What are the corresponding temperatures in Kelvin for 0°C and 100°C?

Solution:

0°C = (0 + 273) K = 273 K

1000 (= (100 + 273) K =373 K

For thermometers using the Celsius scale, we use the following equationto measure temperatures using an unmarked thermometer.

$\theta \frac{x_\theta - x_0}{x_{100} - x_0} \times 100°C$, where X_θ is the property at the unknown temperature,

X_{100} is the property at the upper fixed point (100°C),

$X_0$is the property at the lower fixed point (0°C).

Worked Example

The bulb of a mercury-in-glass thermometer is placed', in turn, in melting ice, in steam and in liquid X. The lengths of mercury thread above the bulb are 20 mm, 170 mm and 50 mm respectively. What is the temperature of X?

Solution:

Temperature of $X = \frac{50-20}{170-20}$

$= 20^{oC}$

- A sensitive thermometer is one which gives a large change in its thermometric property for a small change in temperature.
- The range of a thermometer refers to the range of temperatures it can measure.
- The following are a few types of thermometers which are commonly used:

(a) Mercury-in-glass thermometer

This thermometer uses the length of the mercury column above the bulb to determine temperature. It can be made to

(i) be more sensitive by using a capillary tube with a narrow bore,

(ii) respond more quickly by having a thin-walled bulb.

(b) Clinical thermometer

It uses the same thermometric property as the mercury-in-glass thermometer but it has the following features.

(i) It measures a short range of temperatures, from 35°C to 42°C.

(ii) It has a constriction just above the bulb of the thermometer to prevent the mercury from falling back into the bulb.

(c) Thermocouple

A thermocouple consists of two wires made of different metals joined together to form two junctions. If the two junctions are placed at different temperatures, then an electro-motive force will be set up.

The voltage of this electro-motive force is proportional to the temperature difference between the two junctions.

The advantages of a thermocouple are as follows:

(i) It can measure rapidly varying temperatures.

(ii) It can measure a wide range of temperatures from -200°C to I 500°C.

10.3 Heat Capacity

(iii) Heat capacity is defined as the amount of heat ener ",y required to raise the temperature of a substance by 1 K.

(iv) The unit for heat capacity is Joule per Kelvin ($J K^{-1}$).

(v) Specific heat capacity is defined as the amount of heat energy needed to raise the temperature of 1 kg of substance by I K.

(vi) The amount of heat energy absorbed or released (Q) depends on:

(a) specific heat capacity of the substance, c

(vii) (b) mass of substance, *In*

(viii) (c) change in temperature, 68 (either measured in "C or K)

$Q = mc\Delta\theta$

Worked Example

How much heat energy is required to raise 2 kg of water from 20°C to its boiling point, given that specific heat capacity of water is 4 200J kg^{-1} K^{-1}?

Solution

$\Delta\theta = 100 - 20 = 80°C$

Heat energy required $= mc\Delta\theta$

$= 2 \times 4200 \times 80$

$= 672\,000$ J

10.4 Latent Heat

When a substance undergoes change of state,

(a) its temperature remains constant,

(b) latent heat is given off or absorbed by the substance.

(a) Specific latent heat of fusion

- Specific latent heat of fusion of a substance is the quantity of heat required to convert a unit mass of that substance from a solid to a liquid without changing its temperature.
- The S.I unit is Joule per kilogram (J kg^{-1}).
- This change of state is also known as melting.
- The temperature at which this happens is termed the melting point of the substance.
- In the process of melting. the latent heat is taken in to overcome the auractive forces between the molecules in a solid so that the molecules can break away from the lattice structure and attain some freedom of movement.
- When the substance is changed from a liquid to a solid. latent heat is released and this process is called freezing.

$$Solid \underset{Freezing\ (heat\ given\ out)}{\overset{melting\ (Heat\ absorbed)}{\rightleftharpoons}} liquid$$

(b) Specific latent heat of vaporisation

- Specific latent heat of vaporisation is the quantity of heat required to change a unit mass of liquid into vapour without changing the temperature
- The S.I. unit is also J
- This process is also called boiling.
- The temperature at which rhis occurs is known as the boiling point of the substance.
- In the process of boiling, the latent hear is absorbed to overcome the intermolecular forces of attraction in the liquid and also to enable the vapour to expand against atmospheric pressure.
- When the substance is changed from a gaseous state to a liquid stare, latent heat is given off and this process is called condensation.

$$liquid \underset{condensation\ (heat\ given\ out)}{\overset{boiling\ (heat\ absorbed)}{\rightleftharpoons}} gas$$

Evaporation also involves the conversion of a liquid to a gas which results in the further cooling of the liquid

- The distances between boiling and evaporation are listed below:

Evaporation	Boiling
Occurs only at the surface of the liquid	Occurs throughout the whole liquid
Occurs at any temperature	Occurs at a fixed temperature
No bubbles are formed	Bubbles are formed within the liquid

- The factors affecting the rate of evaporation are as follows:

(i) The temperature of the liquid; the higher the temperature, the faster the rate.
(ii) The surface area of the liquid; the larger the surface area, the faster the rate.
(iii) The humidity of the _u ounding air; the higher the humidity, the slower the rate.
(iv) The presence of moving air above the liquid surface In calculations, the following equation is used:

$$Q = ml$$

Where Q is the heat released or absorbed by the substance, m is the mass of substance and l is the specific latent heat of vaporisation or fusion.

10.5 Transfer Of Heat

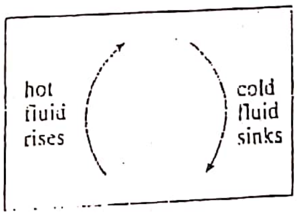
Conduction, convection and radiation are the main ways in which heat energy is transferred.

(a) Conduction

- This is [he process by which heat energy is transferred due to vibration of particles about their mean positions (lattice vibrations).
- Good conductors are used where heat has to be readily transmitted or removed.
- Poor conductors or insulators are used to prevent heat loss or unwanted heat gain.
- Solids are much better conductors than liquids or gases. Metalsare good thermal conductors while air is a poor conductor. Good insulation can be achieved by trapping a layer of air between double-walled surfaces.

(b) Convection

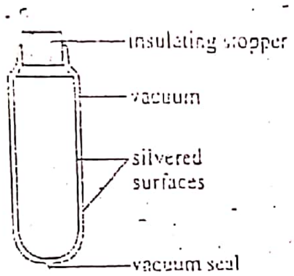
- This is the process whereby heat is transmitted from one place to another by the movement of heated particles in liquids and gases.



- The part of the fluid that is heated becomes less dense and rises while the colder, denser part of the fluid sinks. This sets up convection currents in the fluid.
- Application of convection currents:
- (i) Hot water system (ii) Land and sea breezes
- (c) Radiation
- This is the process whereby heat is transferred in the form of electromagnetic waves.

Such radiant heat does not require a medium and hence can travel through vacuum.

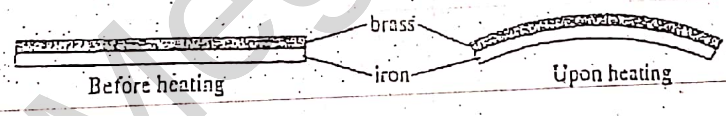
- When radiant heat falls on a surface, it can be reflected or absorbed, depending on the type of surface:
- Dull, black surfaces are good absorbers and radiators of heat. Shiny, smooth surfaces are good reflectors of heat.



- The vacuum flask is a useful device which minimises conduction, convection and radiation, so that heat is not easily lost or absorbed by substances stored inside the flask.
- It consists of a double-walled glass container with a vacuum between the walls and the opening on top is covered with an insulating stopper.
- The walls which enclose the vacuum are silvered to reduce the loss of heat by radiation.
- The vacuum prevents the transfer of heat by conduction and convection.
- The stopper reduces heat loss by conduction and evaporation .

10.6 Expansion Of Solids, Liquids And Gases

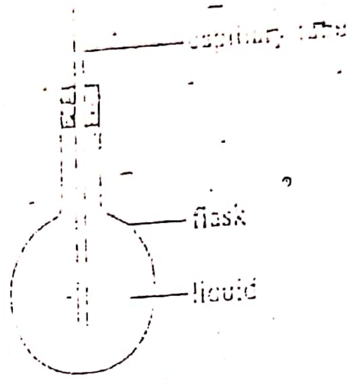
- (a) Expansion of solids
- When a solid substance is heated, it expands. This is termed **thermal expansion.**
- Different substances expand by different amounts for the same amount of heating.
- The bimetallic strip consists of two metal strips, e.g. brass and iron, welded together.
- As brass expands more than iron upon heating, bending of the bimetallic strip occurs.



- An important application of the bimetallic strip is the thermostat, which is a device used to maintain steady temperatures in appliances such as electric irons and refrigerators.

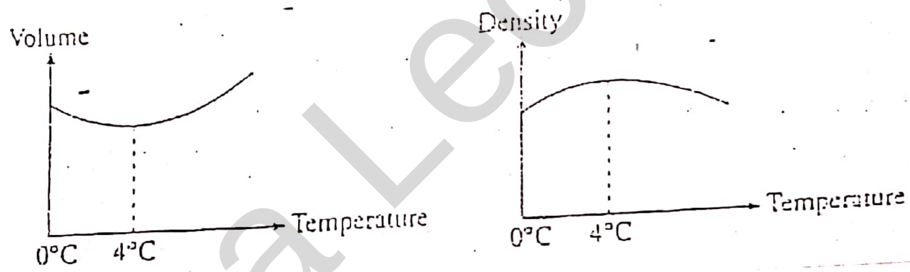
(b) Expansion of liquids

Liquids expand more than solids upon heating. This can be observed from the following set-up.



Heat

- Observation:- Upon heating, the level of the liquid falls a little before it begins to rise.
- Explanation: Initial fall is due to the fact that glass expands faster than the liquid. It rises later because the liquid expands more than glass.
- Water has an unusual behaviour from 0°C to 4°C. It contracts when it is heated from 0°C' to 4°C. When its temperature is above 4°e, it will expand when heated like other substances.
- This leads to [he fact [hat water has its minimum volume and hence maximum density at 4°C.



- The importance of the unusual expansion of water is that it allows for the preservation of marine life during cold weather.
- As the temperature of waterfalls, it contracts and sinks until all the water is at 4°C (maximum density). Upon further cooling, the water on top expands and becomes less dense, thereby preventing it from sinking and setting up convection currents. In due course, ice, which is a bad conductor, would form on top and heat loss of the water below the ice layer is reduced. Thus. there will always be water at 4°C beneath the ice which enables marine life to survive.

(c) Expansion of gases

- The expansion of a gas IS much larger than that of a liquid for the same rise in temperature.
- The behaviour of gas for thermal changes is governed by three gas laws.

11 – The Gas Laws

11.1 Kinetic Theory Of Gases

- A gas consists of a large number of molecules that are always in constant, random motion.

- Pressure of a gas exerted on its container comes about because of the bombardment of the gas molecules on the container walls.
- Temperature of a gas is a measure of the amount of kinetic energy possessed by the gas molecules. The higher the temperature, the faster the motion of the molecules. For calculations, temperature is always expressed in units of Kelvin (K).
- Volume of a gas is the volume of the vessel which contains the gas.

11.2 The Gas Laws

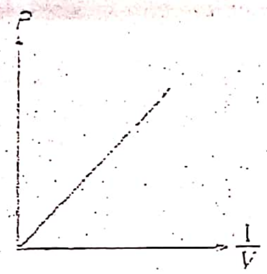
- There are three gas laws.

a) Boyle's Law

It states that the volume of a fixed mass of gas is inversely proportional to its pressure at
constant temperature.

$$p \propto \frac{1}{V}$$

$$\Rightarrow PV = constant$$

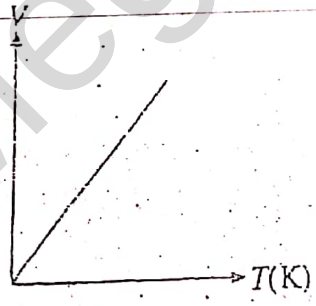


(b) Charles' Law

It slates that the volume of a fixed mass of gas is proportional to its temperature at constant pressure

$$V \propto T$$

$$\Rightarrow \frac{V}{T} = constant$$



e) Pressure Law

- It states that the pressure of a fixed mass of gas is proportional to its temperature at constant volume

$$p \propto T$$

$$\Rightarrow \frac{P}{T} = constant$$

- Combining the three laws, we have $\frac{P}{T} = constant$.

Worked Example

A bubble of gas released at the bottom of a lake increases to 8 times its original volume when it reaches the surface. Find the pressure at the bottom of the lake.

Solution:

Original volume = V; final volume = 8 V

Let P be atmospheric pressure and P_1 be pressure at bottom of lake.

Using Boyle's Law

$$P_1 \times V = P \times 8V$$

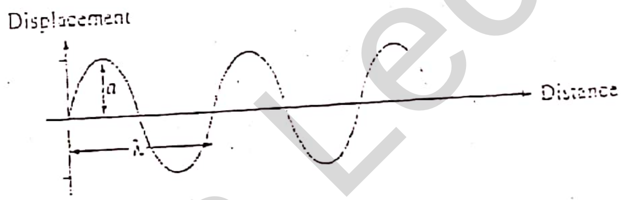
$$\therefore P_1 = 8P$$

Pressure at bottom of lake =8 atmospheric pressures

(12)Waves

12.1 Introduction

Wave is a phenomenon in which energy is transferred from one point to another. It involves the wave particles oscillating or vibrating about their rest position and can be represented by the following diagram.



- There are two types of wave motion:
  (a) **Longitudinal** waves
  These are waves in which the vibration of the particles is parallel to the direction of propagation of wave motion.
  (b) **Transverse** waves
  These are waves in which the vibration of the particles IS perpendicular to the direction of travel of the wave motion.
- An example of a longitudinal wave *is* the sound wave.
- Examples of transverse waves arc water waves, light waves and electromagnetic *(EM)* waves.

12.2 Definitions And Units

- The following terms are commonly used in waves.

Terms	Symbol	Definition	Unit
Amplitude	α	Maximum displacement of the particle from its rest position (see above diagram)	mm,cm,m
Wavelength	λ	Distance between two successive troughs or two successive crests (see above diagram)	mm,cm,m

Frequency	f	Number to oscillations made in 1 second	Hz
Period	T	Time taken for 1 complete oscillation	S
Velocity	V	Distance moved by the wave in 1 second	Cms^{-1}, ms^{-1}

Note that frequency of a wave is also equal to the reciprocal of its period.

$$f = \frac{1}{T}$$

- Using the above terms, the following wave equation can be written down:

  Velocity of a wave = Frequency × wavelength

$$v = f \times \lambda$$

Worked Example

Find the frequency and velocity of a wave which has a wavelength of 0.1 m and a period of 0.01 s.

Solution: Frequency $f = \frac{1}{T}$

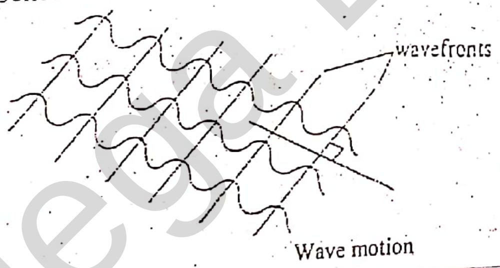
$$f = \frac{1}{T}$$

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

Velocity $v = f \times \lambda$

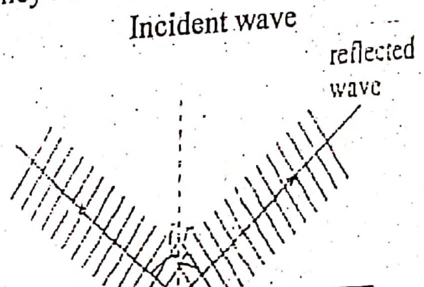
$=100 \times 0.1 = 10ms^{-1}$

A wavefront is a line joining all panicles that are in the same state of displacement. The direction of wave motion is always perpendicular to its wavefront



12.3 Reflection Of Waves

- Waves can be reflected off a surface.
- The angle of incidence (i) is equal to the angle of reflection *(r)*.
- The wavelength, frequency and velocity of the wave are unchanged after reflection.

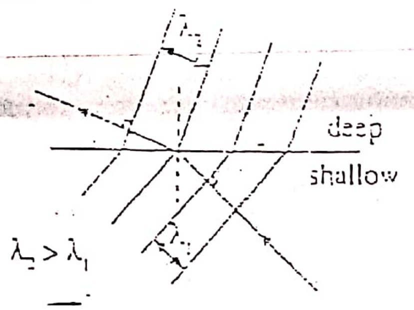


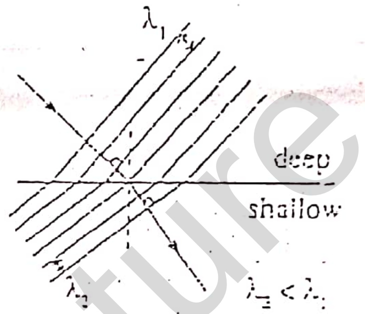
12.4 Refraction Of Waves

When water waves move from shallow to deep water or vice versa, the direction of the wave motion can change. This is known as refraction of the water waves.

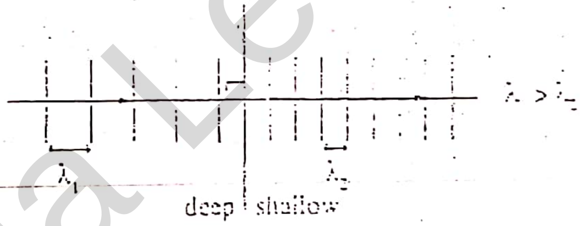
- The changes in the various wave quantities for the two cases are compared below:

Quantity	From shallow to deep	From deep to shallow
speed	increases	decreases
wavelength	increases	decreases
frequency	unchanged	unchanged
direction of	Bends away from the normal	bends away from the





Note that the direction of wave motion will only remain unchanged if the wave approaches the boundary between the shallow and deep water at a right angle.



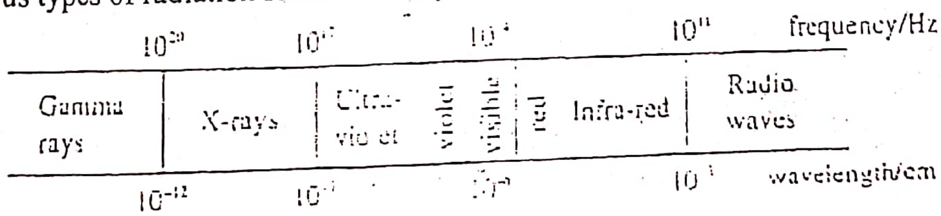
12.5 Electromagnetic Waves

These are waves that make up the **electromagnetic** (EM) **spectrum.** They have the following properties:

(a) They are all transverse waves.

(b) They all travel at the speed of light, $v = 3\text{x}10^8$ m s' in vacuum.

- Below shows a portion of the EM spectrum followed by a table listing the properties of various types of radiation found in the spectrum:



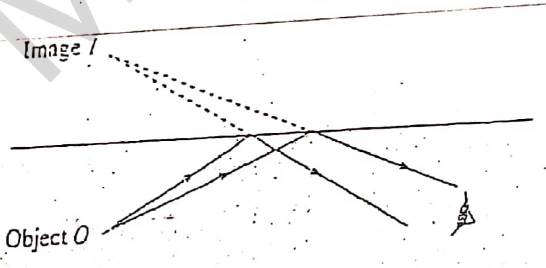
Rays	Source	Detection	Uses
Radio	Radio transmitting equipment	Radio receiving equipment	Broadcasting, communication
Infra-red	Hot bodies	Thermopile phototransistor	Infra-red photography, thermal photocopy
Visible	Incandescent object	Eye, photographic films	Vision
Ultra-violet	Mercury vapour lamps, sun	Photographic film (produces fluorescence in certain salts)	To detect forgery, burglar alarms
X-rays	X-ray tube	Photographic plate, photoelectric effect	Radiography, detecting flaws in metals
Gamma	Radioactive substances	Geiger Muller Tube	Cancer treatment, detecting flaws in metal castings

Light (13)

13.1 Reflection Of Light

- The laws of reflection of light are as follows:
  (1) The incident ray, the reflected ray and the normal [O the mirror at the point of incidence all lie in the same plane.
  (2) The angle of incidence is equal to the angle of reflection. Images formed in a plane mirror have the following characteristics:
  (a) They are of the same size as the object.
  (b) They are at the same distance behind the mirror as the object is in front of the mirror.
  (c) They are laterally inverted.
  (d) They are virtual.

- To locate the image formed by an object in a plane mirror, two light rays are required.



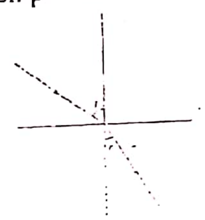
13.2 Refraction Of Light

Refraction is the bending of light as it travels from one medium to another at a glancing angle. This deviation occurs because light travels at different speeds in different media.

- Note that no such deviation will be observed if the light is incident at 90° to the boundary between the two media.

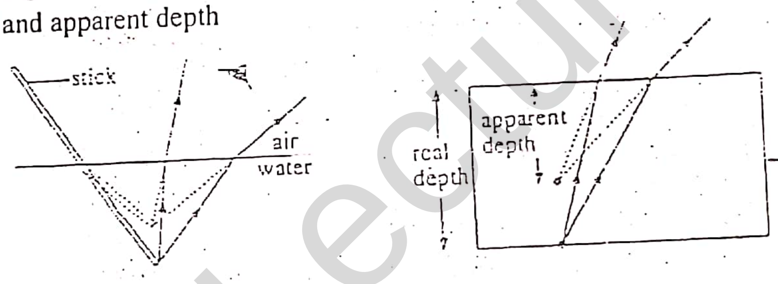
- The laws of refraction of light are as follows:
  (1) The incident ray, the refracted ray and the normal to the boundary between the two media at the point of incidence all lie in the same plane.

(Snell's Law)
The ratio of the sine of the angle of incidence (i) to the sine of the angle of refraction (r) is a constant for a given pair of media and is called the refractive **index.**



Refractive index $(n) = \frac{\sin i}{\sin r}$

- Refraction leads to the following optical effects:
  (a) Bending of a stick in water
  (b) Real and apparent depth



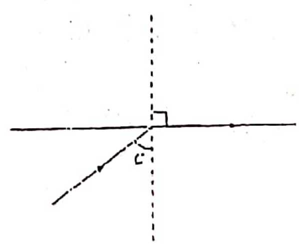
Other formulae of refractive index are:

$$n = \frac{speed\ of\ light\ in\ vacuum}{speed\ of\ light\ in\ medium}$$

$$n = \frac{real\ depth}{apparent\ depth}$$

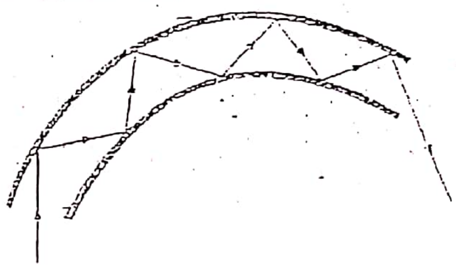
- The refractive index of vacuum is set to be 1. The refractive indices of all other media must be greater than 1.

- The critical angle c is the angle of incidence in the denser medium which results in the angle of refraction in the less dense medium to be 90°.



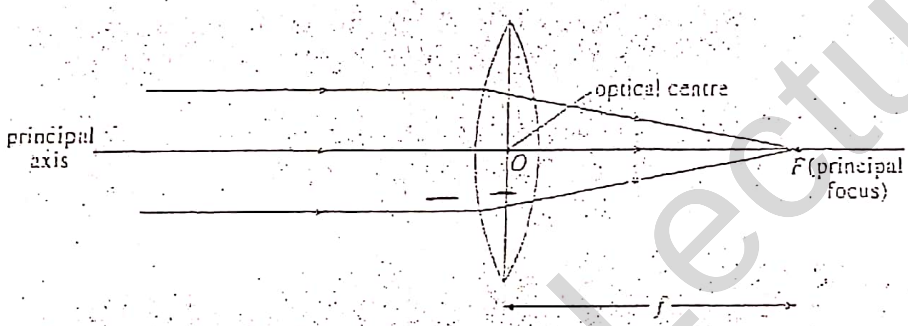
- Refractive index $n = \frac{1}{\sin c}$

- Total internal reflection occurs when we have the following situations:
  (a) Light travels from a denser to a less dense medium.
  (b) The angle of incidence is greater than the critical angle for that medium.
- The main advantage of total internal reflection is that all light is reflected and there is no loss in light intensity.
- An application of total internal reflection is in optical fibers. This involves a long tube made of good quality glass of high refractive index coated with a thin glass layer of lower refractive index. Light is then transmitted from one end of the fiber to the other end by multiple total internal reflections without any loss in light intensity.



13.3 Thin Converging Lens

Below is a diagram of a converging lens



- The principal focus *(F)* of a lens is a point on the principal axis to which all rays close and parallel to the axis will converge after passing through the lens.
- Tile distance between the principal focus and the optical centre *(0)* of the lens is known as the focal length *(f)* of the lens.
- Formation of images by converging lens an be illustrated by ray diagrams. Two important points to bear in mind when drawing ray diagrams are:
  (a) Rays parallel to the principal axis will pass through the principal focus after refraction through the lens.
  (b) Rays passing through the optical centre are not deviated.
- The type of image formed by a converging lens depends on the object distance.

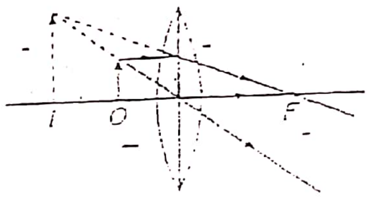
Object distance	Nature of image	Image distance	Application
Greater than 2*f*	Real, inverted, diminished	Between *f* and 2*f* on the opposite side of	Camera
Equals 2*f*	Real, inverted, same size as object	Exactly at 2f on the opposite side of lens	Photocopier

A real image is one which can be captured on screen and is formed by the intersection of light rays.

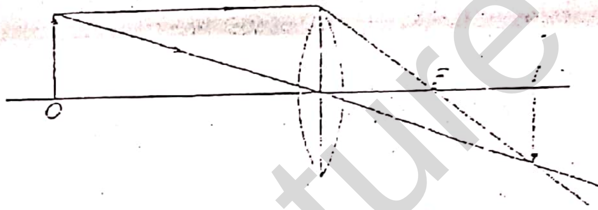
A virtual image cannot be captured on screen as no light rays reach the point where the image is located.

The following ray diagrams show the use of convex lens in:

(a) A magnifying glass



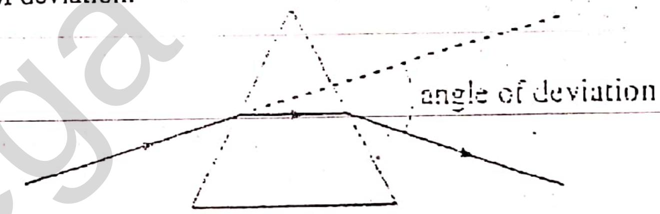
(b) A Camera



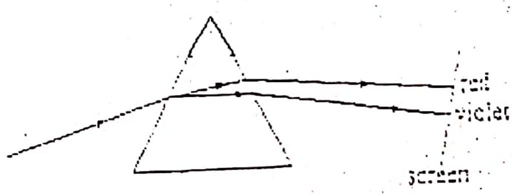
- $Magnification = \frac{image\ heigh}{object\ height} = \frac{image\ distance}{object\ distance}$

13.4 Dispersion Of Light

When a light ray of a single colour is incident on a prism, it is deviated from its original direction. The angle between the original and final directions is known as the angle of deviation.



The amount of deviation is dependent on the wavelength of the light ray. Red light is least deviated while violet light is most deviated.

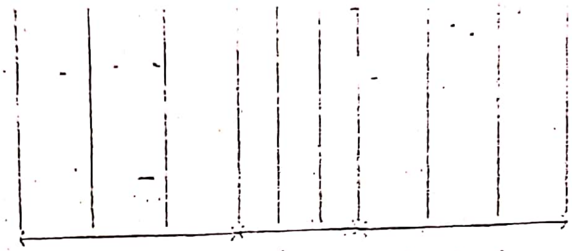


- Thus, a ray of white light upon passing through a prism will split into its component colours of red, orange, yellow, green, blue, indigo and violet.
- This is known as the dispersion of light and the colours are collectively called the **spectrum** of white light.

Sound (14)

14.1 Basic Concepts

Sound is a longitudinal wave. It consists of rarefactions and compressions as shown in the diagram below.



(a) Rarefactions are regions in the waves where the particles are further apart.
(b) Compressions are those regions where the particles are closer together

- The distance between two successive compressions or two successive rarefactions is known as the wavelength.
- Sound requires a medium to travel. It travels fastest in solids and slowest in gases.
- Sound cannot travel through a vacuum.
- The approximate range of audible frequencies of the human ear is 20 Hz to 20 kHz.

Characteristics of sound:

(a) The **pitch** of a note depends on the frequency of the sound wave. A high frequency gives a high pitch.
(b) The **loudness** of a sound depends on the amplitude of the wave. A large amplitude gives a loud sound.
(c) The **quality or timbre** of a note depends on the harmonics or overtones present.

Echoes are produced by reflection of sound.

14.2 Speed Of Sound

- The speed of sound in air near the surface of the Earth is about 340 m s^{-1},
- It can be determined by using either of the following methods:

(a) Direct method

(i) Measure the distance between the sound source and the observer, *d*.
(ii) Measure the time taken for the sound to travel from the source to the observer, *t*.
(iii) Speed of sound = d/t

(b) Echo method

i. Measure the distance between an observer and a reflecting wall, d,
ii. The observer produces a loud sound, for example, by shouting.
iii. Measure the time taken for the echo to reach the observer, t.
iv. Speed of sound $\frac{2d}{t}$

Static Electricity (15)

15.1 Introduction

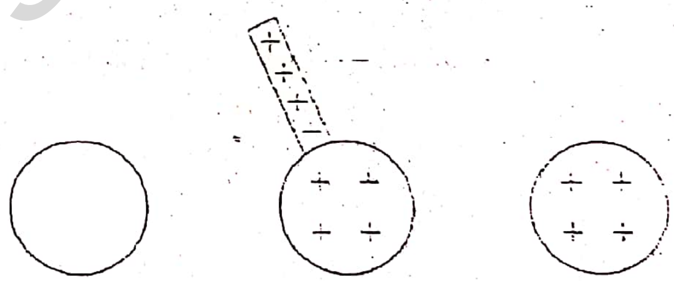
- There are only two types of electric charges: the positive charge (+) and the negative charge (-).
- Like charges **repel** i.e. positive repels positive, negative repels negative.
- Unlike charges **attract** i.e. positive attracts negative.
- The S.I. unit for charge is the coulomb (C).
- One electron carries a negative charge of 1.6×10^{-19} C.
- When an object gains excess electrons, it becomes negatively charged.
- When an object loses electrons, it becomes positively charged.
- When an object has an equal number of positive and negative charges, it is neutral.

15.2 Charging An Object

- Objects can be classified as electrical insulators or electrical conductors. Insulators do not allow charges to flow through them easily. This is because the electrons are tightly bound to their atoms and are unable to move freely.
- Conductors allow charges to pass through them easily. Here, the electrons can move freely from one atom to another (free electrons) within the conductor.
- Insulators can only be charged by friction. For example, rubbing a glass rod with silk will result in the glass rod becoming positively charged while silk will become negatively charged. This is cue to the fact that some electrons were transferred from the glass rod to the silk during the rubbing process.
- Conductors can be charged by
  (a) contact with a charged body,
  (b) electrostatic induction.

(a) Charging by contact

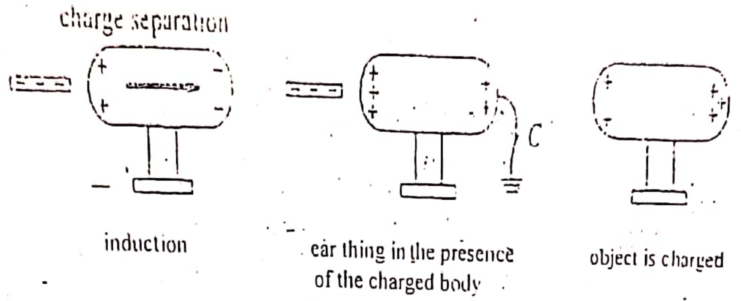
- This is the process whereby an object is charged by direct contact with a charged body.
- Note that the object carries the same charge as the charging body.



(b) Charging by induction

This is the process whereby a conductor is charged by bringing it near a charged body without any direct contact.

The charge that is carried by the object is opposite to [hat carried by the charging body.

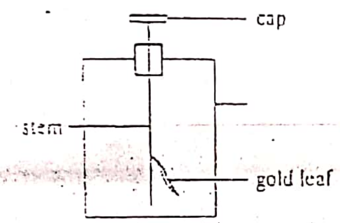


15.3 Gold-leaf Electroscope.

The gold-leaf electroscope is an instrument used to:

(a) detect the presence of charges on a body,

(b) test the sign of charges on a body.

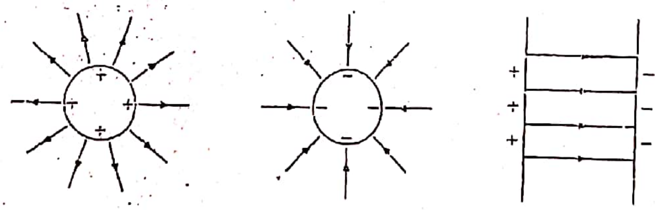


- To detect charges on a body, an uncharged electroscope must be used. If the gold leaf diverges when the body is brought near the cap of the electroscope, then the body is charged.
- To test the sign of charges on an object, the electroscope must first be charged and the sign of the charge must be known. **Increased divergence** of the gold leaf when the object is brought near the C3P will mean that the object carries the same charge as the charge on the electroscope.
- Note that increased divergence is the only sure test. Reduced divergence can either mean that the object is uncharged or it carries a charge that is opposite in sign to that on the electroscope.

15.4 Electric Field

- An electric field is a region where charges experience electrical forces.
- The direction of the electric **field** is defined by the direction of the electrical force on a positive charge.
- An electric field can be illustrated ~y using electric field lines. These lines are directed away from positive charges but towards negative charges.

Examples.



16-Current Electricity

16.1 Current And Potential Difference

- Current (I) is defined as the quantity of electric charge passing a given point in one second.

$$I = \frac{Q}{t}$$

- Where Q is the amount of charge in coulombs and t is time in seconds.
- The unit for current is the ampere (A). One ampere means one coulomb of charge flowing every second.
- A potential difference (p.d.) has to be present across the ends of a conductor in order for current to flow.
- Potential difference (V) between two points is defined as the work done in carrying one coulomb of charge across the points.

$$V = \frac{W}{Q}$$

- Where W is work done in Joules and Q is the amount of charge in coulombs.
- The unit for potential difference is the volt (V). If 1 J of work is done in moving 1-C of charge between two points, then the potential difference is I V.
- **Electromotive force** (emf) of a cell is defined as the total work done per coulomb when driving a charge through the whole circuit.
- The unit for emf is also the volt (V).

16.2 Ohm's Law And Resistance

- Ohm's Law states that the current j flowing In a conductor is directly proportional to the potential difference V between its ends. provided the temperature remains constant.

$$I \propto or \frac{V}{I} = constant = R$$

- R is known as the resistance of the conductor and measures the opposition of the conductor to current flow.
- The unit for resistance is the ohm (Ω).

Worked Example

Calculate the current flowing through a 4-Ω resistor when a p.d. of 6 V IS applied across it.

Solution:

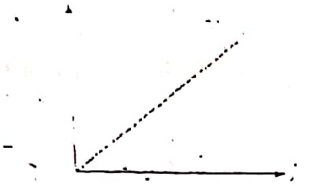
$$R = \frac{V}{I}$$

$$\therefore R = \frac{V}{R}$$

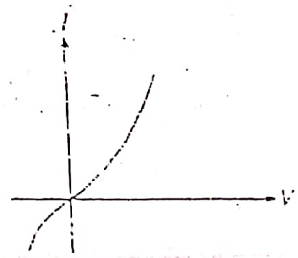
$$= \frac{5}{4}$$

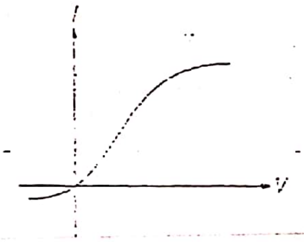
$$= 1.5A$$

Metals that obey Ohm's **Law** are called **ohmic** conductors



- Metals that do not obey Ohm's Law are called **non-ohmic** conductors, Examples are thermistors, diodes and light-dependent resistors;



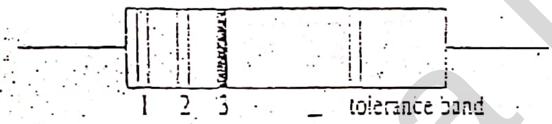


- The resistance of a wire is directly proportional to its length (*l*) and inversely proportional to its cross-sectional area (*A*)

$$R \propto \frac{V}{R}$$

- The longer the wire, the greater the resistance. The thicker the wire, the smaller the resistance.

The values of resistors are usually marked with a standard colour code.



Colour	**1st band = 1st digit**	**2nd brand = 2nd digit**	**3rd brand = number of zero**
Black	0	0	0
Brown	1	1	1
Red	2	2	2
Orange	3	3	3
Yellow	4	4	4
Green	5	5	5

Colour	1st band = 1st digit	2nd band = 2nd digit	3rd band = number of zeros
blue	6	6	6
violet	7	7	7
gray	8	8	8
white	9	9	9

Worked Example

- What is the resistance of a resistor that has red, violet and orange bands?

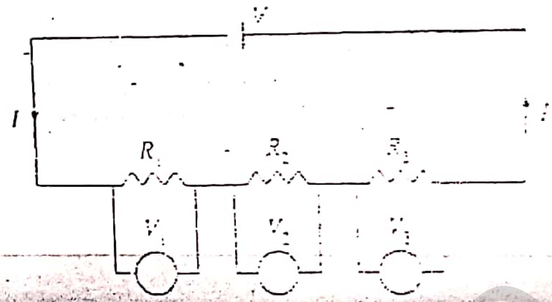
Solution:

Red - 2, violet - 7, orange - 000,

Resistance =27 000 Ω

Electric Circuits (17)

17.1 Resistors in Series



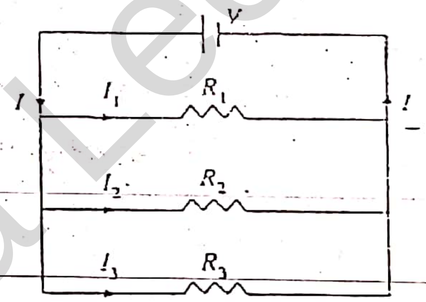
- The current flowing through each part of a series circuit is the same.
- The total potential difference *V* across the resistors is the sum of the potential difference across each resistor.

  $V = V_1 + V_2 + V_3$

- The total resistance *R* in the circuit is equal to the sum of the individual resistance.

$R = R_1 + R_1 + R_1$

17.2 Resistors In Parallel



- The main current I is equal to the sum of me individual currents in the branch circuits.

$I = I_1 + I_2 + I_3$

- The potential difference across R_1, R_2 and R_3 is the same and is equal to V
- The combined resistance *R* in the circuit is given by:

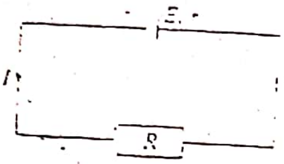
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

- For two resistors in parallel:

$$R = \frac{R_1 R_2}{R_1 + R_1}$$

17.3 Internal Resistance

When cells have internal resistance, we have:



17.4 Direct And Alternating Currents

- There are two types of power supplies; one which gives direct current (dc) and the other which gives **alternating current** (ac).
- Direct current means that the current flow is in one direction only. Batteries and cells provide direct currents.
- Alternating current means that the current flow alternates from one direction to the other. Household mains provide alternating currents.

Practical Electrical Circuitry (18)

18.1 Electrical Energy And Power

- When charges flow from a higher potential to a lower potential, energy is released. This energy (E) can be calculated using the formula:
  E=Q ×V
- Where Q is the amount of charge in coulombs and V is p.d. in V.
- The following equations for E can also be derived:

$$E = VIt (from\ Q = It)$$

$$E = I^2Rt \quad (from\ V = IR)$$

$$E = \frac{V^2}{R}t \quad (from I = E = \frac{V}{R})$$

Electrical power is the rate of electrical energy released.

Using the definition of power $P = \frac{E}{t}$ the following equations can be obtained.

$$P = VI$$

$$P = I^2R$$

$$p = \frac{V^2}{R}$$

18.2 Cost Of Electricity

- Electricity is sold in units of kilowatt-hour (kWh).
- 1 kWh is the amount of energy consumed by a device working at a power of 1 kW for 1 hour.

1 kWh = 1 000 W x 1 h
= 1 000 × 60 × 60
=3 600 000 J

- To calculate the cost of household consumption of electrical energy, find the energy consumed in units of kWh and then use the formula:

Cost = Number of kWh × cost perkWh.

Worked Example

Find the cost of running a television set at 180 W for 7 hours given that the cost of 1 kWh of electricity is $0.50.

Solution:

Energy used = $P \times t$

= 180 W × 7 h

=0.18kW×7h

=1.26 kWh

Cost = 1.26 × $0.50

= $0.63

18.3 Wiring In The Home

- Electricity is supplied to the home using a cable which contains two wires which are well. insulated from each other. One is the live wire and the other is the neutral wire.
- The live wire carries current at 230 V.
- The neutral wire carries current at earth potential.
- The p.d. between the two wires is thus 230 V.
- For safety reasons, switches and fuses are always connected to the live wire.
- The switch serves to break the connection of the live wire with the power supply once electricity is not required.
- **Fuses** are short lengths of thin wire which melt and break the circuit if the current exceeds its rated value. They are connected to the live wire to prevent appliances from becoming live when the fuses blow.
- There is a third wire, the earth wire, which connects the metallic casing of appliances to the earth. It serves to prevent the user from getting an electric shock in the event of a current leakage by drawing the leaked charges away to earth.
- The colour code adopted for the three wires are as follows:
  (a) live wire - brown .
  (b) neutral wire - blue
  (c) earth wire - green and yellow
- Lamps in a lighting circuit and electrical appliances in power circuits are always connected in parallel so that they can operate independently of one another.

Magnetism (19)

19.1 Introduction

- A magnet attracts magnetic substances.
- A magnet which is freely pivoted will rest in a north-south direction. The end facing the north is called the north pole (N) while the other end is called the south pole (S).
- Unlike poles attract each other while like poles repel each other.
- Examples of strongly magnetic or ferromagnetic materials are iron, nickel, cobalt and certain alloys.

- Magnetic induction is the process of magnetizing magnetic substances which are in contact with or are placed near a permanent magnet.
- A magnet attracts substances through magnetic induction.

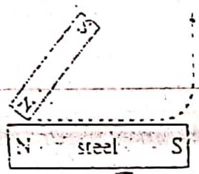
19.2 Magnetization And Demagnetization

- Magnetization is the process of turning magnetic substances into magnets. Note that only magnetic substances can be magnetized.
- There are two methods: the stroking method and the electrical method.

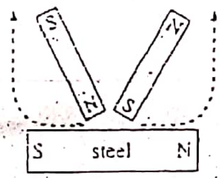
(a) Stroking method

- The substance can be stroked with one permanent magnet or with two permanent magnets. It is essential that the direction of stroking remains unchanged during the process.

(i) Single touch method

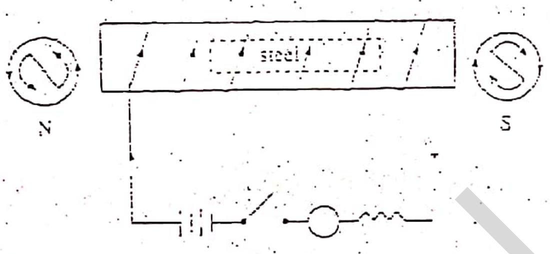


(ii) Divided touch method



(b) Electrical Method.

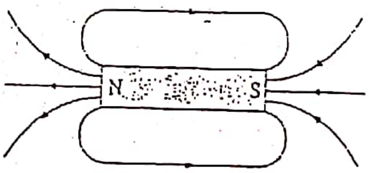
- The substance is placed in a solenoid connected to a dc supply.



- If the current is flowing in an anticlockwise direction when viewed from the side, that end of the rod will be a North pole. If the current is in a Clockwise direction, the end will be a South pole.

Demagnetization is the process of removing magnetism from a magnet, The three commonly used methods are as follows:
(a) Place the magnet in a solenoid connected to an ac Source.
(b) Heat the magnet strongly and then let it cool lying in a east-west direction.
(c) Hammer or drop the magnet repeatedly.

19.3 Magnetic Fields



- The region of space surrounding a magnet in which magnetic forces can be felt is termed the magnetic field of the magnet.
- This field contains magnetic flux which can be represented by magnetic lines of force.
- The direction of the magnetic field is always from the N-pole to the S- pole.
- Magnetic flux patterns can be traced out by
  (a) Scattering iron filings round the magnet.
  (b) Using a compass to plot out the line of force.
- Earth has its own magnetic field in which the magnetic flux run from south to north.

19.4 Magnetic Properties Of Iron And Steel

The differences between the magnetic properties of iron and steel are as follows:

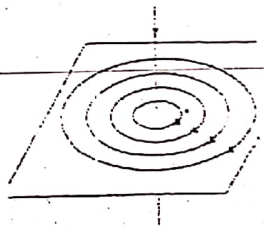
Property	Iron	Steel
Magnetization	Easy	Difficult
Demagnetization	Easy	Difficult
Magnetism	Temporary	Permanent
Strength of magnetism	Strong	Weak

- Uses of soft iron: magnetic shielding, electromagnets
- Uses of steel: making of permanent magnets

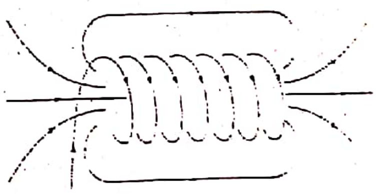
(20) Electromagnetism

20.1 Magnetic Effects Of A Current

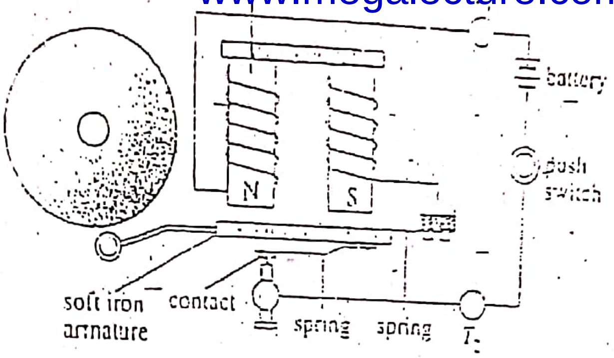
- A current in a conductor produces a magnetic field around it. This is the basis for making an electromagnet.
- The magnetic flux pattern due to a current in a long straight wire is as shown



- The magnetic flux pattern for a solenoid is similar to that for a bar magnet.



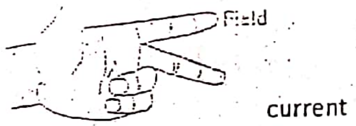
- One application of the electromagnet is he electric bell.



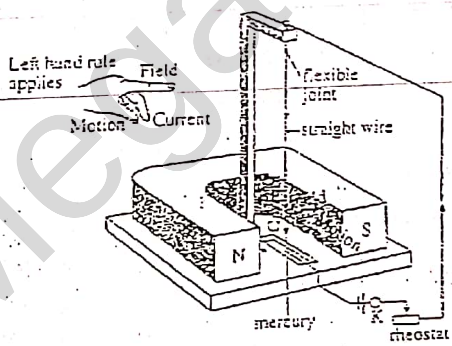
- When the switch is dosed, the electromagnet becomes magnetised and attracts the soft iron armature.
- The armature separates from the contact and breaks the circuit. The electromagnet loses its magnetism.
- The armature is returned to its original position by the spring.

20.2 Force On A Current-Carrying Conductor In A Magnetic Field

- When a current-carrying wire is placed perpendicular to a magnetic field, it will experience a force.
- The direction of this force can be determined by using Fleming's **Left Hand Rule**, as shown on the right. Note that if the current runs parallel to the magnetic field, there will be no force.



Example



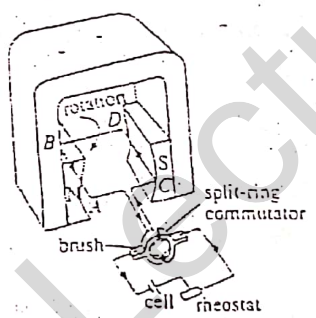
The setup above can be used to demonstrate the force produced by a current- carrying wire.

- When the switch is closed, the wire swings forward as dictated by Fleming's Left Hand Rule.
- If the battery connections were reversed, the wire will swing backwards.

- If the direction of the magnetic field is reversed, the wire will also swing backwards.
- An important application of this phenomenon is in loudspeakers.
- A loudspeaker consists of a voice coil, which is connected to a paper cone, placed between the poles of a pot magnet.
- Varying currents which correspond to the sound signals are passed through the coil.
- Magnetic forces are set up and the coil, together with the paper cone, starts to vibrate. The vibration of the cone produces the sound which is transmitted through the air.

20.3 DC Motor

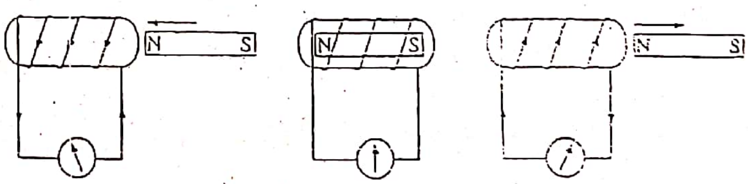
- The dc motor is a device which converts electrical energy into mechanical energy.
- It consists of a rectangular coil. which is placed between the poles of a magnet. connected to a dc source via a split-ring commutator.
- When the current is switched on, the side *AS* of the coil experiences an upward force while the side *CD* feels a downward force. This sets up a couple which rotates the coil clockwise.
- When the coil reaches the vertical position, the split-ring changes contact from one brush to the other, thus enabling the coil to rotate continuously in the same direction.



- To increase the speed of rotation of the motor, the following can be done:
  (a) Increase the number of turns in the coil.
  (b) Increase the magnitude of the current.
  (c) Increase the strength of the magnet.
  (d) Insert a soft iron core in the coil.

20.4 Electromagnetic Induction

- **Electromagnetic induction** is the phenomenon whereby an electromotive force is induced between the ends of a conductor whenever there is a change in the magnetic flux: linking the conductor. If the ends of the Conductor is connected to a galvanometer, induced current will flow.

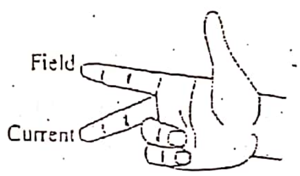


Lenz's Law states that the direction of flow of the induced current is such as to oppose the change that produces it.

- The following factors affect the size of the induced emf. or current.

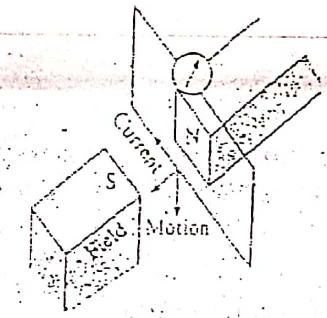
(a) The number of turns of coils; the more the number of turns, the greater the emf.
(b) The strength of the magnet; the stronger the magnet, the larger the emf
(c) The speed of movement causing the change in flux; the faster the speed, the bigger the emf.

- The direction of induced current can be found by using Fleming's Right Hand Rule, as shown below.



Example

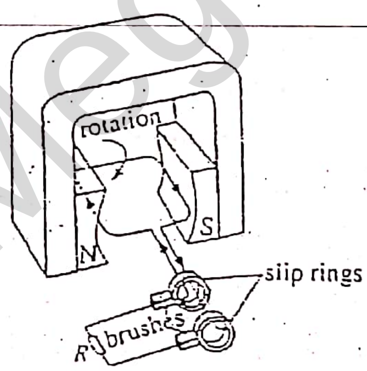
A current is induced in the coil when it is moving down at right angles to the magnetic field. The direction of the current is as shown in the diagram on the right.



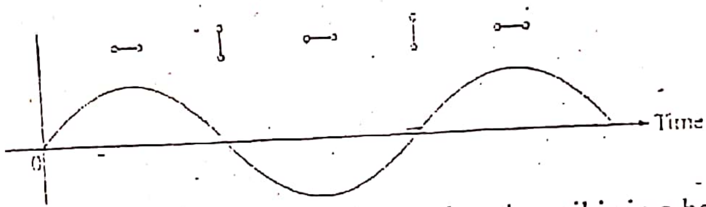
20.5 AC Generator

The ac generator converts mechanical energy into electrical energy using the principle of electromagnetic induction.

- It consists of a rectangular coil which is rotated between the poles of a radial magnet. The ends of the coils are connected via two slip rings in contact with carbon brushes to an external circuit. As the coil is rotated, an ac is obtained in the external circuit.



- The positions of the coil relating to the induced emf produced is shown below.



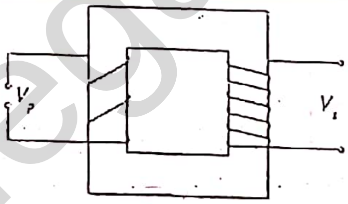
- The induced emf is maximum when the coil is in a horizontal position. It is zero when the coil is in a vertical position.
- If the speed of rotation is doubled, the frequency of the ac and the maximum output voltage is doubled.
- If the number of turns in the rectangular coil is doubled, only the maximum output voltage is doubled, the frequency of the ac remains unchanged.

20.6 'Transformers

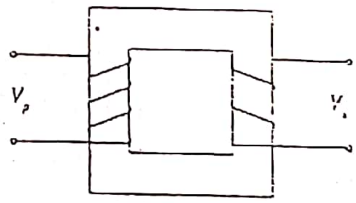
- A transformer is a device used to convert high voltage to low voltage or vice versa by the process of mutual induction.
- It consists of a laminated core of magnetic material (usually soft iron) around which IS wound a primary coil and ii secondary con.
- The primary and secondary emf are related in the following way:

where V_s is the secondary emf,
V_p is the primary emf,
V_3 is the number of turns in the secondary coil,
N_p is the number of turns in the primary coil.

- If N_s is large than N_P, then V_p. This is known as a step-up transformer.
- If N_s is smaller than N_p, then V_s Is smaller than V_p this is called a step down transformer.



Step-up



Step-down

- Assuming a 1009C efficiency in the transformer, then secondary power output = primary power output

$$V_s I_s = V_p I_p$$
$$\frac{V_s}{V_p} = \frac{I_p}{I_s}$$

20.7 Power Transmission

- Power is transmitted as an alternating current at very high voltage.
- The main advantage of using alternating currents is that it can be stepped up or

stepped down to different voltages easily.

- The reason for transmitting at very high voltage is that this reduces power loss as heat. When using high voltage, a small current flows through the cables. Since power loss as heat is given by $p = I^2R$,, a small I will imply a minimal heat loss.

The atomic Model (21)

21.1 Geiger-Marsden Experiment

- A beam of α particles was fired at a very thin sheet of gold foil. The scattering of the α particles after passing through the foil were detected by means of a spinthariscope.
- Observations from the experiment:
  (a) Most of the α particles went straight through the foil.
  (b) Some α particles were deflected through small angles.
  (c) A few were scattered back through 180^0.
- The conclusion drawn from this experiment was that the atom has a small but heavy **nucleus** which is positively charged.

21.2 Atomic Structure

The atom is made up of protons, neutrons and electrons.

Protons and neutrons are found in the atomic nucleus which the electrons orbit found the nucleus.

The properties of these sub-atomic particles are tabulated below.

Particle	Proton	Neutron	Electron
Charge	+1	0	-1
Mass	I unit	1 unit	$\frac{1}{2000}unit$
Symbol	^1_1p	^0_1n	$^0_{-1}e$

- As the atom is electrically neutral, the number of protons must equal the number of electrons in an atom.
- Atoms are represented in the following manner ^A_ZX. This is known as J nuclide of X, where X refers to the chemical symbol of the element the atom represents,
- The upper number *(A)* is known as the mass number or nucleon number and it gives the total number of protons and neutrons in the nucleus.
- The lower number (2) is known as the atomic number and this is the number of protons in the nucleus.
- *(A* - Z) will give the number of neutrons in the nucleus.
- Isotopes are atoms which have the same atomic number (same number of protons) but different mass numbers (different number of neutrons).

Example

^1_1H , ^2_1H and ^3_1H are isotopes of hydrogen. All of them have Jproton in the nucleus.

The ^1_1H isotope has 1-1=0 neutron.

The ^2_1H isotope has 2 - I =I neutron.

The $^{3}_{1}H$ isotope has 3 - 1 = 2 neutrons.

Uses of radioactive isotopes:

(a) Cobalt-60 is used in cancer treatment.

(b) Carbon-Fa is used to date archaeological specimens.

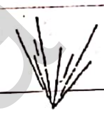
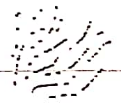
(c) Phosphorus-32 and Iodine-131 are used as tracers in bodies for medical diagnosis.

(d) Other radioisotopes are used in industries to check thickness detecting wear and tear of materials.

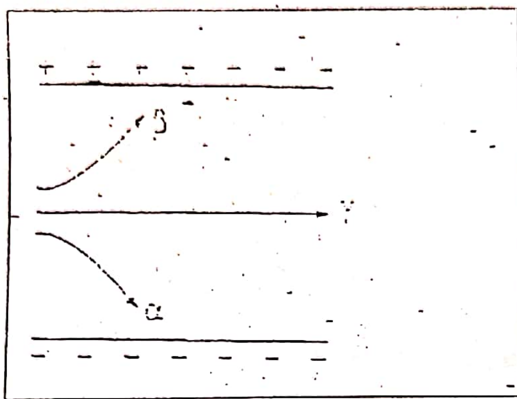
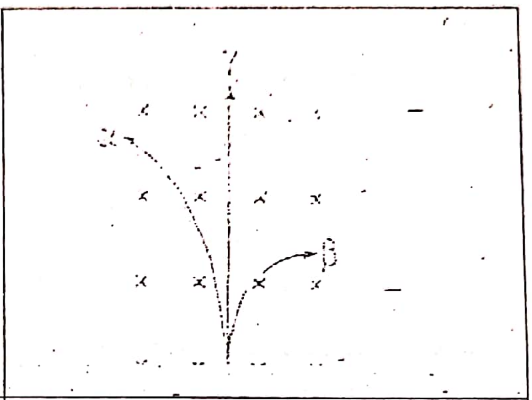
Radioactivity (22)

22.1 Introduction

- Radioactivity is the spontaneous random emission of particles from the nucleus of the atom.
- There are three types of radiation emitted from radioactive substances. They are alpha (α) particles. beta (β) panicles and gamma (γ) rays.
- The characteristics of these radiations are as follows:

Property	α particle	β particle	γ ray
Nature	Helium nuclei $^{3}_{i}H^{2+}$	High energy electrons $^{n}_{-1}e$	Electromagnetic wave
Ionization power	Very strong	NO very strong	Very weak
Penetrating	A few cm in air, can be stopped by a sheet of paper	Several meters can be stopped by a few mm of aluminum	Can pass through several cm of lead
Detection in a cloud chamber	Straight thick tracks 	Thin irregular tracks 	Thinner, shorter irregular tracks 
Deflection in magnetic and electric fields	Deflected like a positively-charged particle	Deflected like a negatively-charged particle	Not deflected at all

- The deflections of the three types of radiation in an electric field and in a magnetic field are as shown.

	
Electric field (α particle is attracted to - plate while β particle is attracted to + plate)	Magnetic field (the paths are determined by using Fleming's Left Hand Rule)

22.2 Radioactive Decay

(a) Alpha decay

When an α panicle is emitted by a nucleus, the mass number of the new nucleus decreases by 4 while the atomic number reduces by 2.

(b) Beta Decay

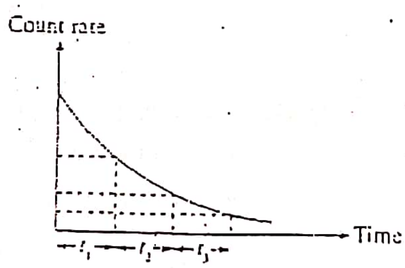
When a β particle is emitted by a nucleus, the mass number of the new nucleus remains unchanged while the atomic number increases by *I*.

General Equation $^A_ZX \longrightarrow {}_{Z+1}^{A}X + \beta$

Example $^{214}_{82}X \longrightarrow {}^{214}_{83}Bi + \beta$

(c) Gamma decay

- The emission of γ rays has no effect On the mass number and atomic number of the nucleus. It only reduces the energy content of the nucleus.
  General equation $^A_ZX \longrightarrow {}^A_ZX + \alpha$
- Half-life is the time taken for the number of radioactive particles emitted per un it time to drop to half its original value. This can be seen from the decay curve below.



$t_1 = t_2 = t_3$ = half life of substance

22.3 Safety Precautions

- Radioactive sources are to be kept in boxes made of lead.
- They are to be handled by tongs or forceps and not by hand.
- Special clothing, normally with lead shielding, are to be worn in situations where the amount of radiation is large.

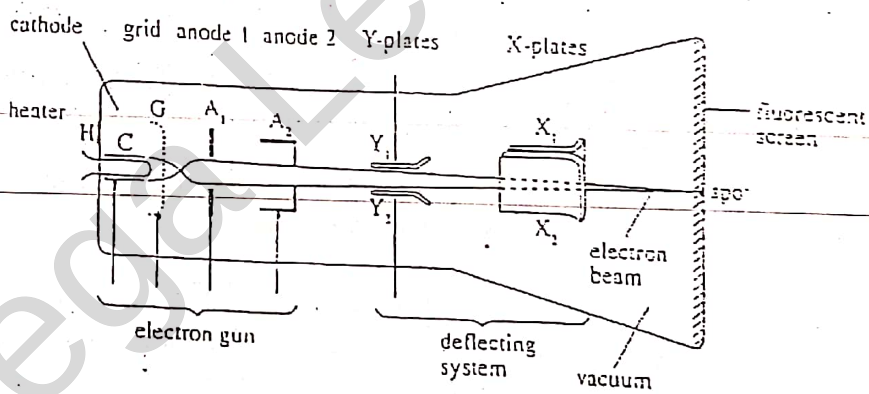
The Cathode Ray Oscilloscope (C.R.O.) (23)

23.1 Thermionic Emission

- Thermionic emission is the process whereby electrons are liberated from a heated metal.
- The heated metal which emits the electrons is *called* the cathode and the electrons can *also* be known us cathode rays.
- In an electric field, the electrons, being negatively charged, are attracted towards the positive plate.
- In a magnetic field, the electrons are deflected into circular paths in accordance with Fleming's Left Hand Rule.

23.2 The C.R.O

- The cathode ray oscilloscope (c.r.o.) is an instrument which displays electrical signals. It consists of 3 main parts: the electron gun, the deflecting system and the fluorescent screen.



(a) The electron gun

- This pair of the C.LO. produces a narrow beam of electrons.
- It consists of a cathode, a control grid and a set of anodes.
- The heated cathode, a control grid an a set of anodes. leaving lilt: cathode is controlled by the grid. The anodes serve to accelerate and focus the electron beam.

(b) The deflecting system

- This consists of two sets of plates which deflect tile electron beam by the application of an electric field.
- The X plates are a pair of vertical plates that deflect the beam horizontal! y.

- The Y plates are a pair of horizontal plates that deflect the beam vertical! y.
- Note that input voltages or signals are normally connected to the Y plates.
- The c.r.o. can be used to
  a) measure voltages.
  b) measure short interval, of time,
  c) display waveforms of input signal
  d) compare frequencies of input signal.

Electronic Circuit Components (24)

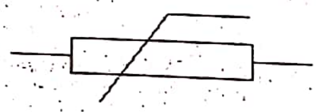
224.1 Thermistors and LDRs

- A transducer is a device which is capable of converting energy from one form to another. Thermistors and light dependent resistors (LDRs) are examples of input transducers.

(a) Thermistors

- Thermistors are ternperature-sensiti resistances. They convert heat energy into electrical energy when connected to an electrical source.
- For most thermistors, their resistance decrease when temperature is increased.

Symbol:

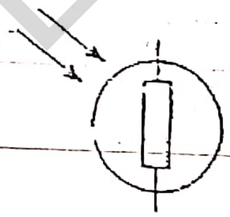


They are used for measurement of tempera ure ur in temperature- sensitive devices. e.g. fire alarm, thermostat.

(b) Light Dependent Resistor (I.D.R)

- LDRs are light sensitive devices. They convert lighl energy into electrical energy when connected to an eke ric sour-e.
- The resistance of a LOR decreases when the light intensity incident on it increases.

Symbol:

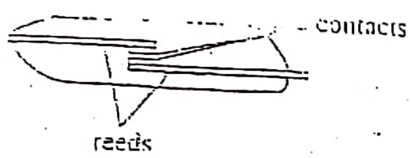


- They arc: used in light-sensitive devices, e.g. lift control circuitry. burglar alarms for bank vaults and safes

2.4.2 Reed Switches And Relays

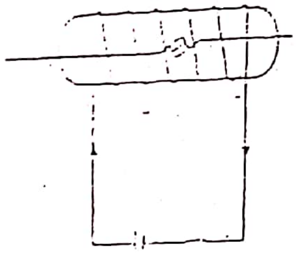
(a) Reed Switches

- A reed switch contains a pai of iron strips freeds inside a sealed glass tube.
- There is a small gap between the reeds which is closed when the reeds are bent by app lying a magnetic field.



(b) Reed Relays

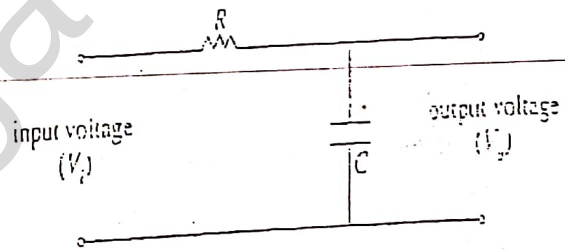
- If the reed switch is operated by an electromagnet, it is known as a reed relay.
- This is achieved by placing the reed switch inside a solenoid connected to all electrical source.



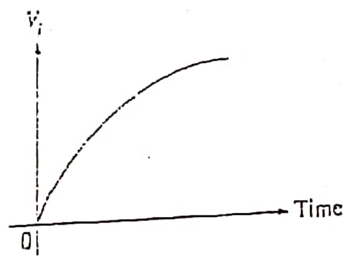
- When current flows through the solenoid, the reeds are: magnetizedand attract one another to complete .he circuit.
- When the current is switched o rt, the reeds lose their magnetism and the contact is broken.
- A small current through the relay-can switch on or off another circuit without any direct electrical contact between them. Hence relays are often used to (urn on J. high voltage (dangerous) supply with a low voltage: (safe) supply, e.g. ignition switch for a car motor.

24.3 Capacitors

- A capacitor consists of two conductors (usually metal plates) placed close to each other, separated by a non-conducting material called a dielectric.
- The capacitance of a capacitor is the measure of the ability to store electrical energy.
- When a capacitor is charged by an electrical source, the electrical energy supplied is stored as separate electrical charges on the conductors.
- When it is discharged. electrical energy will be released.
- A time delay circuit 0.0 be constructed by connecting a capacitor In series with a resistor as shown:



- The output voltage Vo only attains the value of the input voltage Vi after a certain interval of time as the capacitor takes some time to charge up.
- This time interval is dependent on the values of the resistance and capacitance in the circuit.



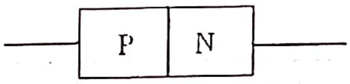
Electronics System (25)

25.1 Semiconductors

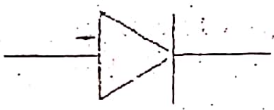
- Semiconductors arc materials which allow for a slight conduction of electricity. Examples are silicon and germanium.
- The electrical resistance of semiconductors decreases with an increase in temperature.
- Current flow in semiconductors is due to the now of electrons and positive 'holes'.
- Doping means adding a very small amount of impurity to a semiconductor to increase its conductivity.
- There are two types of semiconductors –p-type (positive) and n-type (negative).

25.2 Diodes

- A diode is construed from a $P\text{–}n$ junction. which is a piece of p type and piece of n-type semiconductor journed together.



- The circuit symbol for the diode is:

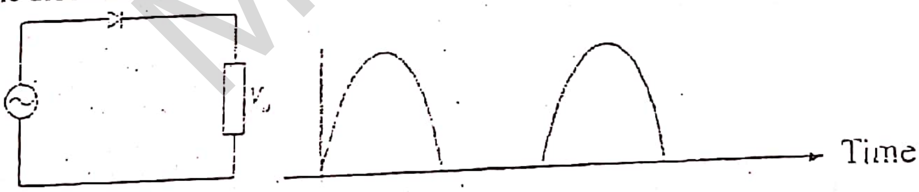


- A diode allows current to now in one direction only.
- When the voltage on the p-type is more positive than that on the p-type, the diode is forward based and current flows from the p-type to the .r-type.

The diode is used as a rectifier, which means it converts alternating current to direct current.

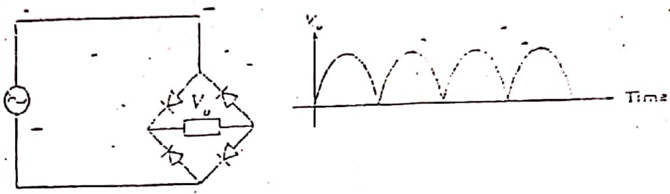
(a) Half-wave rectification

- Only (he positive half cycle of the a.c. will be allowed to now through the resistor if one diode is used.



(b) Full-wave rectification

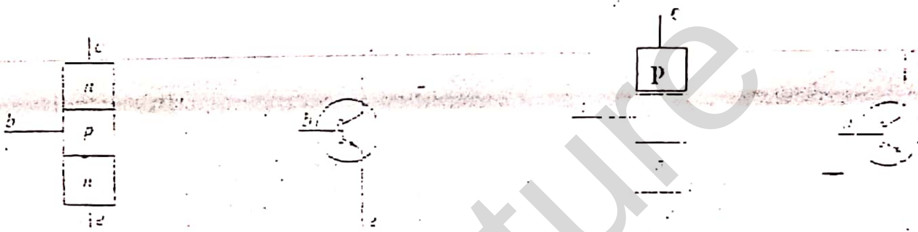
- Using four diodes, both the positive and negative cycles will be allowed to now.



25.3 Bipolar Transistors

Bipolar transistors have two *p-n* junctions and three terminals: base, emitter and collector.

- There are two types of bipolar transistors; the *n-p-n the p-np* transistors.

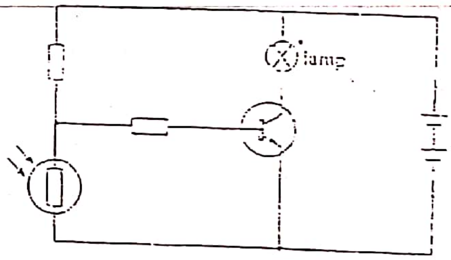


- For normal operations, the junction between the base and the collector is reverse biased while that between {he emitter and the base is forward biased.

- The most common use of the transistor is as a switch.

Example

The circuit on the right turns on the! light when it gets dark. This is because the resistance of the LDR increases when light intensity drops. This will increase the potential at the base which will turn the transistor on and allow current to flow through the lamp.



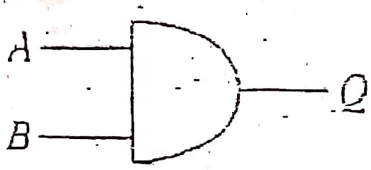
- The advantages of using transistor switches are as follows:
  (a) They have fast switching speed.
  (b) They call be integrated into electronic circuits

25.4 Logic Gates

A logic gate is an electronic system which gives an output only under certain input conditions

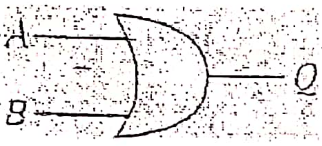
(a) AND gate

(b)



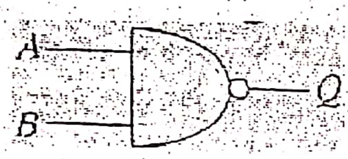
Inputs		Output
A	B	Q
0	0	0
0	I	0
I	0	0
I	I	I

(b) OR gate



A	B	Q
0	0	0
0	I	I
I	0	I
I	I	I

(c) NAND gate



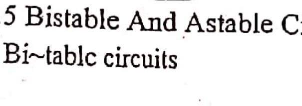
A	B	Q
0	0	I
0	r	1
1	a	I
1	I	0

(d) NOR gate

A	B	Q
0	0	I
0	I	0
1	0	O
1	1	0

(e) NOT gate

The NOT gate is also known as the inverter gate



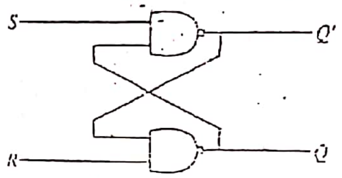
A	Q
0	1
1	0

- The NAND gate is a uni versa! bui lding block and can be used to construct all other logic gates. For example, it can be used to build the NOT gate as shown.

25.5 Bistable And Astable Circuits

(a) Bi~tablc circuits

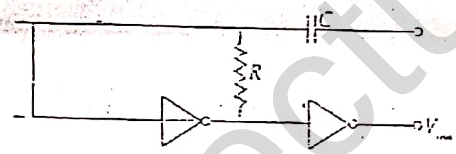
- A histable circuit has two stable states. They can be constructed by having two cross-coupled NAND gates.



- A property of bistabel circuits is that they exhibit memory capabilities and they form the basis of memory circuits

(b) Astable circuits

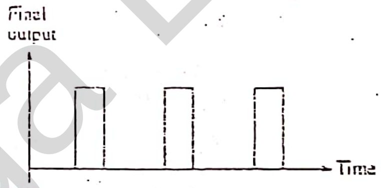
An astable logic circuit has no stable states. It only oscillates between two temporary Stales at a steady rate. It can be used as a digital oscillator or a pulse train generator, which is shown below.



- The frequency of switching for the circuit is dependent on the values of Rand C.

(i) The greater the values of Rand C, the lower is the frequency.

(ii) The lower the values of Rand C, (he higher is the frequency.



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