INTRODUCTION TO PHYSICS

The primary school science syllabus covers topics such as matter and its properties, energy in its various forms for example heat, light, sound and their corresponding sources, machines and the way they make work easier, balancing and weighing of various shapes of objects, electricity and magnetism.
These topics and more are covered in physics.

MEANING OF PHYSICS

Physics is the study of **matter** and its relation to energy. **Matter** is anything that occupies space and has weight.
The study of physics allows one to understand and enjoy other subjects
As a subject, the study of physics involves measurement of quantities and collection of data.
Through experimentation and observation, hypotheses are drawn, test and laws and principles established.
Physics explain the how and why behind the following phenomena;

- Formation of rainbow.
- Occurrence eclipse.
- The falling of the objects towards the earth's surface.
- The seasonal occurrence of ocean and sea tides
- The crackling sound heard when nylon cloth is removed from the body.
- Formation of shadow and many more.

Physics gives scientific, systematic and consistent explanation based on the concepts of physics.

BRANCHES OF PHYSICS

Physics may be split into the following key areas;

- ✓ **Mechanics-** is a branch of physics that deals with the study of the motion of the bodies under the influence of forces. It is divided into two key areas namely; **kinematics** and **dynamics**. Kinematics is *the study of the motion of the bodies disregarding the forces acting on it while dynamics is the study of the motion of bodies with regard to forces acting on the body. Under this branch, we look into details the aspects of linear, circular and oscillatory motions as well as motion of fluids.*
- ✓ **Electricity and magnetism-** this branch looks at the interaction between electric fields and magnetic fields and the applications of such interactions e.g. electric motors, microphones, electric speakers etc.
- ✓ **Thermodynamics-** This branch looks at how heat as a form of energy is transformed to/from other forms of energy.
- ✓ **Geometrical optics-** This branch takes a keen look at the behavior of light in various media e.g. optic fibre, microscopes, and lenses e.t.c.
- ✓ **Waves-** It deals with the study of the propagation of energy through space. It involves properties of waves such as refraction, reflection, diffraction and polarization
- ✓ **Atomic physics**- This area of study is targeted at the behavior of particles of the nucleus and the accompanying energy changes. It involves radioactivity, nuclear fission and fusion. It is the basis of the production of nuclear energy.

RELATIONSHIP BETWEEN PHYSICS AND OTHER SUBJECTS

Physics does not only relate the remaining two science subjects but also enjoys a relationship with other subjects as well. For instance, it is the foundation of **technological development** in any country.

- Physics and history- Carbon dating is an application of radioactivity which serves as a crucial tool to history in establishing fossil age and hence past pattern of life.
- Physics and Geography- Establishment of weather patterns rely on accurate use of instruments like thermometer, wind vane and hygrometer .Heat transfer by convection explains the formation of conventional rainfall and pressure variation that determine wind patterns. All these are physics concepts.
- Physics and Home Science
- Physics and religion- Systems in the universe reveal great orderliness which can be traced back to the creator. Study of physics has come up with findings which are in total agreement with orderliness. Matter can be reduced to nothing scientifically the reverse is true which confirms that matter was created from nothing by God.
- Physics and Biology- Knowledge of lenses in physics are used in making microscope used in study of cells in biology. Physics formulae are used in calculation of magnification by microscopes.
- Physics and Chemistry- Physics has helped in explaining forces within atoms and therefore atomic structure. It is this structure of the atom that then determines the reactivity of the atom as explained in chemistry
- Physics and Mathematics- Many physics concepts are expressed mathematically. Many physics formulae are expressed mathematically.
- Physics and Technology- some areas of technology that requires knowledge of physics are:
  a) Medicine; in medicine, x-rays, lasers, scanners which are applications of physics are used in diagnosis and treatment of diseases.
  b) Communication; satellite communication, internet, fibre optics are applications of internet which requires strong foundation in physics.
  c) Industrial application; in the area of defense, physics has many applications e.g. war planes, LGB (laser-guided bombs) which has high level accuracy.
  In entrainment industry, knowledge of physics has use in mixing various colours to bring out the desirable stage effects. Is application of science to solve problems in everyday situation most forms of technology are due to Physics e.g. Information and Technology, Computer Science, Mobile Phones, building technology, automotive technology.

CAREER OPPORTUNITIES IN PHYSICS

The study of Physics can open up many avenues of professions including engineering, degree, diploma or certificate courses.
A physics student will have the following opportunities in the following areas;

- Bachelor of Architecture.
- Bachelor of pharmacy.
- Bachelor of medicine.
- Bachelor of dental surgery.
- Bachelor of science(nursing)
- Bachelor of education science(physics)

- ❖ Bachelor of science(Electrical and electronic Engineering)
- ❖ Bachelor of Veterinary Medicine.

At college level, some of the courses are offered.

- ❖ Diploma in building and construction.
- ❖ Diploma in mechanical Engineering.
- ❖ Diploma in physiotherapy.
- ❖ Diploma in electrical Engineering.
- ❖ Diploma in computer science.

BASIC LABORATORY RULES

LABORATORY- This is a room containing facilities, apparatus and equipment that aid the investigative study of physics

BASIC LABORATORY RULES

1) Proper dressing
2) Note the location of electricity switches, fire-fighting equipments, First aid kit, gas supply and water supply taps.
3) When in the laboratory open doors and windows to let in fresh air.
4) Follow instructions given carefully.
5) No eating or drinking in the laboratory.
6) Turn off electrical switches, gas and water taps when not in use.
7) When handling electrical apparatus hands must be dry.
8) Do not plug foreign objects into electrical sockets.
9) Keep floors and working surfaces dry.
10) Clean and return all apparatus used in their correct location.
11) All equipments should not be taken out of the laboratory.
12) Wash your hands before leaving the laboratory.
13) All instructions given must be followed strictly. Never attempt anything while in doubt.
14) Windows and doors should be kept open while working in the laboratory
15) Any wastes after experiments must be disposed appropriately after use

FIRST AID MEASURES

- **CUTS** -These may result from poor handling of glass apparatus or cutting tools like razors and scalpels. In case of cuts, assistance should be sought to stop bleeding and for immediate depressing up of the wound.
- **BURNS** - Burns may result from naked flames or even splashes of concentrated acids and bases. In case of burns caused by acids or bases, quickly run cold water over the affected part as you seek help for further treatment.
- **POISONING** - This may result from inhaling poisonous fumes or actual swallowing of poisonous chemicals. Assistance should be sought immediately.
- **EYE DAMAGE** -Eyes must be safeguarded from dangerous chemicals and bits of solids. In case an irritating chemical lands in the eye, it should be washed off immediately with a lot of cold water
- **ELECTRIC SHOCK** -This may result from touching exposed wires or using faulty electrical appliances. When such an accident occurs, first put off the main switch before treating for the shock.

TOPIC 2: MEASUREMENT

Scientists from various parts of the world were giving measurements in different units and languages. Some used pounds, inches and seconds while others were using grams, centimetres and seconds. This was undesirable, especially when a comparison of results was necessary.
This made it impossible for them to compare discoveries. Consequently, scientists agreed on one international system of units to be used, the Systeme International d'Unites (International System of Units), shortened to SI units, in all languages. This system has seven basic physical quantities and units on one Universal System of units called **system international d' unites** (International system of units) **SI units** which assigned seven basic quantities as shown below.

UNIT	**Symbol of quantity**	S.I UNIT	SYMBOL OF UNIT
1. Length	L	metres	m
2. Mass	m	kilogram	kg
3. Time	t	seconds	s
4. Electric Current	I	ampere	A
5. Thermodynamic temperature	T	kelvin	K
6. Luminous Intensity		Candela	Cd
7. Amount of Substance		mole	mol

These quantities above cannot be obtained from any other physical quantities. Measurements are made by comparing the magnitude of a quantity with that of a given unit of that quantity. A physical quantity is a measurable aspect of matter.
Basic Physical Quantity -These are quantities that cannot be obtained by any other quantity e.g. mass, time, length.
Derived Quantity-These are quantities obtained by multiplication or division of basic physical quantities e.g. Area, Volume, Density.

LENGTH

This is the distance between two fixed points. **It is the measure of distance between two points in space.** The SI unit for length is the **metre (m).**
Other units of length include;

unit	**symbol**	**Equivalence in metres**
Kilometre	Km	1000
Hectometre	Hm	100
Decametre	Dm	10
Decimetre	dm	0.1
Centimetre	Cm	0.01
Millimetre	mm	0.001
Micrometre	**μm**	0.000001

MEASUREMENT OF LENGTH

Length can be estimated or measured accurately using appropriate measuring instrument. The type of instrument to be used at any time depends on two factors:

- The size of the object to be measured
- The desired accuracy

The methods used include;

a) **Approximation/ Estimation**
b) **Accurate measuring using standard instruments**

a) <u>Estimation</u>

This method involves comparing the object to be measured with another of standard measure. For example, the height of a tall flag post can be compared with that of a wooden rod whose length is known. Thus at any given time;

$$\frac{\textbf{Height of flag post}}{\textbf{Height of rod}} = \frac{\textbf{Length of shadow of post}}{\textbf{Length of shadow of rod}}$$

From this expression, the height of the flag post can be estimated.

<u>Example;</u>

Suppose the height of the rod= 1m, length of shadow of rod= 120cm and length of shadow of post= 480cm, then the height of the flag post is given by;

$$\frac{\text{Height of post, } H_p}{100\text{cm}} = \frac{480\text{cm}}{120\text{cm}}$$

$$\text{Height of post, } H_p = 100 \times 4$$

$$= 400\text{cm}$$

Also, the thickness of a sheet of paper may be estimated by taking several sheets of the paper and measuring their thickness then dividing by the number of sheets of paper;

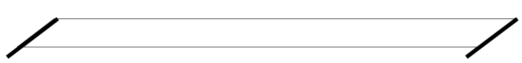
$$\text{Thickness of a sheet of paper} = \frac{\text{Thickness of n papers}}{\text{Number of papers, n}}$$

b) <u>Using a standard measure(instruments)</u>

This involves the use of standard measure or instruments. To measure length accurately, the instruments used are metre rules, half metre rules, tape measure, vernier calipers and micrometer screw gauges

a) <u>Metre rule</u>

A metre rule is marked in centimetres. It is marked 0 and 100cm at its extreme ends.



0 **100cm**

(a) a metre rule

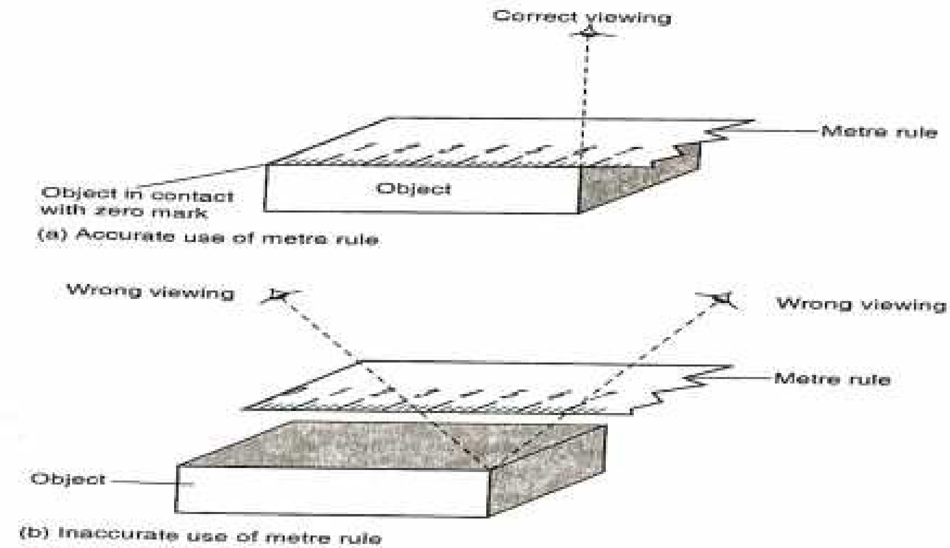
The smallest scale division of a metre rule is 0.1cm (1mm). The smallest scale division of any instrument is known as its accuracy. Thus the accuracy of a metre rule is 0.1cm.

When using a metre, one must ensure the following:

- That the object to be measured is in contact with the metre rule.
- That one end of the object is at 0cm mark i.e. zero (0) mark to coincide with the start of the object to be measured.

- That the eye is perpendicular to the scale so as to avoid parallax error. This ensures that accurate reading is obtained.

Metre rules and half metre rules used are graduated in centimetres and millimetre.
They are made of wood, plastic or steel.

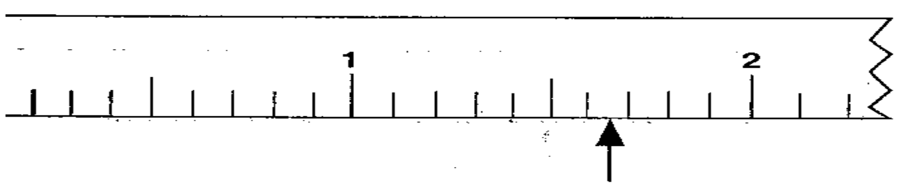


When using a ruler the following precautions should be taken;

- Never drop a metre rule
- Never use it as a walking stick
- Never use it as a cane
- Keep it in a dry place away from corrosive substances

<u>EXAMPLE 1</u>

The reading should be taken in terms of the least count of the metre rule. For a metre rule the least count is 0.001m=0.1cm=1mm.



The reading shown above is 0.0165m=1.65cm=16.5mm.The metre rule cannot read 4th, 2nd or 1st decimal places of metre, centimeters or millimeters respectively. This is only approximated.

<u>EXAMPLE 2</u>

Figure below shows a fencing post whose length is being measured using a strip of a measuring tape.

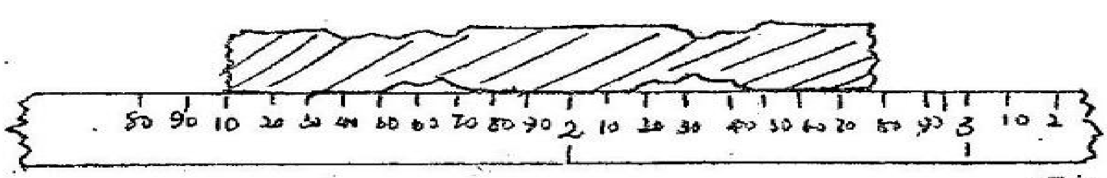


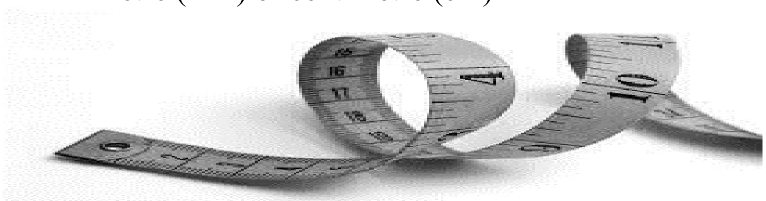
Fig. 1

(a) State the accuracy of the tape:
(b)What is the length of the post?

SOLN
(a)Accuracy of measuring tape is 10mm or o.1 cm + 5cm or o.o5m.
(b)Length of post is 1.5 m

b) Tape measure

It is graduated in millimetre (mm) or centimetre (cm)



They are three types;

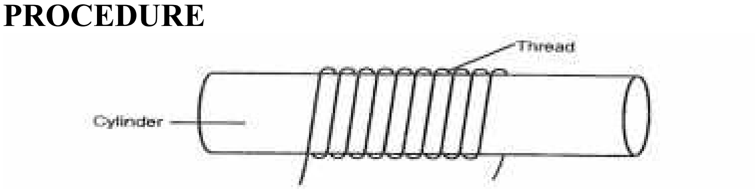
i) Tailor's tape measure
ii) Carpenter's tape measure
iii) Surveyor's tape measure

NOTE: The choice of a tape measure depends on accuracy required and the size of object to measure. A tape measure can be made up of cloth, steel or flexible plastic. Always ensure that the tape measure is taut when measuring.

MEASUREMENT OF CURVED LENGTH

Curved length can be measured using a thread. The thread is placed along the required length and the length is found by placing the thread on a scale.

EXPERIMENT: Measuring the circumference of a cylinder using a thread.
APPARATUS: A cylinder, a thread and a metre rule
PROCEDURE



i) Wrap a thin thread say 10 times around the cylinder
ii) Mark with ink the beginning and end of turns as shown
iii) The circumference of the cylinder will be given by;

$$\text{Circumference} = \frac{[\text{length of thread}]}{10}$$

But; Circumference $= \pi d$ or $2\pi r$ (where r is the radius of the cylinder)

ESTIMATION OF LENGTH

EXPERIMENT: To estimate the height of a tree
APPARATUS: A metre rule, tape measure
PROCEDURE

i) Measure the length of the metre rule when upright using a tape measure followed by measuring its shadow.
ii) Measure the shadow of the tree in the school compound.

RESULTS

Height of metre rule = ...Cm
Height of shadow of metre rule=...........Cm
Height of shadow of the tree =..............Cm

Estimation of the height of the tree is given by the formula provided above.

AREA

Area is defined as the measure of surface enclosed by the boundaries of the body. Its SI Unit is the square metre (m^2). Since it is measured in metre-square (m^2), this means it's a derived quantity.

Other multiples and sub-multiples of area are; cm^2, mm^2, km^2, hectares etc.

Area can also be estimated or calculated accurately.

CONVERTING

a) mm^2 to m2

$1m^2$ = 1000 X 1000
= 1000000 mm^2
$1mm^2$ = {1÷1000000} m2 **(Divide by 1million)**
= 0.000001 m^2

b) m^2 to mm^2

$1m^2$ = 1000000 mm^2 **{multiply by 1 million}**

c) cm^2 to m^2

1cm = 0.01m
$1cm^2$ = 0.01m X 0.01m
= $0.0001m^2$ **{multiply by 0.0001}**

d) m2 to cm^2

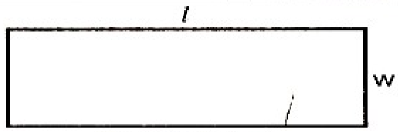
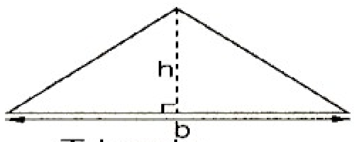
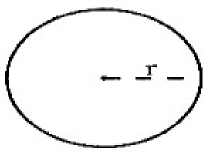
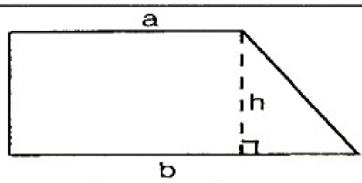
1m = 100cm
1m2 = 100cm X 100cm
= $10000cm^2$ **{multiply by 10000}**

EXERCISE

1) Convert $7.5m^2$ to cm^2
2) Convert $940mm^2$ to cm^2
3) Convert $12000mm^2$ to m^2

Measurement of area (Accurate Measurement)

The area of regularly shaped objects can be found by applying an appropriate formula shown below;

Shape	*Area*
 Rectangle	$A = \text{length} \times \text{width}$ $= l \times w$ $= lw$
 Triangle	$A = \frac{1}{2}(\text{base} \times \text{height})$ $= \frac{1}{2} b \times h = \frac{1}{2} bh$
 Circle	$A = \pi r^2$
 Trapezium	$A = \frac{1}{2}(\text{sum of parallel sides}) \times \text{height}$ $= \frac{1}{2}(a + b)\, h$

APPROXIMATION OF AREA OF IRREGULAR BODIES

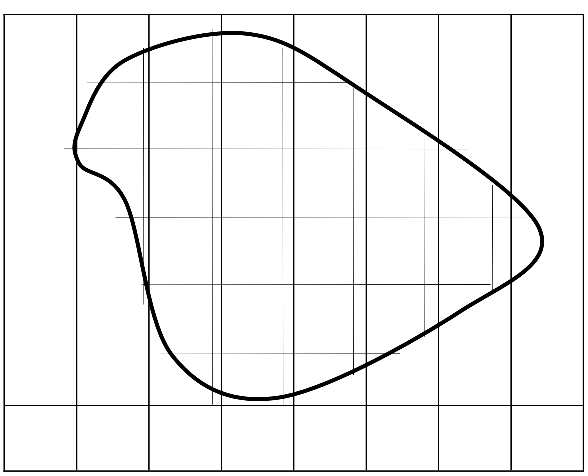
We trace their outline on the square paper of 1cm^2 e.g.

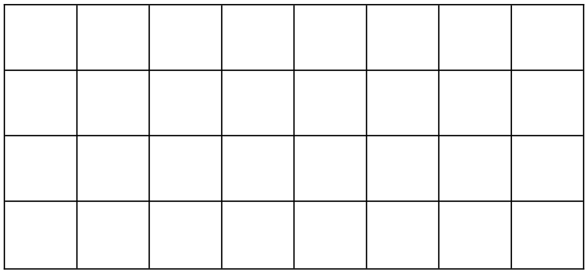
Full squares = ...cm^2

½ full squares = ...cm^2

AREA = full square+½full squares

Consider the figure below of an irregularly- shaped object.



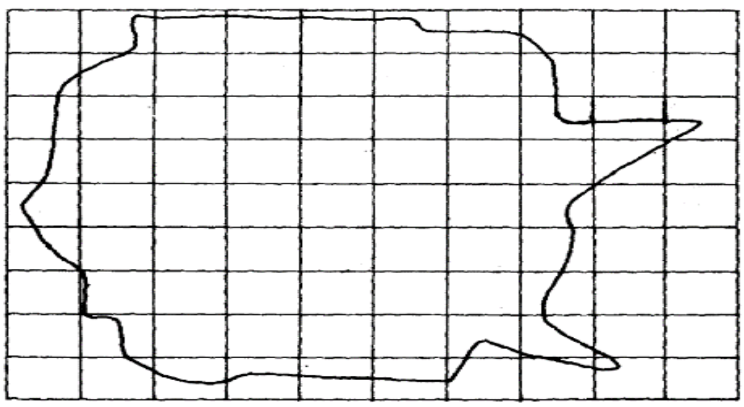


The number of complete squares covered by the shape= 14
The number of incomplete squares covered by the shape=19
Therefore, the number of complete squares covered by the shape is approximately (14+ 19/2) = 23.5 squares.
Suppose the area of one square is 1cm^2, and then the area of the shape is approximately;

Area = 23.5 x 1
= 23.5 cm^2

EXAMPLE 3

Estimate the area of the irregular surface shown below by counting the small squares.



SOLN

The number of complete squares = 39
Number of incomplete squares = 34
These are equal to $\frac{34}{2}$ = 17 complete squares
Therefore, the number of complete squares = 39 + 17 = 56
Hence, the estimated of the area of the surface = 56 x 1 cm^2= 56cm^2

VOLUME

Volume is the amount of space occupied by space. The SI unit of volume is cubic metres [m^3].
It is a derived quantity of length
Multiples and submultiples are; mm^3, cm^3 and km^3

CONVERTING

a) From m^3 to mm^3

1m = 1000mm
1m^3 = 1000mm X 1000mm X 1000mm
= 1000000000mm^3

To change m3 to mm3 you multiply by 1 billion

b) From mm^3 to m^3

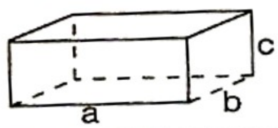
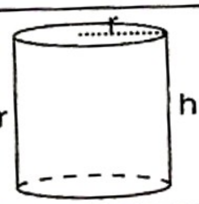
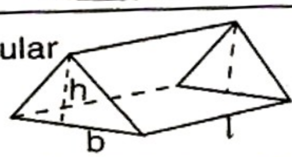
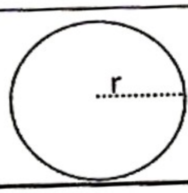
To change m^3 to mm^3 you divide by 1 billion i.e. 1/10000000000

EXAMPLE 4

- Express $9cm^3$ in m^3
- Express $9000000000mm^3$ in m^3
- Express $0.0546m^3$ to cm^3

MEASUREMENT OF VOLUME

The volume of regularly shaped solids can be obtained by applying the appropriate formula i.e

Object	*Volume*
Cuboid 	Volume = area of cross-section x height $= (ab)c$ $= abc$
Cylinder 	Volume = area of cross-section x height $= (\pi r^2)h$ $= \pi r^2 h$
Triangular prism 	Volume = area of cross-section x length $= \frac{1}{2} bhl$
Sphere 	Volume $= \frac{4}{3} \pi r^3$

EXAMPLE 5

A block of glass is 5.0 cm long, 4.0 cm thick and 2.5 cm high. Calculate its volume.

SOLN

Volume of the glass block = area of cross section x height

$= 5.0 \times 4.0 \times 2.5$

$= 50.0\ cm^3$

EXAMPLE 6

Find the volume of cylindrical tin of radius 7.0 cm and height 3.0 cm.

SOLN

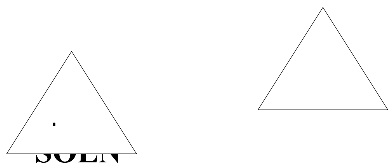
Volume of the tin = area of cross section x height

$= \frac{22}{7} \times 7 \times 7 \times 3$

$= 462.0\ cm^3$

EXAMPLE 7

Find the volume of the triangular prism shown below given that base length is 12.0 cm, h= 5.0 cm and the width 6.0 cm:



SOLN

Volume of the prism = area of cross section x height

$= \frac{1}{2} \times 6.0 \times 5.0 \times 12.0$

$= 180.0\ cm^3$

EXAMPLE 8

Find the volume of a sphere whose radius is 3.0 cm

SOLN

Volume of a sphere $= \frac{4}{3}\pi r^3$

$= \frac{4}{3} \times \frac{22}{7} \times 3.0 \times 3.0 \times 3.0$

$= 113.14\ cm^3$

EXAMPLE 9

A sphere of diameter 6.0 cm is moulded into a thin uniform wire of diameter 0.2 mm. Calculate the length of the wire in metres. (Take π = 22/7)

SOLN

Volume of the sphere and the wire are equal

Volume of the sphere = volume of the wire

$\frac{4}{3} \times \frac{22}{7} \times 3.0 \times 3.0 \times 3.0 = \frac{22}{7} \times 0.01 \times 0.01 \times L$

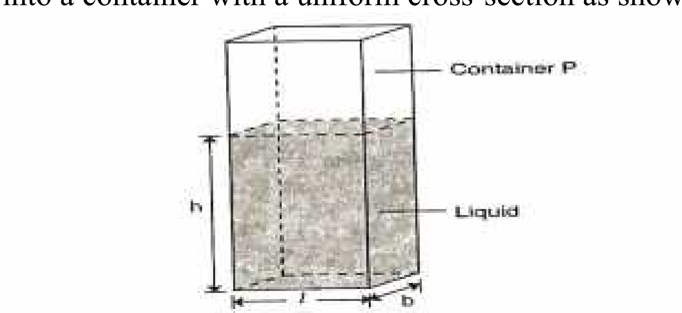
$\frac{4 \times 3.0 \times 3.0 \times 3.0}{3 \times 0.01 \times 0.01} = L$

Therefore, length L = 360000cm

= 3600 m

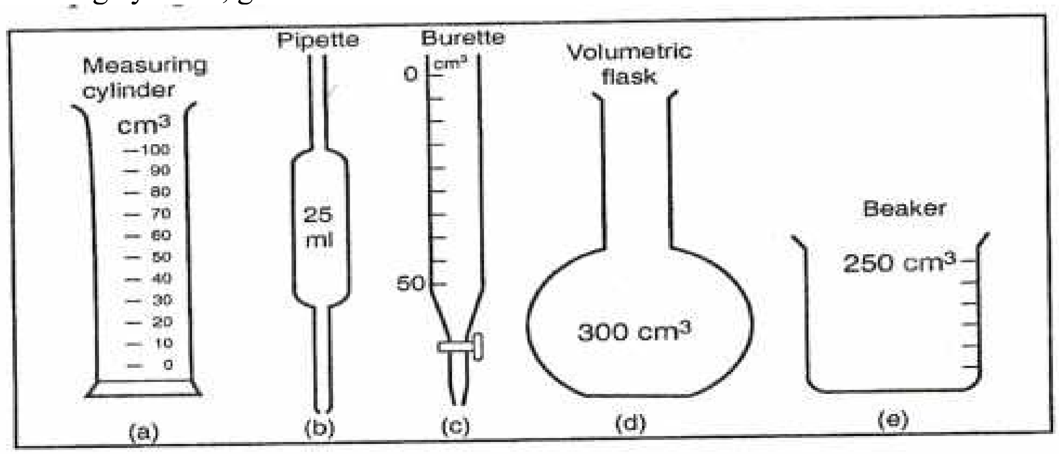
MEASUREMENT OF VOLUME OF LIQUIDS

Liquids have no definite shape but they assume the shapes of the container in which they are put. One of the methods which can be used to measure the volume of liquids is to pour the liquids into a container with a uniform cross-section as shown,



Volume = Area of cross-section x height
= A h; where A=LX b
= l b h

Instruments can also be used to measure the volume of liquids. They include; Burette, Pipette, Measuring cylinder, graduated beaker and Volumetric flask.

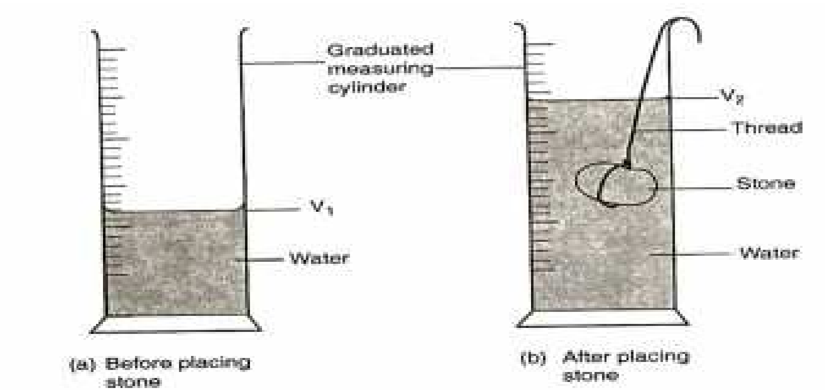


NOTE: The scale of the Burette begins from zero at the top and increases downwards to the maximum value e.g. a reading of 31.0ml on the burette means that volume of the liquid is [50-31] ml = 19ml.

MEASUREMENT OF VOLUME OF IRREGULAR OBJECTS

a) Using a measuring cylinder

PROCEDURE



- Fill the measuring cylinder with water.
- Record the volume of water as V_1
- Submerge gently a stone [irregular object] tied around a thread.
- Record the volume of water and the stone as V_2.
- Volume of the stone = $V_2 - V_1$

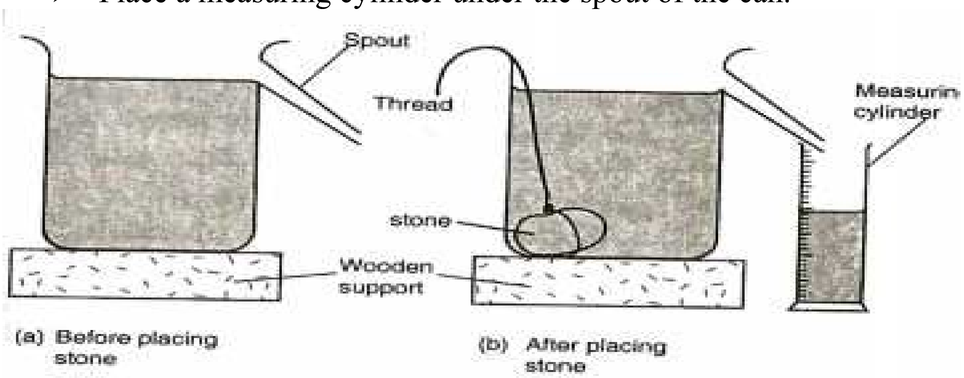
b) Using a Eureka can

A Eureka or displacement can is a container with a spout from the side.

Apparatus; Eureka can, measuring cylinder, irregular object e.g. a stone, water

Procedure

- Fill the Eureka can with water until it flows out of the spout.
- Place a measuring cylinder under the spout of the can.



- Tie the solid [irregular object] with a thread and submerge it gently inside the can.
- The result [water] collected to the measuring cylinder is the volume of the irregular object.

EXERCISE 2.5 KLB

MASS

Mass is a quantity of matter in a body. Its S.I unit is kilogrammes (Kg)
It is measured using a beam balance or top pan balance.
The multiples and submultiples include;

Unit	symbol	Equivalence in Kg
Tonne	t	1000
Gram	g	0.001
Milligram	mg	0.000001

The mass of an object is the same everywhere because the number of particles in an object remains constant.

MEASUREMENT OF MASS

There are two common types of balances for measuring mass; Electrical and mechanical types.
Electrical types are very accurate and the mass of the object is read on display
(Top Pan Balance).
A Mechanical type (Beam Balance), the object whose mass to be measured is balanced against a known standard mass on an equal level.
The three balances used in measuring are;

1) Top Pan Balance
2) Beam balance
3) Level balance

In a level balance combination of levers moves the pointer along a scale when the mass is placed on it.
EXERCISE 2.6 KLB

DENSITY

The density of a substance is defined as its mass per unit volume. Its symbol is rho (ρ).
The SI unit is kilogram per cubic metre (Kg/m^3)

Conversion from kg/m^3 to g/cm^3

$1g/cm^3 = 1000kg/m^3$

EXAMPLE 10

A Block of glass of mass 187.5g is 5cm long, 2.0cm and 7.5cm high. Calculate the density of the glass block.

Solution

$$\text{Density} = \frac{\text{mass}}{\text{Volume}}$$

$$= \frac{187.5g}{2.0cm \times 5cm \times 7.5cm}$$

$$= 2.5 g/cm3 \text{ or } 2500 kg/m^3$$

EXAMPLE 11

A block of glass of mass 187.5 g is 5.0 cm long, 2.0 cm thick and 7.5 cm high. Calculate the density of the glass in kgm-3.

SOLN

Density = mass / volume

= (187.5 /1000) / (2.0 × 7.5 × 5.0 /1,000,000)

= 2500 kgm^{-3}.

EXAMPLE 12

The density of concentrated sulphuric acid is 1.8 g/cm3. Calculate the volume of 3.1 kg of the acid.

SOLN

Volume = mass / density

= 3,100 / 1.8

= 1722 cm^3 or 0.001722 m^3.

MEASUREMENT OF DENSITY

The density of an object is calculated from the formula;

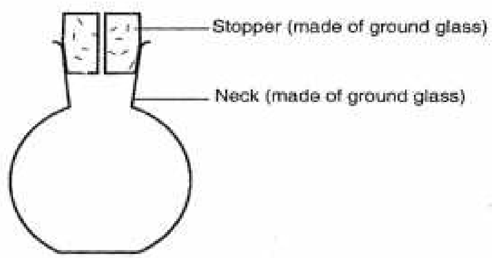
$$\text{Density} = \frac{\text{mass}}{\text{Volume}}$$

Density of common substances

Substance	Density	
	gcm^{-3}	kgm^{-3}
Platinum	21.4	21 400
Gold	19.3	19 300
Lead	11.3	11 300
Silver	10.5	10 500
Copper	8.93	8 930
Iron	7.86	7 860
Aluminium	2.7	2 700
Glass	2.5	2 500
Ice	0.92	920
Mercury	13.6	13 600
Sea water	1.03	1 030
Water	1.0	1 000
Kerosene	0.80	800
Alcohol	0.79	790
Carbon dioxide	0.00197	1.97
Air	0.00131	1.31
Hydrogen	0.000089	0.089

DENSITY BOTTLE

A Density bottle is a small glass bottle fitted with a glass stopper which has a hole through which excess liquid flows out.
Normally, the density bottle has its capacity indicated on the side.



To find the density of the liquid using a density, measure the mass m_1 of a dry clean density bottle with its stopper.
Fill the bottle with liquid and replace the stopper. Dry the bottle on outside (excess liquid overflows through the hole in the stopper).
Measure the mass m_2 of the bottle plus the liquid.
If the volume of the liquid is V then;

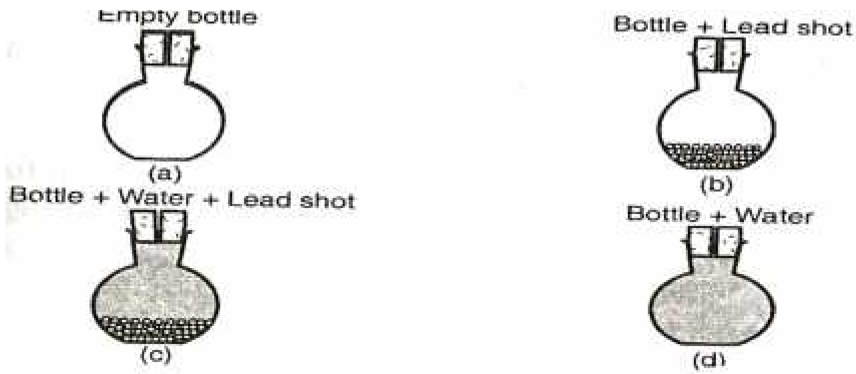
$$\text{Density} = \frac{(m_2-m_1)}{V}$$

PRECAUTIONS

- The bottle is held by the neck when wiping it dry. This is because when held in hands, it may expand due to warmth from the hand.
- The outside of the bottle must be wiped carefully.
- Ensure that there is no air bubbles when the bottle is filled with liquid

TO MEASURE THE DENSITY OF A SOLID USING A DENSITY BOTTLE

This method is used for solids in form of grains, beads or turnings
Apparatus: density bottle, lead shots and beam balance.



PROCEDURE

- Measure the mass m_1 of a clean dry empty density bottle
- Fill the bottle partly with the solid (lead shots) and measure mass m_2
- Fill up the bottle with water up to the neck and measure its mass as m_3.
- Empty the bottle and rinse it
- Fill it with water and replace it with the stopper, wipe outside dry and measure the mass m_4 of the bottle filled with water.

RESULTS

Mass of water = $(m_4 - m_1)$ g

Volume of water = $(m_4 - m_1)$ cm3 (since density of water is 1g/cm3)

Mass of lead shots (solid) = $(m_2 - m_1)$ g

Mass of water present when the bottle is filled with lead and water = $(m_3 - m_2)$ g

Volume of water = $(m_3 - m_2)$ cm^3

Volume of lead shots = $(m_4-m_1)-(m_3-m_2)$ cm^3 (since density of water is 1g/cm^3)

Therefore density of lead shot= $(m_2-m_1)-\{(m_4-m_1)-(m_3-m_2)\}$

NOTE: This method is unsuitable for solids which are either soluble or react with it.

EXAMPLE 13

The mass of a density bottle is 20g when empty and 45g when full of water. When full of mercury, its mass is 360g. Calculate the density of mercury.

SOLUTION

Mass of water = 45-20 =25g

Volume of water = 25g/1g/cm^3

= 25cm^3

Volume of bottle = 25cm^3

Mass of mercury = 360-20 =340g

Volume of mercury= 25cm^3

Density of mercury= 340 ÷25

=13.6g/cm^3 or 13600kg/m^3

EXAMPLE 14

In an experiment to determine the density of sand using a density bottle, the following measurements were recorded:

Mass of empty density bottle =43.2g

Mass of density bottle full of water =66.4g

Mass of density bottle with some sand =67.5g
Mass of density bottle with some sand filled up with water=82.3g
Use above data to determine the;

(a) Mass of water that completely filled the bottle.
(b) Volume of water that completely filled the bottle.
(c) Volume of the density bottle.
(d) Mass of sand.
(e) Mass of water that filled the space above the sand.
(f) Volume of the sand.
(g) Density of the sand.

SOLN

a) 66.4 - 43.2 = 23.2g
b) $23.2cm^3$
c) $23.2cm^3$
d) (67.5 - 43.2) g = 24.3g
e) 82.3 - 67.5 = 14.8g
f) Volume of the sand = volume of bottle - volume of added water
= 23.2 - 14.8= $8.4cm^3$
g) P = M/V = 24.3g / $2.893cm^3$
= $8.4cm^3$

EXAMPLE 15

The mass of an empty density bottle is 20 g. Its mass when filled with water is 40.0 g and 50.0 g when filled with liquid X. Calculate the density of liquid X if the density of water is 1000 kgm^{-3}.

SOLN

Mass of water = 40 – 20 = 20 g = 0.02 kg.
Volume of water = 0.02 / 1,000
= 0.00002 m^3.
Volume of liquid = volume of bottle
Mass of liquid = 50 – 20
= 30 g = 0.03 kg
Therefore density of liquid = 0.03 / 0.00002
= 1500 kgm^{-3}

DENSITY OF MIXTURES

A Mixture is obtained by putting together two or more substances such that they do not react with one another. The density of the mixture lies between the densities of its constituent substances and depends on their proportions.

$$\text{Density of the mixture} = \frac{\text{mass of the mixture}}{\text{Volume of the mixture}}$$

EXAMPLE 16

100cm3 of fresh water of density 1000kg/m3 is mixed with 100cm3 of sea water of density 1030kg/m3. Calculate the density of the mixture.

Solution

Mass of fresh water = density x volume
= $1g/cm^3 \times 100cm^3$
= 100g

Mass of sea water = 1.03 x 100
= 103g

Mass of the mixture = 100+103
= 203g

Volume of the mixture = 100+100
= $200cm^3$

Density of the mixture = 203÷200
= $1.015g/cm^3$

Exercise 2.7 no. 2 &3 KLB

TIME

It is a measure of duration of an event. Some ancient measuring instruments were the **sundial** and **the hour glass**

The SI unit of time is seconds (s)

MULTIPLES AND SUBMULTIPLES OF TIME

Time	symbol	Equivalent in seconds
Microsecond	μs	0.000001
millisecond	ms	0.001
Minute	min	60
Hour	hr	3600
Day	day	86400
Week	wk	604800

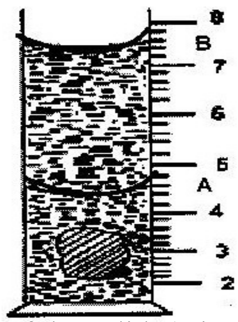
Measurement of time

Time is measured using either a stopwatch (digital) or stop clock

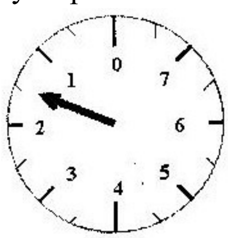
They are used depending on the accuracy required.

QUESTIONS ON THE TOPIC

1. State two factors that should be controlled in manufacturing a cylindrical container of uniform thickness, which should normally be in a standing position.
2. The figure shows a measuring cylinder which contains water initially at level A. A solid mass 11g is immersed in the water, the level rises to B.

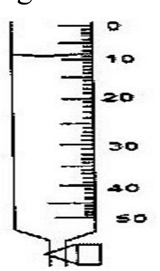


   Determine the density of the solid. (Give your answer to 1 decimal point)
   A butcher has a beam balance and masses 0.5 kg and 2 kg. How would he measure 1.5 kg of meat on the balance at once?
3. Determine the density in kg/m^3 of a solid whose mass is 40g and whose dimensions in cm are 30 x 4 x 3
4. Record as accurately as possible the masses indicated by the pointer in figures A.



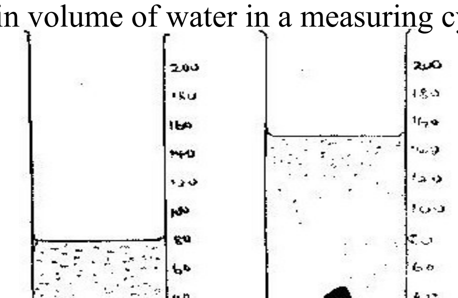
A

5. Figure 1 shows the reading on a burette after 55 drops of a liquid have been used.



   If the initial reading was at 0cm mark, determine the volume of one drop

6. Fig. 1 shows the change in volume of water in a measuring cylinder when an irregular solid is immersed in it.



Given that the mass of the solid is 567g, determine the density of the solid in gcm^{-3}. (Give your answer correct to 2 decimal places.

7. A thin wire was wound 30 times closely over a boiling tube. The total length of the windings was found to be 9.3 mm. Calculate the radius of the wire.
8. (a) Given that a kilogram of copper contains about 10^{25} atoms and that density of copper is about $9000kg/m^3$, estimate the diameter of the copper atom?
   (b) State the assumption made in (9a) above.
9. The density of concentrated Sulphuric acid is $1.8gcm^{-3}$. Calculate the volume of 3.6kg of the acid.
10. 1600 cm^3 of fresh water of density l g/cm^3 are mixed with $1400cm^3$ of seawater of density $1.25g/cm^3$. Determine the density of the mixture.
11. With the aid of a diagram, illustrate the meaning of the parallax error
12. Describe how you can measure the density of a rock which has no definite shape.
13. A shopkeeper has a scale balance and masses of 250g and 2kg. How would he measure 1.75kg of flour on this scale at once
14. A pebble of mass 50g is placed in a measuring cylinder containing some water. The reading of the water level increased from $75cm^3$ to $95cm^3$. Calculate the density of the pebble
15. The container shown below is filled to a depth of 5cm with a liquid.

3.5cm

9cm

Liquid 5cm

(i) Using pie as 22/7, determine the volume of the liquid.
(ii) If the mass of the liquid in the container is 2.554kg, estimate the density of mercury in g/cm^3.
(iii) Calculate the mass of water that would be needed to completely fill the remaining space in the container above the liquid. (Density of water is $1g/cm^3$)
(iv) A pebble of density $9g/cm^3$ is gently dropped into the container full of water and the liquid. Describe and explain what is observed.

SOLUTIONS

1. height, base area
2. Volume of one molecule = 18/ $(6x10^{23})$ = $3x\ 10^{-23}$cm
   $X^3 = 3x\ 10^{-23}\ cm^3$
   $X = 3.11\ x\ 10^{-8}\ cm^3$
3. d= m/v=40g/ 30 x 4 x $3cm^3$ = 0.1111 g/cm^3
4. 1.5 kg
5. D= m/r = $^{567}/_{(150-80)}$ = $^{576-80}/_{70g/cm3}$
6. 2000 cm^3
7. $1.12g/cm^3$

TOPIC 3: FORCE

Force is a pull or a push or that which changes a body way of motion and distort it
Its SI unit is newtons (N)

EFFECTS OF FORCE

- It can increase the speed of a moving object or make a stationary object start moving.
- Slow down or stop a moving object.
- Change the direction of a moving object.
- Distort (change) the shape of an object.

Force is that which changes a body's state of motion or shape. Some forces are small and others are large.
Force is represented by a line with an arrow showing the direction it acts. i.e.

F

Force can be categorized in two ways. These are:

- As either a push or a pull
- As either contact or non-contact force

Contact forces are those forces between bodies which are in contact e.g. action and reaction, viscous drag, friction etc. Non-contact forces act between bodies at a distance e.g. gravitational force, magnetic force, electrostatic force etc.

TYPES OF FORCES

i) Gravitational force
ii) Tensional force
iii) Upthrust
iv) Frictional force
v) Magnetic force
vi) Centripetal force
vii) Cohesive and adhesive force

viii) Molecular force
ix) Electric force
x) Nuclear force
xi) Electrostatic force

- **GRAVITATIONAL FORCE**

This is a force of attraction between two bodies of given mass. Objects thrown from the earth's surface always falls back to the surface of the earth. This force which pulls the body towards the centre of the earth is called **Gravitational force.**
Moon and other planets also have their gravitational force to objects.
The pull of gravity on the body towards the centre is called **weight**. The weight of an object varies on different planets because of different gravitational pull.

- **TENSION FORCE**

Tension force is as a result of two opposing forces applied. The pull or compression of a string or spring at both of its ends is called **Tension**.
Compressed or stretched object will tend to regain its original shape, when the stretching or compressing force is removed .Materials that can be extended without breaking are called **elastic materials.** Such materials can be used to make a spring balance an instrument used to measure force. Other examples include; bows and catapults.

- **UPTHRUST FORCE**

The upward force acting on an object immersed in a fluid (liquid or gas) is called **upthrust force.**
An object in a vacuum will not experience upthrust.

EXAMPLE 1

An object weighs 80N in air and 60N when immersed in water. Calculate force acting on the object.

Solution

Upthrust force = weight of object in air –weight of object in the liquid
= 80 - 60
= 20N

Exercise

a) **An o**bject weighs 100N in air and 26N when immersed in water. Calculate the apparent loss weight of the object. Calculate also the mass of object in water. (1Kg=10N).
b) **2kg** blue band weighs 20N when placed in air .The apparent loss in water is 2N .Calculate the mass of blue band in water.

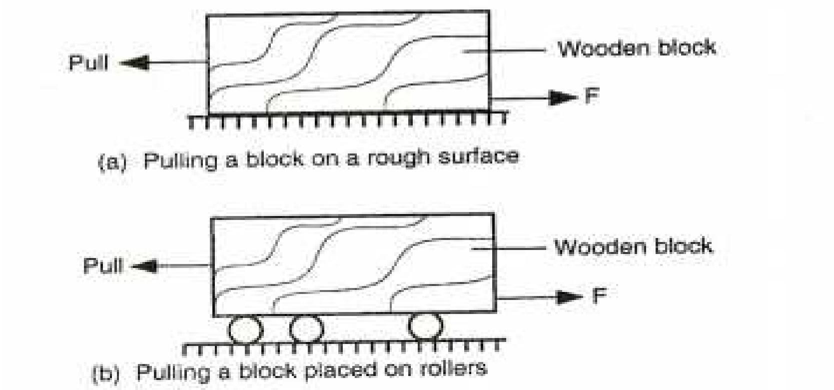
- **FRICTIONAL FORCE**

Frictional force is a force that opposes relative motion between two surfaces in contact.
The opposing force involving a fluid is called **viscous drag** (viscosity).This viscous drag limits the speed with which a body can move in a liquid.
Friction can be applied during walking.

EXPERIMENT: To investigate frictional force.

Apparatus: wooden block, rollers.
Procedure:

1. Put a block of wood on a horizontal surface such as a bench as shown.



2. Pull the block gradually, increasing the force.
3. Repeat the experiment, this time resting on rollers as shown above

Conclusion

The wooden block starts to move when the applied force is just greater than frictional force between the block and the surface of the bench.
Frictional force can be reduced by using rollers, oiling and smoothening.

- **MAGNETIC FORCE**

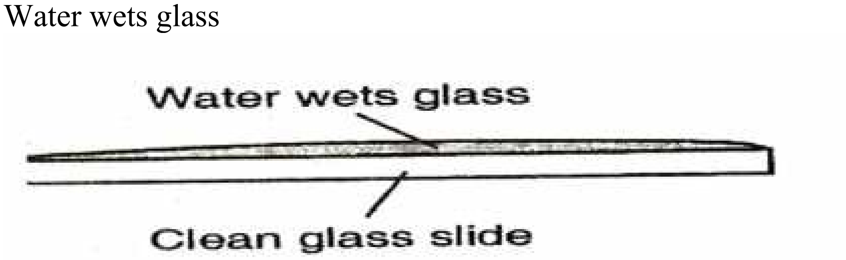
Magnetic force is the force of attraction or repulsion between a magnetic material and a magnet. A magnet has two types of poles, a north pole and a south pole. Like poles repel while unlike poles attract. Some materials are attracted by a magnet while others are not .Those that are attracted are called **magnetic materials** e.g. iron ,steel ,nickel and cobalt while those that are not attracted are called **non-magnetic materials** e.g. wood and aluminium.

- **COHESIVE AND ADHESIVE FORCES**

The force of attraction between molecules of the same kind is known as **cohesive force** e.g. A water molecule and another water molecule. The attraction between molecules of different kinds is known as **adhesive force** e.g. between water molecules and molecules of the container in which the liquid is put.

EXPERIMENT: To see the behaviour of water on different surfaces.

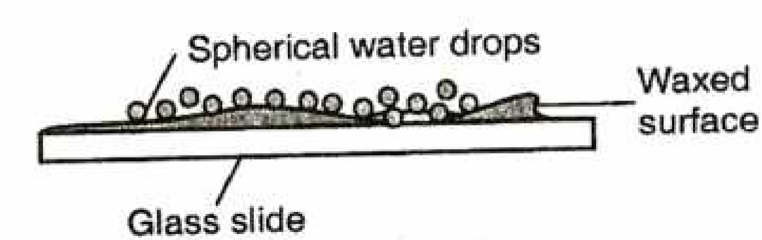
a. Water wets glass



Observation

Water on the glass slide spreads

b. Water forms spherical water drops on waxed surface



OBSERVATION

Small spherical balls was observed on a waxed glass

EXPLANATION

Water wets the glass surface because the adhesive forces between the water molecules and the glass molecules are greater than the cohesive forces between water molecules.

Water does not wet the waxed glass surface because the cohesive force is greater than the adhesive.

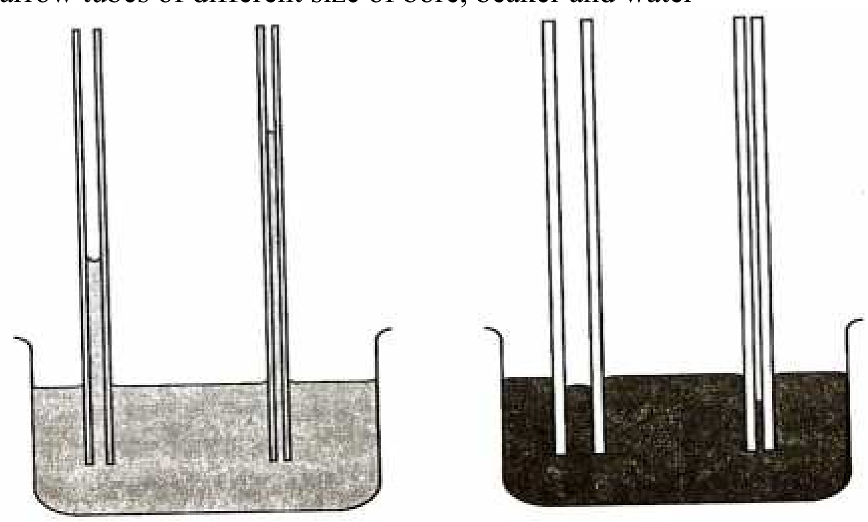
If mercury was used in the experiment it could be observed that small drops on a clean glass dish collect into spherical ball as shown below

This is due stronger cohesive forces between mercury molecules which forms small spherical drops. The adhesive force between mercury and glass makes mercury not wet glass.

N/B: Mercury is poisonous and should not be handled in ordinary laboratory.

EXPERIMENT: To demonstrate cohesive and adhesive forces of liquids on narrow tubes

APPARATUS: narrow tubes of different size of bore, beaker and water



a) Glass tubes dipped in water b) Glass tubes dipped in mercury

OBSERVATION

The level of the water inside the tubes is higher than outside the tubes. A meniscus is formed at the top of the water level and it curves upwards (concave).

The rise in the tube with a smaller bore is higher than in the tube with a larger bore.

Different liquids rise by different heights depending on the diameter of the glass tube.

When mercury is used, the level of mercury inside the tubes goes lower than that outside the tubes. The surface of the mercury will curve downwards (convex).

EXPLANATION

Adhesive forces between the water and glass is greater than cohesive forces between the water molecules, the water rises up the tube so that more water molecules can be in contact with the glass. This wets the glass. Liquids such as glycerol, kerosene and methylated spirit rise in tubes. On the other hand, the force of cohesion with the mercury is greater than the force of adhesion between glass and mercury. The mercury sinks to enable mercury molecules to keep together.

- **SURFACE TENSION**

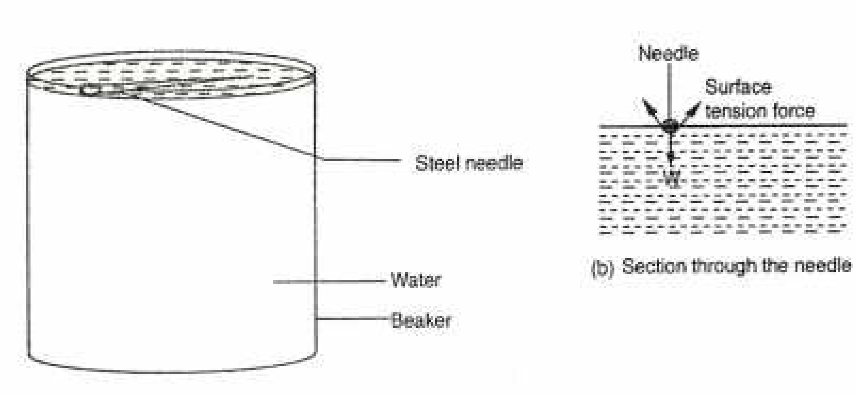
This is a force that causes the surface of a liquid to behave like a stretched plastic skin.
The force is due to the force of attraction between individual molecules in a liquid. Its due to this force that liquids form drops, water wets the surface but runs off others, some insects like pond skaters manage to rest on the surface of water without sinking, water rises up in narrow glass tubes but mercury is pushed down to a lower level in the same tube and steel needle or razor blade floats on water even though steel is denser than water

EXPERIMENT: To investigate the behaviour of a liquid surface

APPARATUS: Beaker, water, soup solution, razor blade or steel needle.

PROCEDURE:

- Fill the beaker with clean water to the brim as shown



(a) Steel needle floating on water (b) Section through the needle

- Place a dry steel needle or razor blade at the edge of the beaker and carefully introduce it on the surface of water. Take care not to break the surface of water. Observe what happens.
- Put a few drops of soap solution and observe what happens.
- Depress the tip of the needle into the water and observe what happens.

OBSERVATIONS

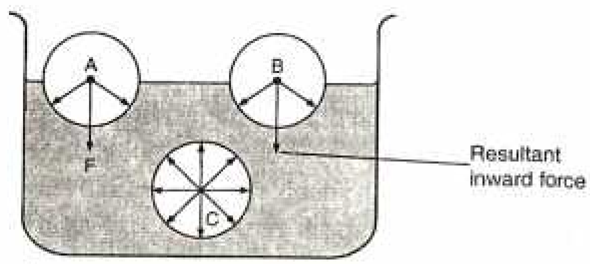
- The razor blade/needle floats on the surface of water and remains resting so long as the water surface is not broken.
- When drops of soap solution are put on the surface of the water around the razor blade/steel needle, the razor blade/steel needle sinks after a few minutes.
- Depressing the razor blade highly allows it to sink very quickly

EXPLANATION

The razor blade/needle floats because the surface of water behaves like a fully stretched, thin, elastic skin. The force which causes the surface of a liquid to behave like a stretched skin is called **surface tension.** This force is due to the force of attraction individual molecules of the liquid (cohesive force)

The needle or blade sinks when drops of soap solution are put near the razor/needle because the soap solution reduces surface tension of the water.
When the tip of the needle or razor is depressed into the liquid, it pierces the surface skin and sinks.

MOLECULAR EXPLANATION OF SURFACE TENSION



A Molecule say C deep in the liquid is surrounded by molecules on all sides so that the net force in it is zero. However, molecules of the surface, say A and B will have fewer molecules on the vapour side and hence it will experience a resultant inward force causing the surface of the liquid to be in tension.

FACTORS AFFECTING SURFACE TENSION

1. **Impurities –** impurities reduces surface tension of a liquid. Detergents weaken the cohesive forces between the liquid molecules.
2. **Temperature –** Increasing the temperature of a liquid increases kinetic theory of molecules. The inter-molecular distance increases and the force of cohesion is decreased hence surface tension is lowered.

CONSEQUENCES/EFFECTS OF SURFACE TENSION

1. Water insects can rest on the surface of water without breaking the surface. The insects skate across the surface at high speed.
2. Mosquito larvae float on water surface. Oiling the surface using kerosene lower surface tension making larvae to sink

NOTE:

a) Behaviour of soap bubbles- the soap bubbles flatten into thin films and try to rise up the funnel. This is because the surface tension makes it to behave as if it is a stretched elastic skin. As it tries to make its surface as small as possible, the bubble rises up the funnel.
b) Behaviour of soap film-the soap films in the wire loop with thread loosely tied across are used in this case. It is observed that when the film is broken on one side, the thread assume a perfect curve. This is because the surface tension will act on one side of the thread. Water tries to make its surface as small as possible, thus pulling the thread in such a way that it forms a perfect curve.
c) The appearance of water drops coming out of a tube- it is observed that the water drop grows to a large spherical drop before falling down. The water behaves as if there is an elastic membrane which stretches as more water gets into it. When it can not hold any more water, it falls.

d) Surface tension of soap is less than that of water- A matchstick or a small toy boat is rubbed with soap at one end and placed on the water surface, it start moving immediately. It moves in one direction only and in such a way that the end that is not rubbed with soap is always in front. The soap lowers/weaken/reduce the surface tension at the end of the stick. The surface tension at the other end which is now greater pulls the stick and makes it move in that direction. The movement gradually weakens and ultimately ceases when the whole surface of water is covered with soap solution. Camphor has the same effect as that of soap.
e) A glass tumbler can be filled with water above the brim. This is because the surface of the water behaves as if it is a thin elastic membrane as it stretches to hold more water.
f) When a brush is in water, the bristles spread but when it is taken out of water, they cling together. When in water, there in no surface tension since the tension is only on the exposed surface. When the brush is taken out of the water, the surface tension acting on the surface of water tends to be as small as possible thus pulling the bristles together.
g) When it is raining, it is advisable not to touch a canvas tent from inside. Touching the canvas tent or umbrella with lower/reduce/weaken the surface tension thus making water to leak into the tent.

- **ELECTROSTATIC FORCE**

This is a type of force which causes attraction or repulsion between charges.
Charges can be positive or negative.
Like charges repel and unlike charges attract

EXAMPLES

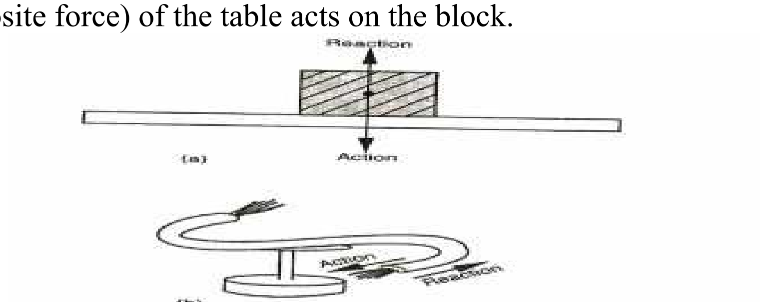
a) A plastic pen or ruler rubbed on a dry hair or fur picks up small pieces of paper lying on a table when it's brought near them. (**Charges are created on the pen and attract the pieces of paper**). The same pen or ruler attracts a stream of water from a tap. **The rubbing creates static charges**
b) When a glass window is wiped with a dry cloth on a dry day, dust particles are attracted on it.
c) When shoes are brushed, they tend to attract dust particles
d) When you remove cloth at night you observe sparks. The sparks are due to neutralization of the static charges formed when a nylon cloth is being pulled off.

- **ELECTRIC FORCE**

It's a force which acts on two conductors carrying electricity.

- **ACTION AND REACTION**

They are two equal forces but acting in opposite to each other. When a block of wood is placed on a table, its weight acts on a table (**action).** It is pressed on the surface downwards. The reaction (opposite force) of the table acts on the block.



When one force acts on a body, an equal and opposite force acts on one another.

MASS AND WEIGHT

Mass is the quantity of matter in an object while weight is a measure of the pull of gravity on an object. The S.I unit of mass is kg (kilogram) and of weight is Newton (N).
Mass of an object is a scalar quantity while weight is a vector quantity (since weight is a pull of gravity directed to the centre of the earth).
Due to the shape and rotation of the earth, the weight of an object varies from place to place while mass is constant (does not change).
A body weighs more at the poles than at the equator.

DIFFERENCES BETWEEN MASS AND WEIGHT

Mass	Weight
1. Its a quantity of matter on a body.	1. It is a pull of gravity on a body.
2. It's measured in kg.	2. It is measured in (N)
3. Same everywhere.	3. Varies from one place to another.
4. Measured using a beam balance.	4.Measured using a spring balance
5.Has magnitude only (scalar quantity)	5.Has both magnitude and direction.(vector quantity)

RELATIONSHIP BETWEEN MASS AND WEIGHT

Weight = Mass x gravitational

$W = mg$

EXAMPLE 2

1. Find the weight of an object whose mass is 50 kg.

$W = mg$
$= 50 \times 10$
$= 500$ N

2. Find the mass of an object whose weight is 900N

$W = mg$
$900/10 = 10/10m$
Mass, $m = 90$kg

3. An astronaut weighs 900N on earth .On the moon; he weighs 150 N.
Calculate the moon's gravitational strength. (g=10N/Kg)

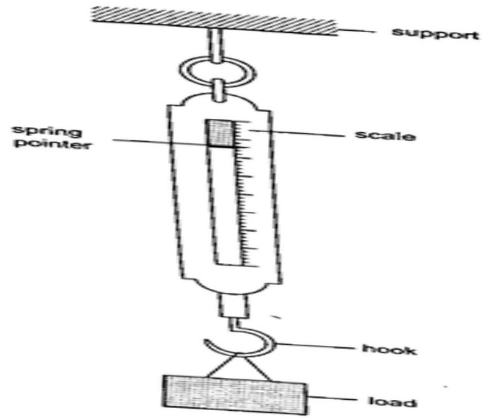
Mass, $m = w/g$
$= 900/10$
$= 90$kg
On moon, $w = mg$
$g = w/m$
$= 150/90$
$= 1.67$N/Kg

EX. 3.2(NOs. 1, 2, 4) KLB

MEASURING FORCE

Force is measured using an instrument called a spring balance.

The extension of a spring can be used to measure an applied force. The larger the force, the more the spring extends.
A spring balance measures forces and should therefore calibrated in newtons.
Some spring balances are calibrated in kilograms. In such cases, one is advised to convert from kilograms to newtons. (1Kg=10N)



EXAMPLE 3

The length of a spring is 16.0cm. Its length becomes 20.0cm when supporting a weight of 5.0N. Calculate the length the length of the spring when supporting a weight of; **a)**2.5N b)6.0N c)200N

Solution

a) 5N - 4cm	b) 5N - 4cm	c) 5N = 4cm
2.5 N- ?	6 N- ?	200N =?
(2.5 x 4)/5=2cm	(6 x 4)/5 =4.8cm	(200 x 4)/5= 160
2+16=18cm	4.8+16 = 20.8cm	160+16 =176cm

Note; In c) extension is too large and spring may straighten out.

EXAMPLE 4

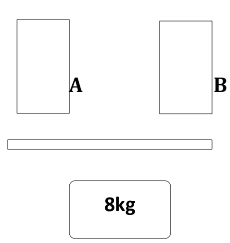
A spring stretches by 8.0mm when supporting a load of 2.0N. (i) By how much will it stretch when supporting a load of 6.0N? (ii) What load would make the spring extend by 2.5cm?

Solution

i) 8.0mm -2.0N	ii) 8.0mm -2.0N
?-5.0N	25mm=?
(5 x 8)/2 =20mm	(25 x2)/8 = 6.25N

EXAMPLE 5

The figure below shows two identical spring balances supported as shown:

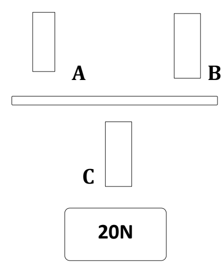


State the reading on each spring balance.

Each spring will read =80/2=40N

EXAMPLE 6

Three identical arranged as shown below were used to support a load of weight 20N. If the beam has a weight of 1N and each spring would extend by 1cm if a load of weight 4N is suspended from it, determine the extension of each spring.



Extension in spring A = Extension in spring B

= {(21/2) x1cm}/4N

= 2.265cm

Extension in spring C = (20Nx1cm)/4N

= 5cm

Exercise 3.3 no.2 KLB

SCALAR AND VECTOR QUANTITIES

A SCALAR QUANTITY – is a quantity which has magnitude (size) only. It can be specified by a number and unit. Examples include; mass, area, density, volume, energy, time, pressure, temperature, and length.

Scalar quantities are added by the normal rules of arithmetic e.g.3cm2+4cm2=7cm2

A VECTOR QUANTITY – is a quantity which has direction and magnitude (size). It can be specified by a number, unit and direction. Examples include; weight, force, velocity, displacement, acceleration, momentum and magnetic field strength.

A vector quantity is represented on a diagram by a straight line with an arrow i.e.

10N or 2N

The sum of two or more vectors is the resultant vector. Parallel forces which act on an object can be added arithmetically.

Examples of addition of parallel forces on a body

a)

b)

c)

d)

NOTE; Forces acting in opposite directions, the resultant is their difference.
To specify resultant force, both magnitude and direction are given

QUESTIONS ON THE TOPIC

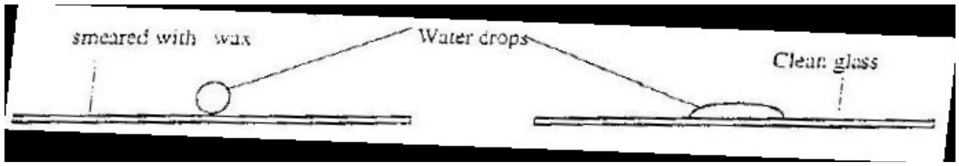
1. A student was heard saying "the mass of a ball on the moon is one sixth its mass on earth". Give a reason why this statement is wrong.
2. In the study of a free fall, it is assumed that the force f acting on a given body of mass m is gravitational, given by F= mg. State two other forces that act on the same body.
3. State how a lubricant reduces friction in the bearings of moving part of a machine.
4. Distinguish between mass and weight of a body stating the units for each.
5. State with reason the purpose of the oil that circulates in a motorcar engine.
6. Name two types of forces which can act between objects without contact.
7. A house in which a cylinder containing cooking gas is kept unfortunately catches fire. The cylinder explodes. Give a reason for the explosion.
8. Give a reason why the weight of a body varies from place to place
9. State why a pin floating on water sinks when a detergent is added.

10. Fig 8 shows water drops on two surfaces. In 8 (a), the glass surface is smeared with wax while in 8 (b) the glass surface is clean.

Figure 8

Explain the difference in the shapes of the drops.

11. An astronaut is on the moon. He drops a hammer from a height of 3.2m and it takes 2.0s to hit the lunar landscape. What is the acceleration due to gravity of the moon?
12. An unloaded spring has a length of 15cm and when under a load of 24N it has a length of 12cm. What will be the load on the spring when length is 10cm?
13. Give a reason why the weight of the body varies from place to place
14. A metal pin was observed to float on the surface of pure water. However the pin sank when a few drops of soap solution were carefully added to the water. Explain his observation.
15. A bag of sugar is found to have the same weight on planet earth as an identical bag of dry sawdust on planet Jupiter. Explain why the masses of the two bags must be different.
16. Fig 4 shows water drops on two surfaces. In (a) the glass surface is smeared with wax while in (b) the glass surface is clean.



Explain the difference in the shapes of the drops.

17. The diagram in figure 5 shows two glass tubes of different diameters dipped in water. Explain why h2 is greater than h1

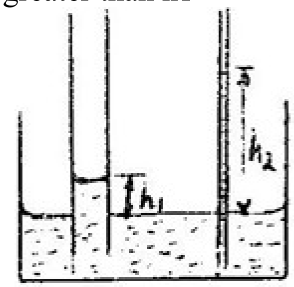


Fig. 4

18. Name two forces that determine the shape of liquid drop on the solid surface.

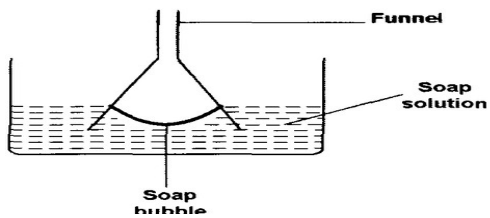
SOLUTIONS

1. The mass of the body is constant as the number of particles in a body remains constant. Mass is constant everywhere
2. Up thrust and frictional force
3. By going between two moving parts so that the parts slid on oil instead of each other.
4. - Weight is a vector quantity while mass is a scalar quantity.
   - Weight varies from place to place while mass is constant.
   - Weight is measured using a spring balance while mass is measured using beam balance.
5. To lubricate the engine/ reduce frictional force
6. Magnetic, electrostatic and gravitational.
7. Kinetic energies of molecules increase hence the pressure increases.
8. Because gravitational force varies with distance from the centre of the earth. Since weight depends on the gravitational pull, then it also varies.
9. The soap reduces the surface tension and hence the weight of pin becomes greater the surface tension.
10. In (a) adhesive forces between glass and wax are weaker than cohesive forces between water & water. The opposite is true (b)
11. 1.6m /s^2
12. 40N
13. Either altitude or latitude/ radius of earth changes/ acceleration due to gravity from place to place away from the earth
14. Addition of soap solution to pure water reduces the strength of the skin total was holding pin from sinking and so it sinks. Surface tension supports the pin. Addition of soap reduces tension/weakens/broken.
15. Acceleration of gravity on Jupiter is higher than that of earth, so a bag of saw dust must be less massive if the greater acceleration on earth is to produce the same pull as sugar bag on earth.

16. In (a) cohesive forces between water molecules are greater than adhesive forces between water and wax while in (b) adhesive forces between water and glass molecules are greater than cohesive forces between water molecules.
17. Surface tension / adhesive forces supports water column or more capillarity in tube 2 than tube 1Surface tension is the same in both tubes and equal to the weight of water column supported Narrow tube has longer column to equate weight to wider tube. Volume of water in the tubes is same hence narrower tube higher column

MORE QUESTIONS

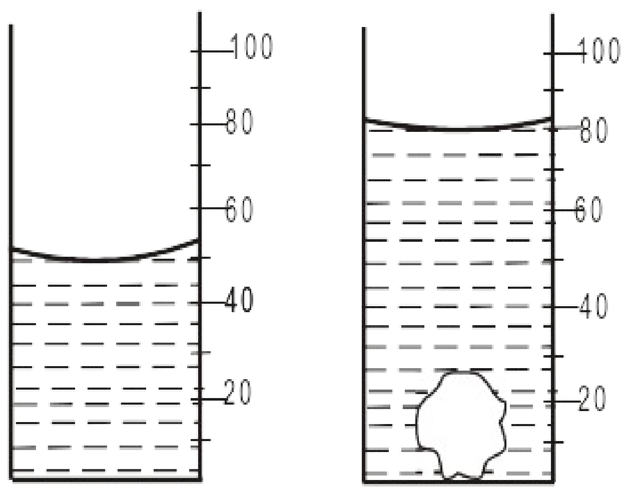
1. Figure 2 shows a funnel dipped into a liquid soap solution.



Explain what happens to the soap bubble when the funnel is removed.

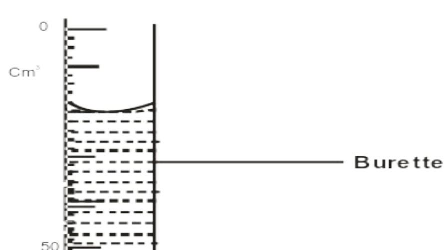
An alloy contains 40% by mass of lead and 60% by mass of tin. Determine the density of the alloy in kgm^3. (Density of lead = 1 l.4g/cm^3 and density of tin = 7.3g/cm^3

2. The water level in a burette is $35cm^3$. If 20 drops of water are added, what is the new level if each drop has a volume of $0.15cm^3$? A cylinder of height 25cm is completely melted and a sphere of the same radius made. Determine the radius of the sphere in metres and express your answer in standard form.
3. The figure below shows the change in volume of a liquid in a measuring cylinder when an irregular solid is immersed in it.



Given that the mass of the solid is 540g, determine the density of the solid in g/cm^3.

4. Figure 2 below shows a measuring cylinder containing some water.



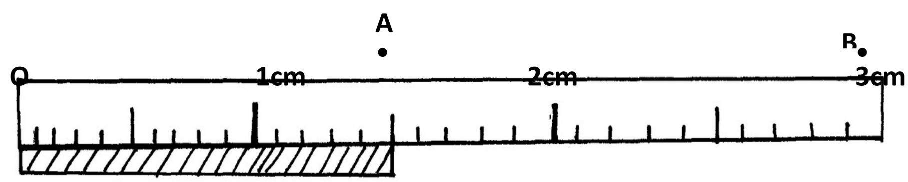
(i) New reading …………………

(ii) New reading

Another 10 cm^3 of water was added to the cylinder from a burette delivering volume from $0cm^3$ to $50cm^3$. Record in the spaces provided the new reading indicated on each vessel.

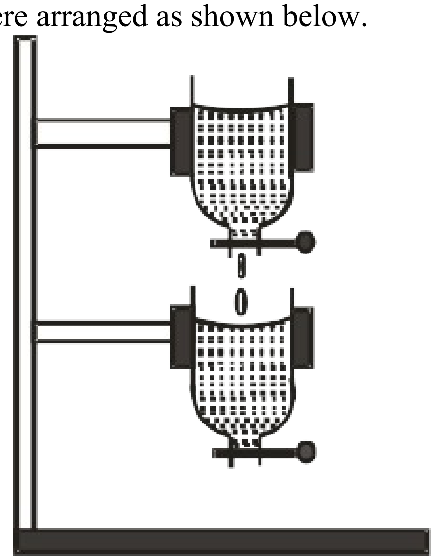
5. Figure 1 shows a millimeter scale placed in a position to measure the length of a block. An observer takes readings from position A and then from position B

Fig 1



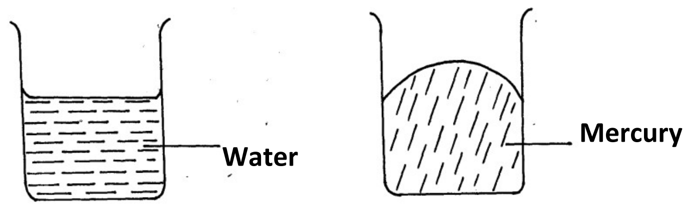
State the difference in readings.

6. Two burettes A and B were arranged as shown below.



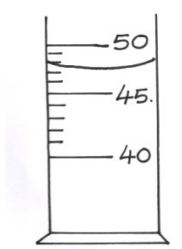
Burette A leaked into burette B at a rate of 10 drops per minute. If the initial reading on both burettes was 25ml, what would be their readings at the end of one hour if B does not leak and the average volume of one drop of water is $2.0 \times 10^{-8} m^3$?

7. State any **two** factors that determine the choice of instrument for measuring length
8. The figure 1 below shows the level of mercury and water in a beaker.



Explain the difference in the shape of the meniscus.

9. The figure below shows part of a measuring cylinder containing a certain liquid



Use this information to answer questions below
(i) State the accuracy of the measuring cylinder
(ii) What is the volume of the liquid in the measuring cylinder?

TOPIC 4: PRESSURE

Pressure is the force acting normally (perpendicularly) per unit area. The SI unit of pressure is N/m^2 or Nm^{-2}, which is also called Pascal (Pa).
Pressure in solids depends on two main factors i.e. force and area

EXAMPLE 1

A force of 100N is applied to an area 100mm2. What is the pressure exerted on the area in Nm^{-2}.

Solution

Area; $100mm^2$ = $.0000001m^2$ and Force = 100N
Pressure = F/A
= $100 \div 0.0000001$
= $1.0 \times 10^9 Nm^{-2}$

A man whose mass is 90kg stands on a floor.

a) If the area of contact between his feet and the floor is $0.0368m^2$, determine how much pressure he able to exert on the floor.

Pressure, P = F/A

= $900N/0.0368m^2$

= $24,456.5217N/m^2$.

b) What pressure will he exert on the floor if now he stands on one foot?

Pressure, P = 900N/ (0.0368/2)

= $48,913.0435N/m^2$

MAXIMUM AND MINIMUM PRESSURE

Maximum pressure = $\frac{\text{Force}}{\text{Minimum area}}$

Maximum Pressure P_{max} = $\frac{F}{A_{min}}$

Minimum pressure = $\frac{\text{Force}}{\text{Maximum area}}$

Minimum pressure P_{min} = F/A_{max}.

EXAMPLE 2

A block of wood measures 2cm by 3cm by 4cm and has a mass of 6 kg.
Calculate its pressure when; a) Area is minimum (maximum pressure) b) Area is maximum (minimum pressure).

Area -2 x 3 =6cm2

-2 x 4 =8cm2

-3 x 4 =12cm2

1. A min =6cm2 =0.006m2 and F =60N

P max =60/0.006 =$100,000Nm^{-2}$

2. A max =12cm2=0.0012m2 and f = 60 N

P_{min} = 60/0.0012 =$50,000Nm^{-2}$

EXERCISE

1. A block of wood measures 3m by 6m by 2m and mass 3kg. Calculate;
   i) Maximum pressure
   ii) Minimum pressure
2. A brick 20cm by 10cm by 5cm has a mass of 500g. Find maximum and minimum pressure. (take g = 10N/kg)

3. How much force must be applied on a blade of length 4cm and thickness 0.1mm to exert pressure of 5,000,000 Pa.?

Exercise 4.1 (no 1, 2, 3, 4, 5) KLB

PRESSURE IN LIQUIDS

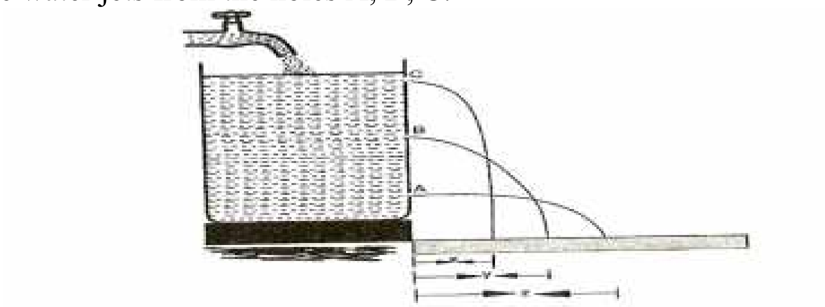
Pressure in liquids depends on the following;

- Depth of the liquid
- Density of the liquid

Pressure in liquids increases with depth and density.

EXPERIMENT: To show variation of pressure in liquids
APPARATUS: A tall tin, nail and water
PROCEDURE

- Using the nail, make 3 holes A, B, C of the same diameter on a vertical line of one side of the tin
- Fill the tin with water as shown below.
- Observe water jets from the holes A, B, C.



OBSERVATION

The lower hole, A, throws water farthest, followed by B and lastly by c

EXPLANATION

The pressure of water at A is greatest than pressure at B and pressure at B is greater than pressure at C. Hence, pressure increases with depth.

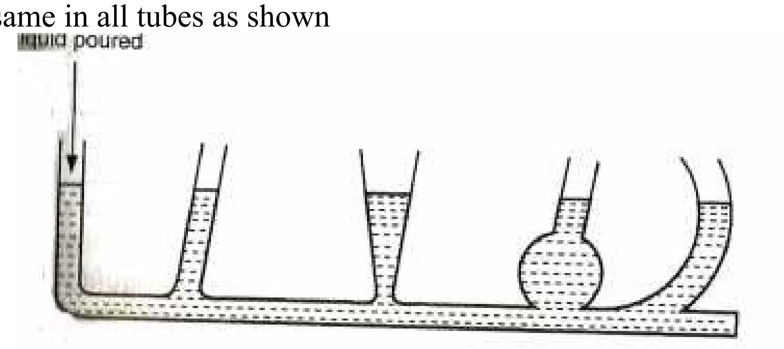
QUESTION

Explain why a diver at the bottom of the dam experiences greatest pressure

At the bottom of the dam depth is greatest and therefore the diver experiences greatest pressure due to the weight above him.

LIQUID LEVELS

When a liquid is poured into a set of connected tubes with different shapes, it flows until the level are the same in all tubes as shown

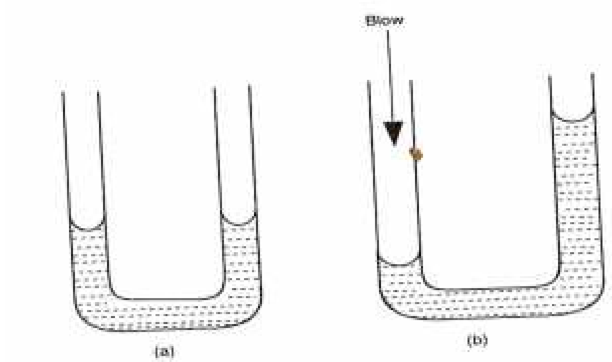


This shows that the liquid flows to find its own level.

LIQUID LEVELS IN A U-TUBE

When water is poured into a u-tube, it will flow into other arm. Water will settle in the tube with the levels on both arms being the same.

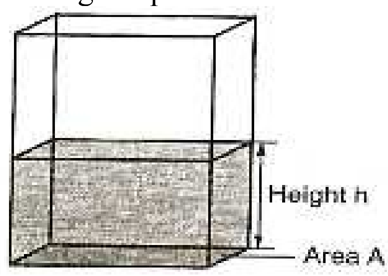
When one arm is blown into with the mouth, the level moves downwards, while on the other arm it rises. This is caused by pressure difference between the two arms as shown,



Pressure in liquids increases with depth below its surface
Pressure in a liquid at a particular depth is same in all directions.
Pressure in a liquid increases with density of the liquid.

FLUID PRESSURE FORMULA

Consider a container containing a liquid as shown below;



If A is the cross-section area of the column, h the height of the column and ρ the density of the liquid then;

Volume of the liquid = cross-section area x density
= Ah
Mass of the liquid = volume of the liquid x density
= A h ρ
Therefore, Weight of the liquid = mass x gravitational force
= A h ρ g
From definition of pressure P = force/area

$$\text{Pressure} = \frac{A\,h\,\rho\,g}{A}$$

$$= h\,\rho\,g$$

From the formula (p = h ρ g) pressure is directly proportional to;

- Height of the column
- The density of the liquid

NOTE: Pressure in liquids does not depend on the cross-section area of the container.
The formula is also used to determine pressure due to a gas column.

EXAMPLE 3

A diver is 10m below the surface of water in a dam. If the density of water is 1000kg/m3, determine the pressure due to the water on the diver. (Take g=10N/Kg)

Solution

Pressure = h ρ g
= (10 x 1000 x 10)

= **100,000 N/m2**

EXAMPLE 4

The density of mercury is 13600Kg/m3. Determine the liquid pressure at a point 76cm below mercury level.

Solution

Pressure = **hρg**

= **0.76 x 13600 x 10**

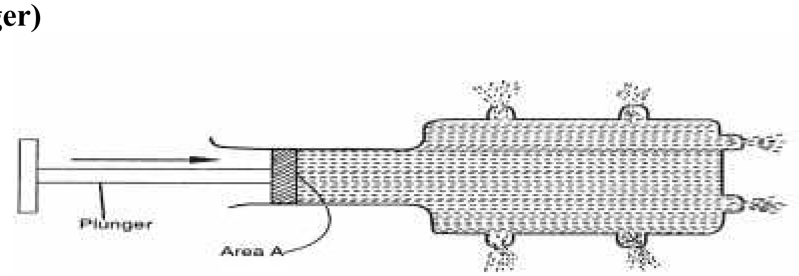
= **103,360 N/m²**

EXAMPLE 5

Calculate the pressure due to water experienced by a diver working 15m below the surface. (Take g = 10N/kg and density of sea water = $1.03g/cm^3$)

TRANSMISSION OF PRESSURE IN LIQUIDS

Pressure applied at one part in a liquid is transmitted equally to all other parts of the enclosed liquid. (**Plunger)**



This is the principle of transmission of pressure in liquids called **Pascal's principle** which states that pressure applied at a given point of the liquid is transmitted uniformly or equally to all other parts of the enclosed liquid or gas.

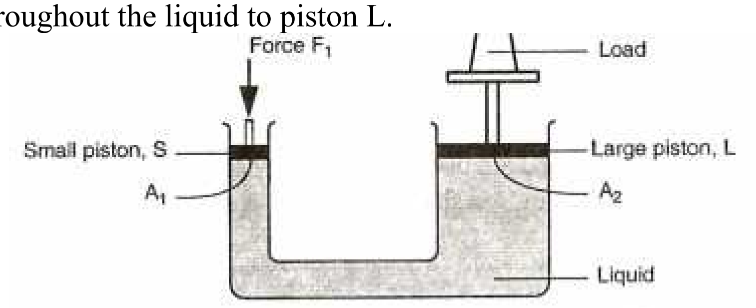
Gases may transmit pressure in a similar way when they are confined and incompressible.

HYDRAULIC MACHINES

The principle of transmission of pressure in liquids is made use in hydraulic machines where a small force applied at one point of a liquid produces a much larger force at some other point of the liquid.

a) HYDRAULIC LIFT

The hydraulic lift consists of a small piston S of cross-section A1 and a large piston L of cross-section area A_2. When a force is applied on piston S, the pressure exerted by the force is transmitted throughout the liquid to piston L.



At the smaller piston S the force applied F_1 cause a pressure P_1 at the cross section area A_1.

Therefore, Pressure $P_1 = \frac{F_1}{A_1}$

The pressure is equally transmitted throughout the liquid to the larger piston.
Thus at small piston pressure is equal to the pressure at the large piston

$$\mathbf{F_2 = P_1 \times A_2}$$

But, $P_1 = \frac{F_1}{A_1}$

$$F_2 = \frac{F_1 \times A_2}{A_1}$$

$$\frac{F_2}{F_1} = \frac{A_2}{A_1}$$

NOTE; Equation applies if pistons are at the same level

EXAMPLE 6

Find F_2 if $A_1 = 0.52m^2$, $A_2 = 10m^2$ and $F_1 = 100N$

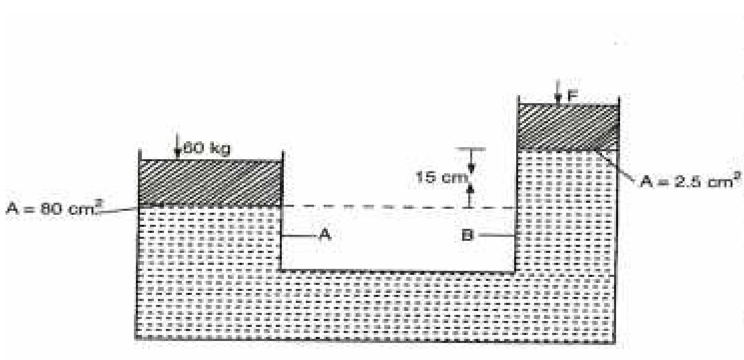
$$\mathbf{\frac{F_2}{100} = \frac{10}{0.25}}$$

$$\mathbf{F_2 = \frac{(100 \times 10)}{0.25}}$$

$$\mathbf{= 4000N}$$

EXAMPLE 7

Determine f2 in the figure below. Density of the liquid =800kg/m3 and g=10N/kg



$$\text{Pressure at A, } P_A = \text{Pressure at B, } P_B$$

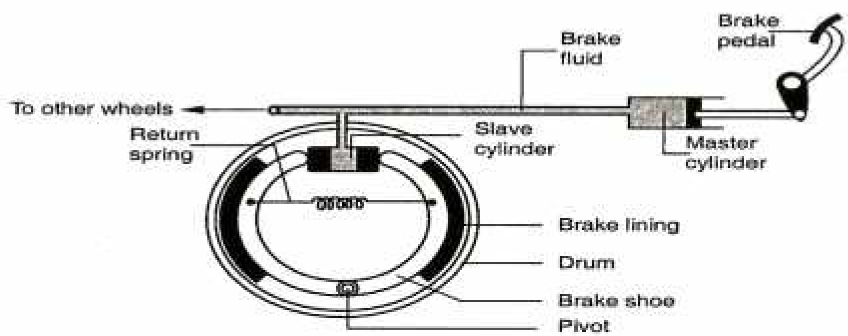
$$\frac{(60 \times 10)}{0.008} = \frac{(F_2)}{0.00025} + (0.15 \times 800 \times 10)$$

$$0.00025(7500 - 1200) = F_2$$

$$F_2 = 18.45\text{N}$$

Exercise 4.2 no.7

b) HYDRAULIC BRAKE SYSTEM



The force applied on the foot pedal exerts pressure on the master cylinder. The pressure is transmitted by the brake fluid to the slave cylinder. This causes the pistons of the slave cylinder to open the brake shoe and hence the brake lining presses the drum. The rotation of the wheel is thus resisted. When the force on the foot pedal is withdrawn the return spring pulls back the brake shoe which then pushes the slave cylinder piston back.

Advantage of this system is that the pressure exerted in master cylinder is transmitted equally to all four wheel cylinders.

The liquid to be used as a brake fluid should have the following properties;

- Be compressible, to ensure that pressure exerted at one point is transmitted equally to all other parts in the liquid
- Have low freezing point and high boiling point.
- Should not corrode the parts of the brake system.

ASSIGNMENT (exercise 4.2 no 1, 2, 3,4,5,6 & 8) KLB

ATMOSPHERIC PRESSURE

Atmosphere means the air surrounding the earth. The air is bound round the earth by the earth's gravity. The atmosphere thins outwards indicating the density of air decreases with the distance from the surface of the earth

The pressure exerted on the surface of the earth by the weight of the air column is called **air pressure**

Atmospheric pressure can be demonstrated by **crushing can experiment.**

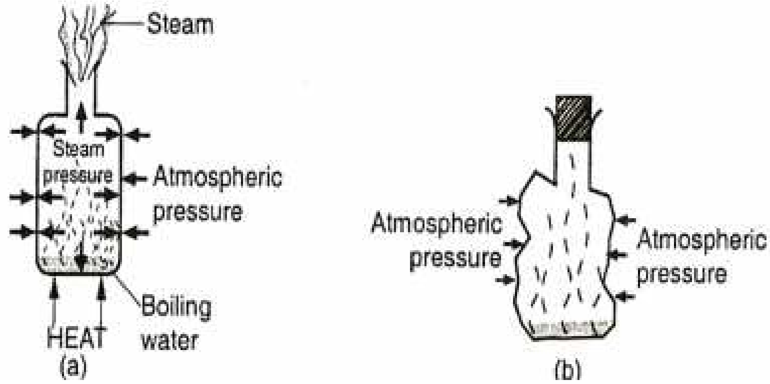
EXPERIMENT: To demonstrate the existence of the atmospheric pressure

APPARATUS: Tin container with a tight-fitting cork, water, tripod stand, Bunsen burner.

PROCEDURE

- Remove the cork from the container and pour in some little water.
- Boil the water for several minutes.

- Replace the cork and allow the container to cool or pour cold water to cool it faster.



OBSERVATION

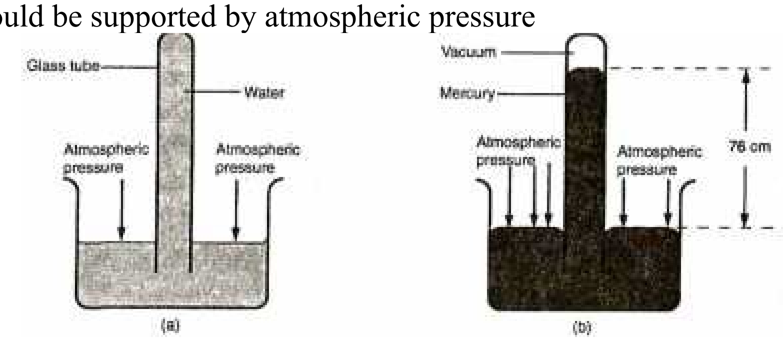
During cooling, the container crushes in.

EXPLANATION

Steam from boiling water drives out most of the air inside the container. When heating, the steam pressure inside the container balances with atmospheric pressure outside.
On cooling the steam condenses. A partial vacuum is therefore created inside the container.
Since pressure inside the container is less than the atmospheric pressure outside, the container crushes in.
NOTE: Steam inside the container condenses lowering the pressure. The outside atmospheric pressure exceeds the pressure inside the container thereby crushing it.

MAXIMUM COLUMN OF LIQUID THAT CAN BE SUPPORTED BY ATMOSPHERIC PRESSURE

When water is sucked up a straw, the air inside the straw reduces. The atmospheric pressure acting on the surface is now greater than the pressure inside the straw. Water is thus pushed up the straw by atmospheric pressure.
If the straw was long enough and sealed at the top, it would be possible to estimate the height of water that would be supported by atmospheric pressure



In case of water the column is too large.
At sea level the atmospheric pressure supports approximately 76cm of mercury column or approximately 10m of water column.

EXAMPLE 8

A girl in a school situated in the coast (sea level) plans to make a barometer using sea-water of density 1030 kg/m^3. If atmospheric pressure is 103,000 N/m^2, what is the minimum length of the tube that she will require?

Solution

P = h e g but p is atmospheric pressure

103,000 = h x 1030 x 10

H = 10m

EXAMPLE 9

A sea diver is 35m below the surface of sea water. If the density of the sea water is $1.03g/cm^3$ and g=10N/kg. Determine the total pressure on him.

Solution

Total pressure, P_T = Pa + h e g

= 103,000 + (35 x 1030 x 10)

= $463,500N/m^2$

EXAMPLE 10

The air pressure at the base of a mountain is 75cm of mercury while at the top is 60cm of mercury. Given that the average density is $1.25kg/m^3$ and density of mercury is $13,600kg/m^3$. Calculate the height of the mountain.

Solution

Pressure difference due to column of air = pressure difference due to mercury column

$$h_a \rho_a g = h_m \rho_m g$$

$$h_a = \frac{h_m \rho_m g}{\rho_a g}$$

$$h_a = \frac{(0.15 \times 13600 \times 10)}{(1.25 \times 10)}$$

$$= 1632m$$

EXERCISE

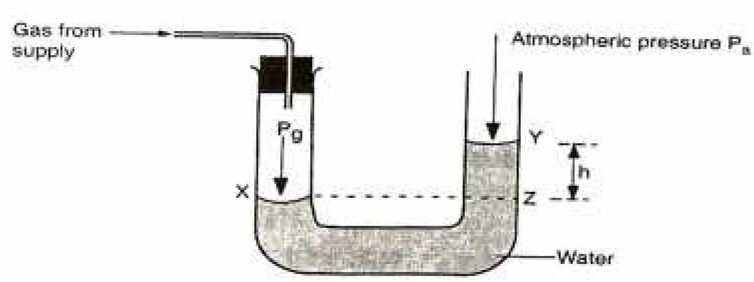
1. The barometric height at sea level is 76cm of mercury while that at a point on a highland is 74cm of mercury. What is the altitude (height) of the point? Take g =10N/kg, density of mercury $=13600kg/m^3$ and density of air $=1.25kg/m^3$.
2. A student in a place where the mercury barometer reads 75cm wanted to make an alcohol barometer, if alcohol has a density of $800kg/m^3$, what is the minimum length of the tube that could be used?

MEASUREMENT OF PRESSURE

a) THE U-TUBE MANOMETER

Is an instrument used to measure fluid pressure.

It consists of a u-tube filled with water or any other suitable liquid or gas as shown



Pressure at **Z** = Atmospheric pressure due to column of water.

Pressure at X = pressure at Z

Pressure at X = P_g

Pressure at Z = atmospheric pressure + pressure due to column of water

$P_g = P_a + h\rho g$.

Since the density of water and gravitational force is known we can determine pressure of a gas if the atmospheric pressure is known.

EXAMPLE 11

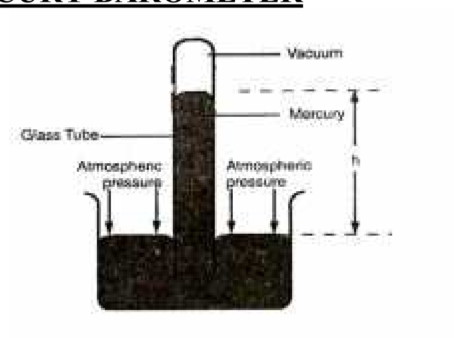
Suppose h=20cm, Pa = 103,000N/m^2 and density=1000kg/m^3, determine the total pressure (P_g)

Solution

$P_g = 103{,}000 + (0.2 \times 1000 \times 10)$

$= 105{,}000\text{N/m}^2$

b) <u>SIMPLE MERCURY BAROMETER</u>



At sea level atmospheric pressure supports approximately 76cm of mercury column or 10m of water column. This difference in height column between mercury and water is that mercury is much denser than water.

Mercury column forms a simple barometer, its height changing inside on the glass tube as air pressure outside changes.

The space above mercury in the barometer tube must contain air or water vapour since the barometer reading will be as shown above.

The space above in mercury in the tube when upright is called **toricellian vacuum**

The height h of the column is a measure of the atmospheric pressure.

At sea level, h=76cm since density of mercury = 13600kg/m^3.

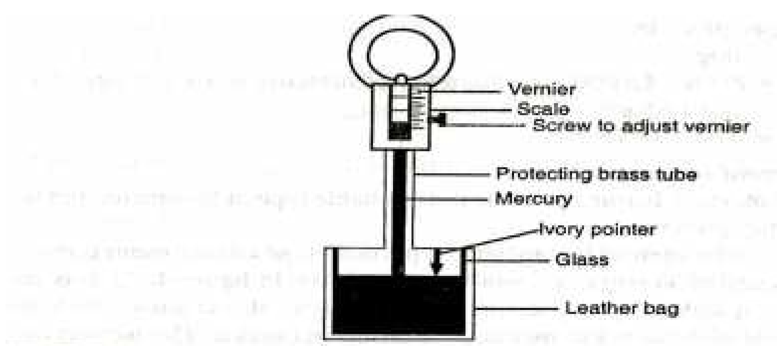
Atmospheric pressure, Pa $= h\rho g$

$= 0.76 \times 13600 \times 10$

$= 103{,}360\text{N/m}^2$ **(it is also referred as one atmosphere 1 atm)**

c) <u>FORTIN BAROMETER.</u>

This is an improved version of a simple mercury barometer. Was designed by FORTIN



The ivory pointer acts as the zero mark of the main scale. The leather bag acts as reservoir of mercury height.

Before taking the reading, the level of mercury surface in the reservoir is adjusted by turning the adjusting screw until the surface of mercury just touches the tip of the ivory index.

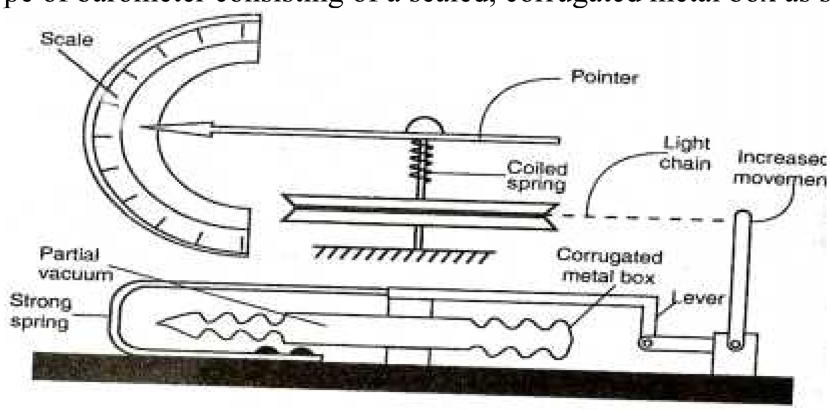
The height is the read from the main scale and vernier scale. The readings obtained from the barometer are in terms of the height of mercury column and written as mmHg or cmHg.

For example at sea level h=760mmHg and density of mercury=13600kg/m3

$$\begin{aligned} \mathbf{Pa} &= \mathbf{h\,\rho\,g} \\ &= \mathbf{0.76 \times 13600 \times 10} \\ &= \mathbf{103{,}360Nm^{-2}} \end{aligned}$$

d) ANEROID BAROMETER

Is a portable type of barometer consisting of a sealed, corrugated metal box as shown below



The pointer would indicate a particular value of atmospheric pressure of the surrounding so that any changes in pressure would be noticeable by movement of the pointer to either side of this atmospheric value on the scale.

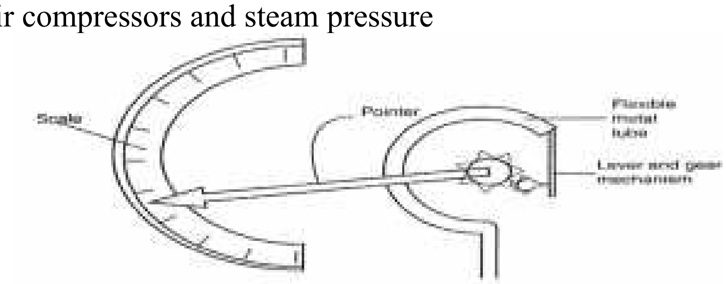
The aneroid barometer movement makes it adaptable to measure heights.

Aneroid barometers (Altimeters) are used in aircrafts to measure heights. Its normally calibrated in millibars. **1 bar=100,000Nm^{-2}**

1millibar (mbar) = 100Nm^{-2}

e) PRESSURE GAUGES

They are portable and are used mostly for measuring gas pressure, tyre pressure, pressure of compressed air compressors and steam pressure



It is made of coiled flexible metal tubes which uncoil when the pressure inside increases. The movement of the tube is made to drive a pointer across a scale, through a combined system of levers and gears.

EXAMPLE 12

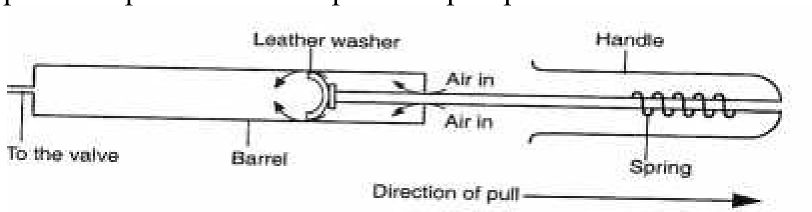
The pressure of a car tyre, measured with a pressure gauge is 40Ncm-2. What is the total pressure of the tyre in Nm^{-2}?

P_{Total} = P_a +gauge pressure
= 103,360 + (40 x 10,000)
= 503,360Nm-2

APPLICATION OF PRESSURE IN LIQUIDS AND GASES

a) THE BICYCLE PUMP

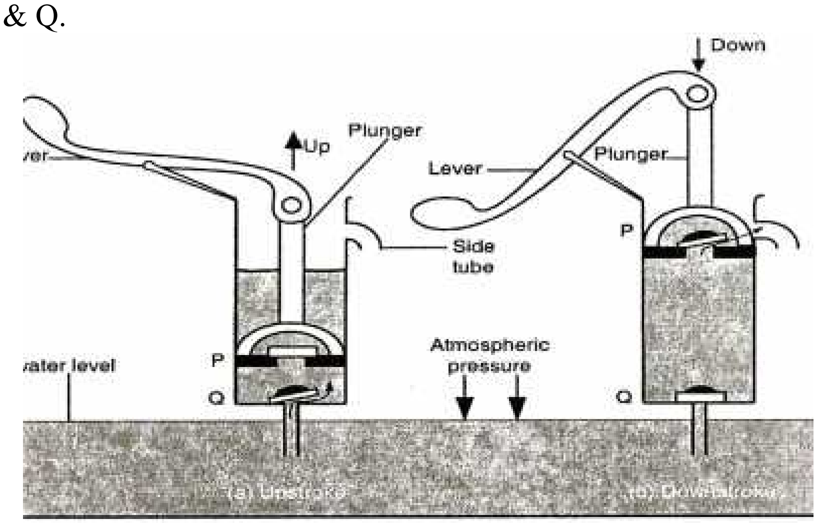
A bicycle pump is a simple form of compression pump.



The pump is connected to a tyre which has a rubber valve in it. When the pump handle is drawn out air below the washer expands and its pressure is reduced below the atmospheric pressure. Air from outside the pump the flows past the leather washer into the barrel. The higher air pressure in the tyre closes the tyre valve.
When the pump handle is pushed in, the air in the pump barrel is compressed.
The high pressure in the barrel presses the leather washer against the sides of the barrel. When the pressure of the compressed air becomes greater than that of air in the tyre, air is forced into the tyre through the tyre valve which now opens.
NOTE: There is an increase in temperature of the pump barrel during pumping because work is done during compressing the air.

b) THE LIFT PUMP

It is used to raise water from wells. It consists of a cylindrical metal barrel with a side tube. It has two valves P & Q.

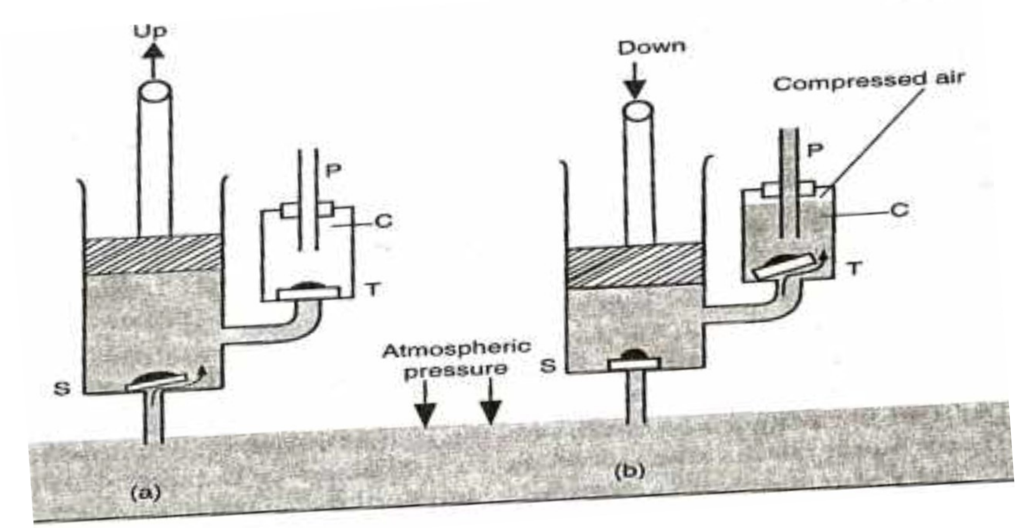


UPSTROKE

When the plunger moves during upstroke, valve P closes due to weight and pressure of water above it. At the same time, air above valve Q expands and the pressure reduces below atmospheric pressure.
The atmospheric pressure on the water surface in the well below this pushes water up past valve Q into the barrel. The plunger is moved up and down until the space between P and Q is filled with water.
DOWNSTROKE
During down stroke valve Q closes due to its weight and pressure of water above its piston.
Limitations of Lift Pump
The atmospheric pressure support only 10m column of water, which is actually a theoretical value but practically this pump raises the water less than 10m because of;

- Low atmospheric pressure in places high above sea level.
- Leakages at the valves and pistons

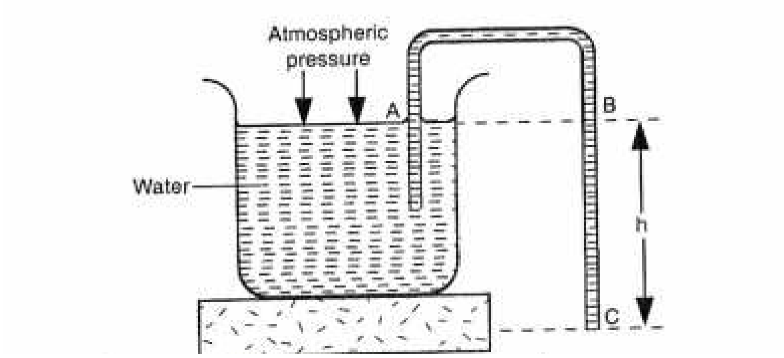
c) FORCE PUMP
This pump can be used to raise water to heights more than 10m.



UPSTROKE
During upstroke, air above the valve S expands and its pressure reduces below atmospheric pressure. The atmospheric pressure on the water in the well below pushes water up past valve S into the barrel.
NOTE: Pressure above valve T is atmospheric hence the valve does not open.
DOWNSTROKE
During down stroke, the valve S closes. Increase in pressure in the water in the barrel opens valve T and forces water into chamber C so that as water fill the chamber air is trapped and compressed at the upper part.
During the next stroke, valve T closes and the compressed air expands ensuring continuous flow.
Advantages of a Force Pump over a Lift pump
(i) Force pump enables continuous flow of water.
(ii) Height to which water can be raised does not depend on the atmospheric pressure. It depends on;

- Amount of forces applied during down stroke.
- Ability of the pump and its working parts to withstand pressure**.**

d) **THE SIPHON**



A tube can be used to empty tanks or draw petrol from petrol tanks in cars.
When used in this way it is referred as **a siphon**
Pressure on the surface of the liquid is atmospheric pressure. Since end C of the tube is below the surface A by height h, pressure at C is greater than that at the surface.
The tube is first filled with the liquid after which it will continue to run so long as end C is below the liquid surface.

Pressure at C = pa + h e g. The excess pressure (h e g) cause the liquid to flow out of end C

The siphon will work only if;
- End of the tube C is below the surface of A of the liquid to be emptied.
- **The t**ube is first filled with the liquid, without any bubbles in it.
- The tube does not rise above the barometric height of the liquid from the surface A of the liquid to be emptied.
- One end of the tube is inside the liquid to be emptied.

NOTE: A siphon can operate in a vacuum.

REVISION QUESTIONS

1. **The** atmospheric pressure on a particular day was measured as 750mmHg. Express this in Nm-2. (Density of mercury = 13600kg/m^3 and g=10N/kg)

   Solution

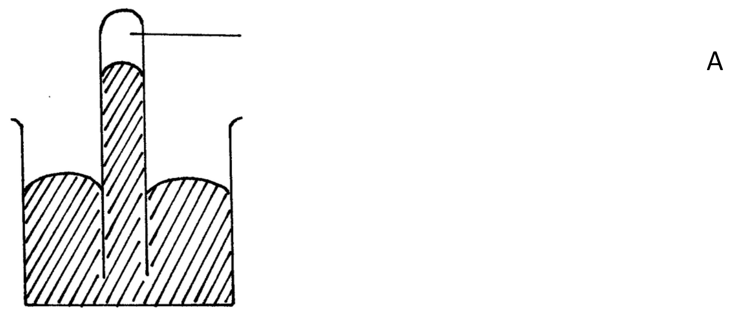
   P = h e g

   = 0.75 x 13600 x 10

   =

2. **A roof** has a surface area of 20,000cm^2. If atmospheric pressure exerted on the roof is 100,000Nm^{-2}, determine the force on it. (Take g = 10N/kg)

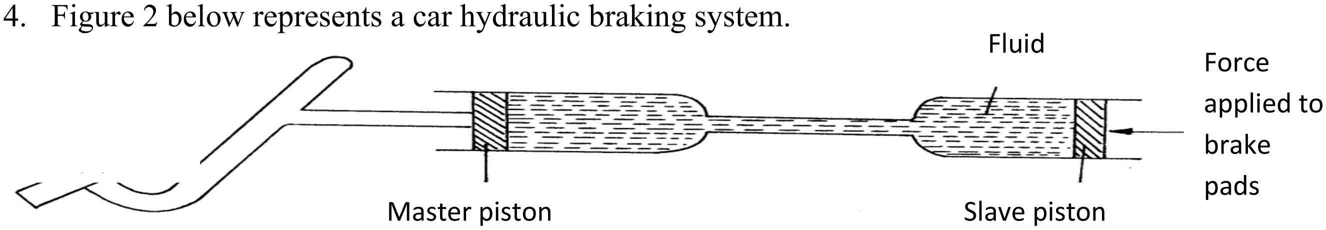
3. The diagram below shows a simple barometer



(i)Name the part labeled A

(ii)Explain what would happen to the level of mercury in the tube if the barometer was taken high up the mountain

4. Figure 2 below represents a car hydraulic braking system.

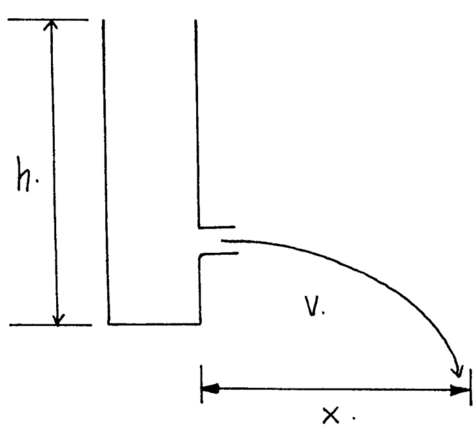


Use the information given in the diagram above to answer question:

a) State one property the fluid should have.

b) Explain briefly how the system operates.

5. The diagram below shows a water tank of height h?



What is the relationship between the velocity V of the water jet and the height h

6. State the possible reason why, if water is used as a barometer liquid, the glass tube required to hold the column of the liquid is longer
7. State the definition of atmospheric pressure
8. What is the density of alcohol?
9. A person's lung pressure as recorded by a mercury manometer is 90 mm Hg. Express this pressure in SI units.

10. The barometric height at sea level is 76cm of mercury while at a point on a highland it is 74cm of mercury. What is the altitude of the point? (Take g = $10m/s^{2,}$ density of mercury = $13600kg/m^3$ and density of air as $1.25kg/m^3$)
11. Figure 4 below shows a measuring cylinder of height 30cm filled to a height of 20cm with water and the rest occupied by kerosene

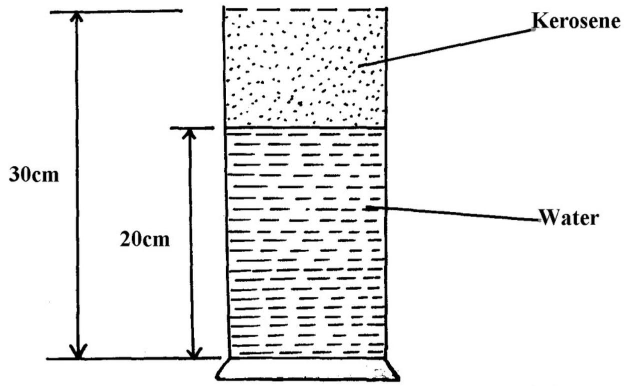
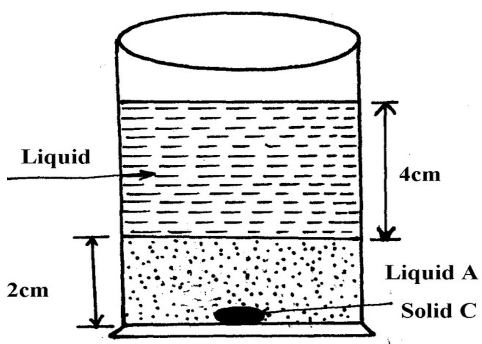


Fig. 4

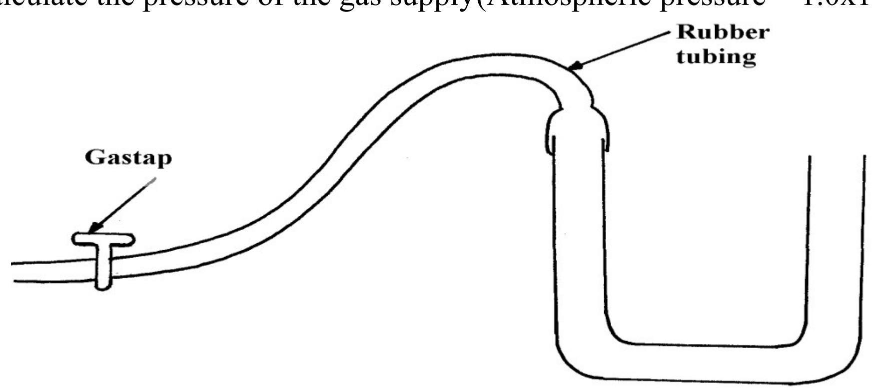
Given that density of water = $1000Kgm^{-3}$, density of kerosene = $800Kgm^{-3}$ and atmospheric pressure = $1.03x10^5$ Pa, determine the pressure acting on the base of the container

12. State Pascal's principle of transmission of pressure
13. A helical spring extends by 1 cm when a force of 1.5N is applied to it. Find the elastic potential energy stored in it.
14. Two immiscible liquids are poured in a container to the levels shown in the diagram below.



If the densities of the liquids **A** and **B** are $1g/cm^3$ and $0.8g/cm^3$ respectively, find the pressure acting upon solid **C** at the bottom of the container due to the liquids

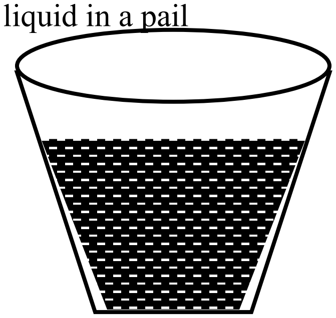
15. Mark the position of the water levels in the manometer when the gas supply is fully turned on
16. Calculate the pressure of the gas supply(Atmospheric pressure = $1.0x10^5Pa$)



17. A small nail may pierce an inflated car tyre and remain there without pressure reduction in the tyre. Explain the observation

18. (a) State **two** ways of increasing pressure in solids

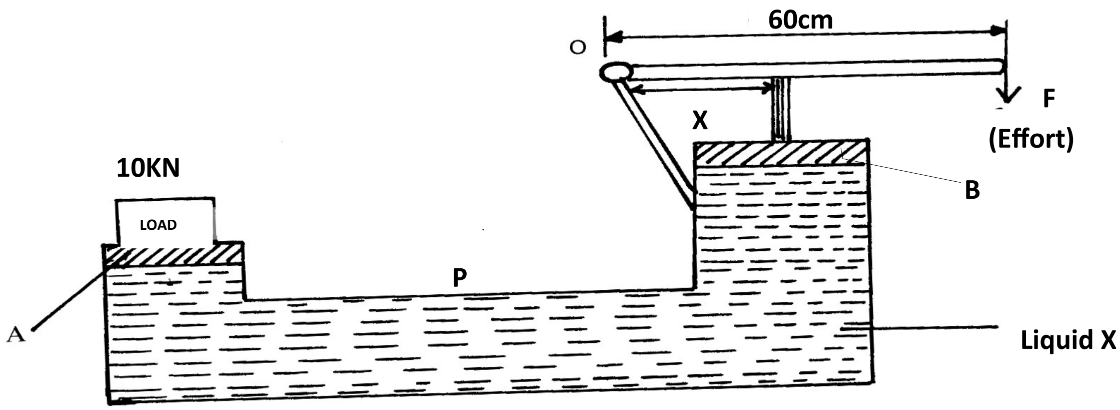
(b) The figure 1 shows a liquid in a pail



Suggest a reason why pail manufacturers prefer the shape shown to other shapes

19. A block measuring 20cm x 10cm by 5cm rests on a flat surface. The block has a weight of 3N. Determine the maximum pressure it exerts on the surface.

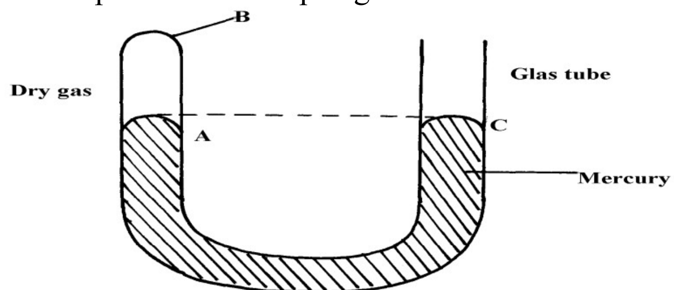
20. The figure below shows a hydraulic press **P** which is used to raise a load of 10KN. A force **F** of 25N is applied at the end of a lever pivoted at O to raise the load



(a) State **one** property of liquid **X**

(b) Determine the distance **x** indicated on the press if force on piston **B** is 100N

21. Mercury –in-glass barometer shows a height of 70cm. What height would be shown in the barometer at the same place if water density $1.0 \times 10^3 kg/m^3$ is used. (Density of mercury = $13600kgm^{-3}$)
22. The total weight of a car with passengers is 25,000N. The area of contact of each of the four tyres with the ground is $0.025m^2$. Determine the minimum car tyre pressure
23. (a) The diagram below represents a u-shaped glass tube sealed at one end and containing mercury



(i) What is the pressure of the gas as shown in the diagram above?

(ii) Explain why the gas should be dry if it is to be used to verify a gas law

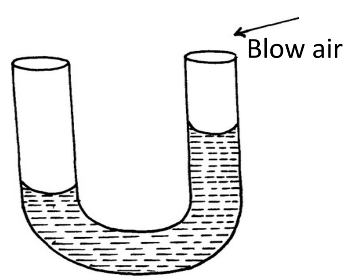
(iii) Describe how the arrangement can be used to verify Boyle's law.

(b) Use the kinetic theory of gases to explain why;

(i) The pressure of a gas increases with temperature increase

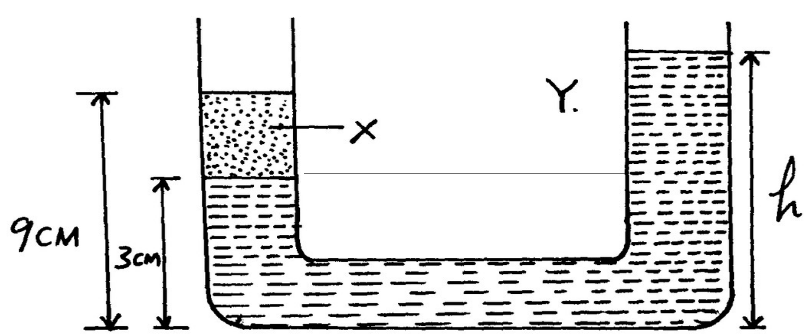
(ii) The pressure of a gas decreases as volume increases

24. The reading on a mercury barometer at Mombasa is 760mm. Calculate the pressure at Mombasa (density mercury is $1.36 \times 10^4 Kgm^{-3}$)
25. The figure below is a manometer containing water. Air is blown across the month of one tube and the levels of the water changes as the figure below.



Explain why the level of water in the right limb of manometer is higher.

26. In the diagram below, the U-tube contains two liquids; **X** and **Y** which do not mix. If the density of liquid **Y** is $900Kgm^{-3}$ and that of **X** is $1200Kgm^{-3}$, calculate the height of liquid **Y**



SOLUTIONS

1.
2.
3.
4.
5.
6. Because of its low density
7. Atmospheric pressure is the pressure exerted on the surface of the surface of the earth by the weight of the air column
8. $h_w \varrho_w g = h_w \varrho_w g$

$\therefore h_w \varrho_w = h_a \varrho_a$

Density of alcohol $= \frac{16 \text{ cm} \times 1\text{g/cm}^3}{20 \text{ cm}} \times 1000$

$= 800 \text{ kgm}^{-3}$

9. $P = h \varrho g$

$= \frac{90 \text{ m} \times 13600\text{kgm}^{-3} \times 10\text{Nkg}^{-1}}{1000}$

$= 12\ 240 \text{ Nm}^{-2}$

10. $\frac{(76 - 74)}{100} \text{ X } 13600 \text{ X } 10 = h \text{ X } 1.25 \text{ X } 10$

$H = \frac{2}{100} \text{ X } \frac{13600}{1.25}$

$= 217.\ 6 \text{ m}$

11. Pressure due to kerosene = h kg

= 800 x 0.1 x 10 = 800p.a√1

Pressure due to water = w h w g

= 1000 x 0.2 x 10 = 2000p.a√1

Atmospheric pressure = 103,000p.a

Total pressure = 800 + 2000 + 103000

= 105800 Pa

12. Pressure applied at one pat in a liquid is transmitted equally to all other parts of the enclosed liquid.

13. Pressure on = L f g

Solid at c = (0.02 x 1000 x 10) + (0.04 x 800 x 10);

= 200 + 320

= 520 N/m^2

14. Difference in the level of water should be 20cm

15. Pressure of the gas = Atmospheric pressure + ehg;

$= 1.0 \times 10^5 + \frac{\underline{20 \times 1000}}{100} \times 10$

$= 1.0 \times 105 + 2.0 \times 103Nm^{-2}$

= 1.02 x 105Pa;

16. - Rubber is elastic; and when a nail is pushed through it stretches and grips firmly the nail without allowing air leakage; or – Valve effect pressure from inside causes tyre rubber to press firmly on the nail;

17. (a) – Increasing the force (weight)

(b) Slanting sides increase the area supporting the weight of the liquid, hence its effect on the bottom of the container

18. Max pressure = $^{Force}/_{Min\ Area}$ √ 1

= $^{3N}/$ 0.1 X $_{0.05}$√1

= $600N/m^2$ √ 1

19. (a) – Incompressible

– Not corrosive

– Has low freezing point and high boiling point (any one)

20. $h_1p_1g = h_2p_2g$

$h_2 = \frac{h_1p_1}{p_2}$

$= \frac{0.7 \times 13600Kg/m^3}{1000kgm^{-3}}$

= 9.52m

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

= <u>2500</u>

4 x 0.025
= 250,000Pa

22. a) i) Atmospheric pressure $1.05 \times 10^5 N/M^2$
ii) Any water vapour available is near its condensing point. Intermolecular forces are therefore appreciable √, so it does not behave like an ideal gas
iii) - Fix a millimeter scale to read the length (L) of air column B √ and the difference in height (h) between the levels A and C√
- Adjust the level of C by adding more mercury a little at a time and record the corresponding values of L and h each time √
- A graph of L against h represents Boyle's law √
(b) i) Increase in temperature causes gas molecules to move faster(increases in kinetic energy), √ hence they generate greater/ higher impulsive force on impact √
iii) With increase in volume gas molecules are sparsely spaced √ so the rate of collision is reduced/ lowered

MORE QUESTIONS

1. The total weight of a car with passengers is 25000N. The area of contact of each of the FOUR tyres with the ground is $0.025m^2$.
   Determine the minimum car tyre pressure.
   I Write an expression for pressure on a liquid in hydraulic jack
   II While using a jack, a mechanic applied a force of 100N on the effort piston while raising the rear part of a car.
      i) Determine the maximum load that can be raised
      ii) Give a reason why gas is not suitable for use in place of the liquid in a jack.
2. The lift pump is effective for pumping water as long as the well is less than 10m deep. Explain.
3. The reading on a mercury barometer at Mombasa is 760mm. Calculate the pressure at Mombasa (density of mercury = 1.36×10^4 Kgm^{-3})
4. State one property of a barometer liquid and explain its effects.
   Figure 1 below shows a liquid being siphoned from one beaker to another. Refer to this diagram where answering questions 5, 6 and 7

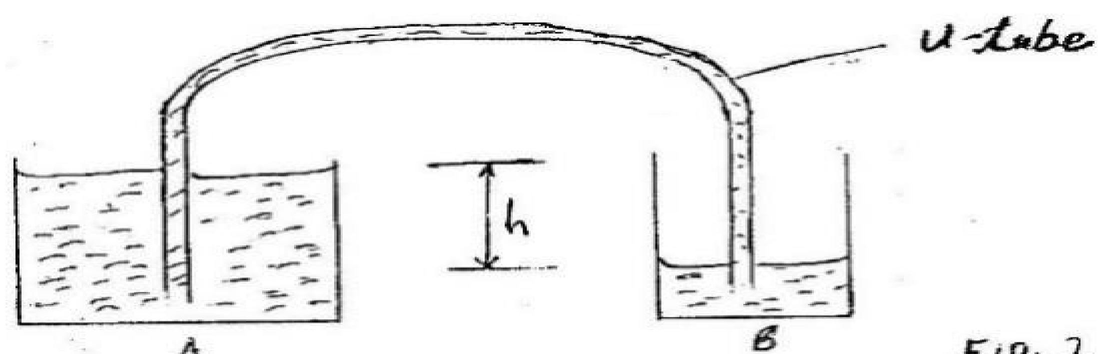


Fig. 2

5. Indicate on the diagram the direction of flow of the liquid

6. Show that the force driving the liquid through the U – tube is proportional to the height, h
7. State what would happen to the flow if the system in figure 2 were put in vacuum.

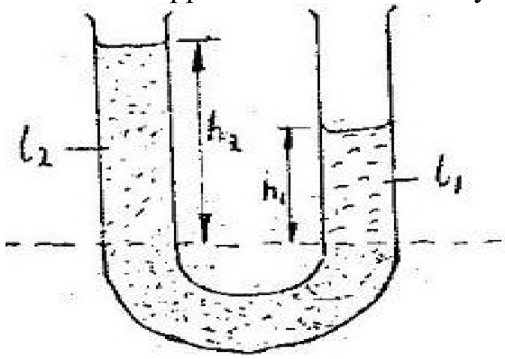


Fig. 2

8. Figure above shows a U tube containing two liquids L1 and L2 of densities 0.8 g cm^{-3} and 1.8 cm^{-3} respectively in equilibrium. Given that h2 = 8 cm determine the value of h1
9. A small nail may pierce an inflated car tyre and remain there without pressure reduction in the tyre. Explain this observation
10. The height of the mercury column in a barometer at a place is 64cm. What would be the height of a column of paraffin in barometer at the same place? (Density of paraffin = 8.0 x 102 kgm^{-3})
11. 7. A vacuum pump was used to pump out air from the glass tube immersed in liquids as shown in figure 3.

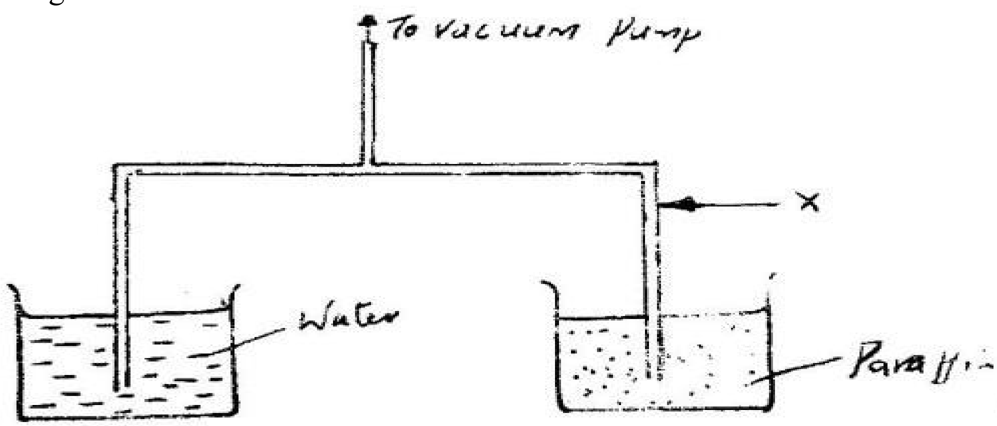


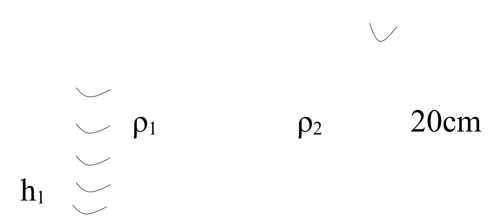
Fig. 3

After sometime the level of paraffin rose to position X. Mark the corresponding position for the water level. Give a reason for your answer.

12. A hole of area 2.0 cm^2 at the bottom of a tank 2.0m deep is closed with a cork. Determine the force on the cork when the tank is filled with water. (Density of water is 1000kg/m^3 and acceleration due to gravity is 10m/s^2).
13. The reading on a mercury barometer at a place in 700mm. What is the pressure at the place Nm^{-2} (Density of mercury is 1.36 x 104 kgm^{-3})
14. In an experiment to demonstrate atmospheric pressure, a plastic bottle is partially filled with hot water and the bottle is then tightly corked. After some time the bottle starts to get deformed
(a) State the purpose of the hot water.
(b) State the reason why the bottle gets deformed. Explain your answer.
15. Figure 4 shows a lift pump.
(a)Explain why, when the piston is;

i) Pulled upwards, valve A opens while valve B closes.
ii) Pushed downwards, valve A closes while valve B opens.
c) After several strokes, water rises above the piston as shown in Figure 5.

16. State how water is removed from the cylinder through the spout.
c) A lift pump can lift water to a maximum height of 10m.
Determine the maximum height to which the pump can raise paraffin. (Take density of paraffin as $800kgm^{-3}$ and density of water as $1000kgm^{-3}$).
d) State one factor that determines the height to which a force pump can lift water.
17. Explain why a dam is thicker at its base than at the top.
18. The pressure exerted by the atmosphere on a table is 100,000Pa. What does this mean?
19. On a dining table of area $1m^2$, air pushes down with force of 101,000N (atmospheric pressure = 101,000Pa). Explain why the table does not collapse or break.
20. Explain why the level of mercury in a mercury barometer varies from day to day.
21. If atmospheric pressure is 101,000 N/m^2, what force is exerted on a wall of area $12m^2$?
22. Explain why you can fill a bucket from a downstairs tap quicker than from an upstairs tap
23. Explain why a giraffe must have a stronger large heart compared to a human being.
24. State why a barometer will show a greater reading when taken down a 200m pit.
25. A hydraulic press has the small piston of area $5cm^2$ and a force of 40N is applied to it.
26. (i) Calculate the pressure transmitted throughout the liquid.
(ii) If the larger piston has an area of $20cm^2$, what is the force exerted on it?
27. Explain why a sharp knife cuts well than a blunt one.
28. State Pascal's principle of pressure.
29. Explain why the atmospheric pressure decreases with increasing the height or altitude.
30. Explain why we do not feel the great air pressure around us.
31. Why do deep sea divers wear diving suits?
32. Why are planes pressurized?
33. Explain how a drinking straw operates when in use.
34. Explain how a syringe operates when being used.
35. Describe the working of a hydraulic press
36. Study the diagram below:

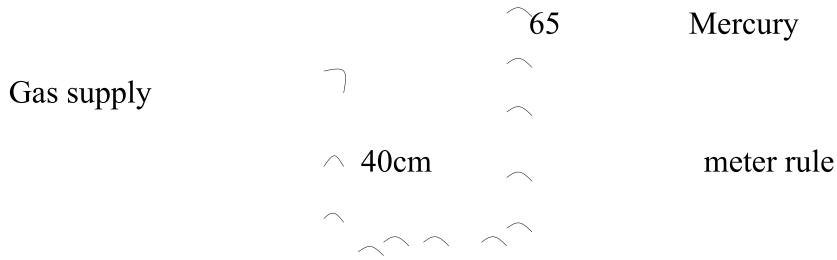


If $\rho_1 = 2000kg/m^3$ and $\rho_2 = 1500kg/m^3$, calculate h_1.

37. Explain why walking on a murrum road in bare feet is more painful than walking on sand.
38. A pressure of 2000Pa acts on an area of $0.05m^2$. What force is produced?
39. At sea level, what is the approximate value of atmospheric pressure in
(a) Pa

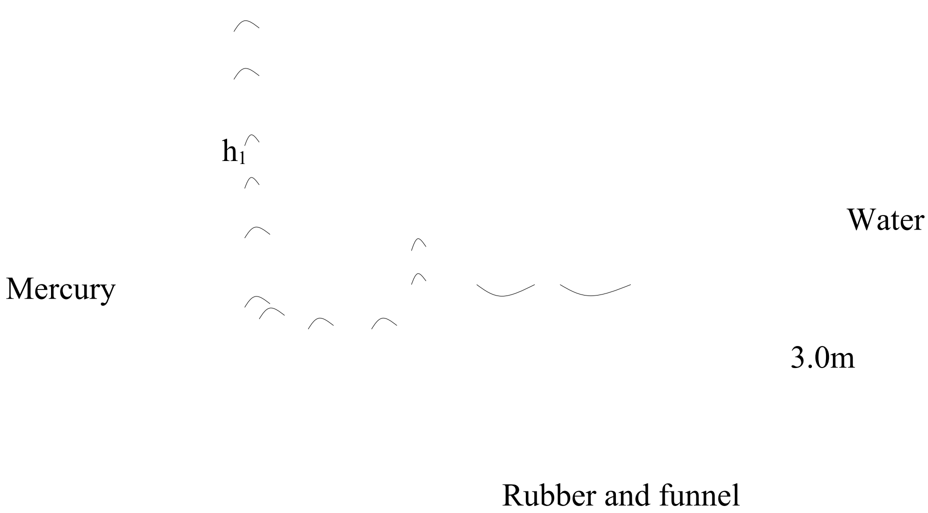
(b) MmHg
(c) Atmospheres

40. Why is mercury used in a barometer rather than water?
41. Study the diagram below:



(a) Record the excess pressure shown by the meter in mmHg
(b) If the atmospheric pressure is 760mmHg, what is the pressure of the gas supply?

42. State one advantage of fitting wide tyres on a vehicle that moves on earth roads.
43. A small nail may piece an inflated car tyre and remain there without pressure reduction in the tyre. Explain this observation.
44. The height of the mercury column in a barometer at a place is 74cm. What would be the height of a column of a water barometer at the same place? (Density of mercury is $13.2 g/cm^3$ and water $1 g/cm^3$.)
45. Explain why it may not be possible to suck a liquid into your mouth using a drinking straw on the moon surface
46. Derive the formula P=h ρ g where P = pressure, h = height or depth, ρ = density of liquid and g = gravity.
47. The figure below shows a manometer connected to a small funnel whose mouth is covered by a rubber membrane. The funnel is dipped into water in a container.

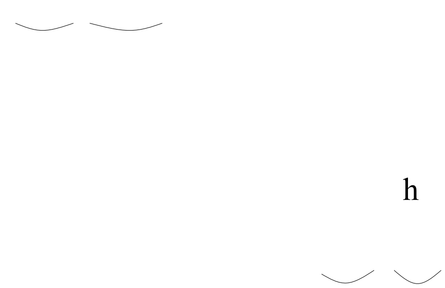


(a) Given that the density of mercury is $13.6 g/cm^3$ and that of water is $1 g/cm^3$, determine the pressure indicated by the manometer.
(b) Determine the height h_1.

48. The diagram below shows a liquid being siphoned from one beaker to another. Use this information to answer the questions that follow:

(a) Indicate on the diagram the direction of flow of the liquid
(b) Show that the force driving the liquid through the pipe is proportional to the height h.

49. State and explain what would happen to the flow in question 2 above if the system in the diagram were put in a vacuum.
50. Give a reason why water is not a suitable liquid for a barometer.
51. A rectangular block measures 10cn x 5cm x 4cm and has a mass of 2.2kg.
52. a) (i) If the gravitational field intensity is 10N/kg, what is the weight of the block?
    (ii) What is the area of the smallest face of the block?
    (iii) What pressure will the block exert when it is resting on a table on its smallest face?
    (iv) What is the least pressure the block exerts on the table?
    (b) Calculate the volume of the block.
    (c) Determine the density of the material from which the block is made.
53. A diving bell is pressurized inside to a pressure of 1,000,000Pa above atmospheric pressure. This diving bell is made for use at 100m below the sea surface for oil exploration. The pressure outside the diving bell must be equal to the pressure inside for its door to open. (Opens from inside.)
    i. Calculate the pressure at 100m depth in water.
    ii. Explain what would happen to the diving bell when the door opens at :
        i. 10m below the surface.
        ii. 200m below the surface.
    iii. When the diving bell is under the sea, how is the pressure on top of it different from that underneath it?
    iv. Explain why the pressure difference in (c) produces buoyancy (upthrust).
54. Study the figure below:



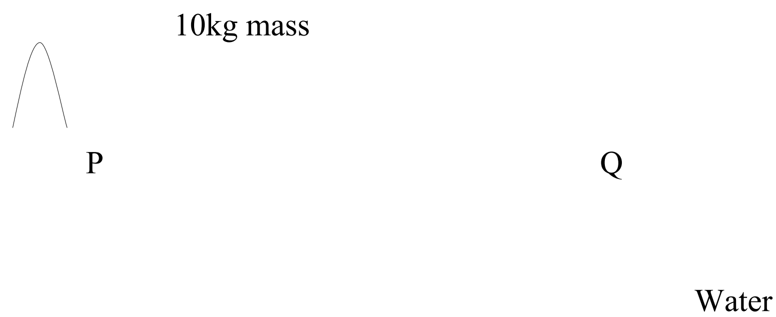
The piston can be pushed in and out but no water can escape. If the larger piston is pushed into the pipe by a force of 200N,

i) Calculate the pressure applied to the water.
ii) Determine the force exerted on the smaller piston.

pipe

Piston area 500cm^2 water piston area120cm^2

55. (a) The figure below shows two cylinders connected by a pipe. in each cylinder there is a piston and the space below each piston is full of water.



The area of piston P is $40cm^2$ and the area of piston Q is $2500cm^2$. A 10kg mass is placed on piston P.

i) Calculate the weight of the 10kg mass.
ii) What is the downward force on piston P.
iii) Determine the pressure on the water
iv) State the pressure on the water at Q.
v) Calculate the upward force on Q.

(b) Kamau suggested that the above device could be used as a car jack.

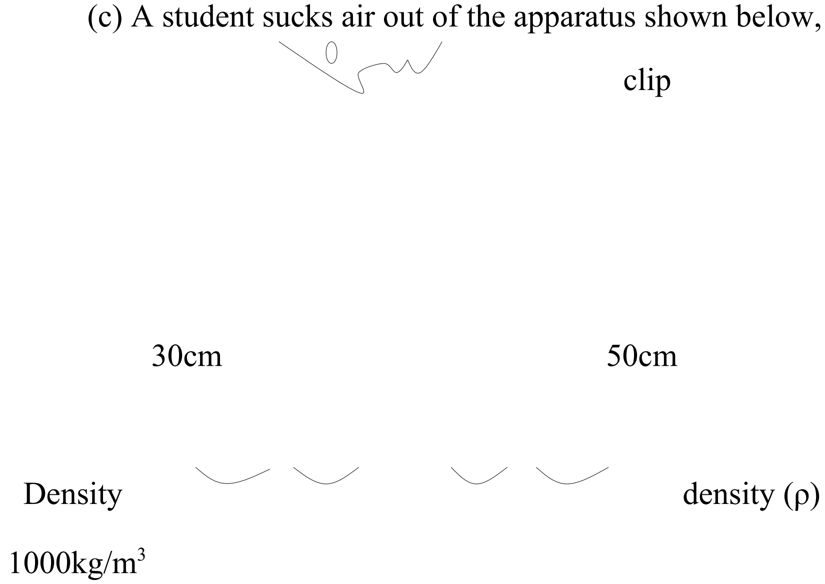
i) Which piston (A, or B) would you use to support the car? Explain your answer.
ii) Name the above device.

56. (a) If a lorry weighs 100,000N and has 4 tyres.

(i) Calculate the force exerted on the road by each tyre
(ii) What assumption have you made in the calculation above
(iii) If each tyre has an area of $0.2m^2$ in contact with the road, calculate the pressure exerted.

(b) Using a diagram, explain how a bicycle pump operates when filling a tyre with air.

(c) A student sucks air out of the apparatus shown below, from the top.



Calculate the density ρ of the other liquid.

57. (a) A car containing six adults and their luggage weighs 20500N. The area of contact of each tyre with the ground is $0.025m^2$.

(i) Calculate the pressure exerted by each tyre on the ground.
(ii) State any two assumptions made.
(iii) The car has to be driven off the road and cross a patch of soft damp sand. The driver thinks that the tyres will sink into the sand and stop the car moving. One of the passengers suggests that the sinking can be prevented by letting some air out of the tyres.
I What effect would this have on the shape of the tyres?
II How would letting air out of the tyres stop the wheels from sinking.
III What other change could be made to stop the tyres sinking into the sand.

(b) The air pressure near the ground is about 101KPa. Some aircrafts fly at height of about 20km where the air pressure is only 27KPa.
i. State two reasons why the outside air pressure is less at 20km than at the ground.
ii. If the air inside the aircraft is 101KPa, what is the difference in air pressure between the inside of the aircraft when fling at a height of 20km?
iii. How does this difference in air pressure influence the choice of material used in the construction of the aircraft.
iv. The door of the aircraft is designed to fit into the door frame from inside the aircraft. Explain why the door is designed to fit in this way.
v. If the fuselage of the aircraft has an area of $4000m^2$, determine the force acting on the fuselage due to the difference in air pressure between the inside and outside of the aircraft at a height of 20km.

58. (a) The diagram below shows a manometer connected to a gas supply.

Gas in

U - Tube

The pressure of the gas supply above atmospheric pressure is equivalent to 20cm column of water.
i) Complete the diagram by marking the position of the levels of the water in the manometer when the gas supply is connected.
ii) If the gas supply had only been partly turned on, what effect, if any, would this have had on the levels of the water in the manometer? Explain your answer.
iii) Calculate the pressure of the gas supply above atmospheric pressure in Pascal's. (ρ_w=$1000kg/m^3$)

(b) The diagram shows water standing to a depth of 20cm in a measuring cylinder. There are $500cm^3$ of water in the measuring cylinder.

Water 20cm

I If the density of water is $1g/cm^3$, calculate the mass and weight of the water in the measuring cylinder

II Using the weight in part (i), calculate the pressure exerted by the water on the bottom of the measuring cylinder.

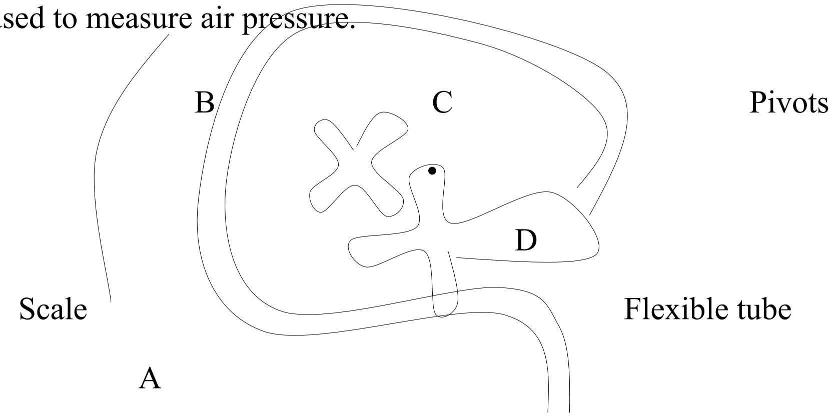
III Mark with a letter P on the diagram above a position where the pressure exerted by the water is a quarter of the pressure calculated in part (ii)

59. a) A newspaper article claimed that a woman wearing shoes with heels which had a small area exerted more pressure on the ground than a n elephant.
    (i) Explain in terms of the area how this is possible.
    (ii) The article claims that the pressure exerted on the ground by a woman weighing 600N wearing shoes with heels each having an area of $0.9cm^2$ was $666.7N/m^2$. What assumption was made about the way the woman was standing? Explain your answer.
    (iii) A typical elephant weighs 30,000N. If each of the elephant feet has an area of $600cm^2$, calculate the pressure exerted by the elephant on the ground.

(b) A water storage tank is 20m above a tap. Given the density of water as $1g/cm^3$,
  i) Calculate the pressure of the water at the tap in N/m^2.
  ii) The area at the end of the tap is $2.0x10^{-4}m^2$; calculate the force needed to stop the water leaving the tap.
  iii) When a shower is directly connected to another water storage tank, it is found that water will only flow when the shower head is lowered and not when it is raised. Why is this so? In which way can this problem be overcome?

60. (a) Describe a laboratory experiment to show that the pressure in a liquid increases with depth.
   (b) The experiment in (a) is repeated with a liquid of lower density. What effect, if any, does this have on the pressure at different depths? Explain your answer.
   (c) How is the fact that pressure increases with depth
   i) Taken into account when constructing the wall of a dam.
   ii) Used in the measurement with a manometer of the excess pressure of the gas supply.

(b) The diagram below shows the inner details of a device called bourdon gauge which can be used to measure air pressure.



Air pressure

As the air pressure increases the flexible tube straightens out. Explain why the pointer moves towards B when the air pressure increases.

61. The graph below shows how the pressure in water changes with depth below the water surface of a creek.

Pressure (kPa)

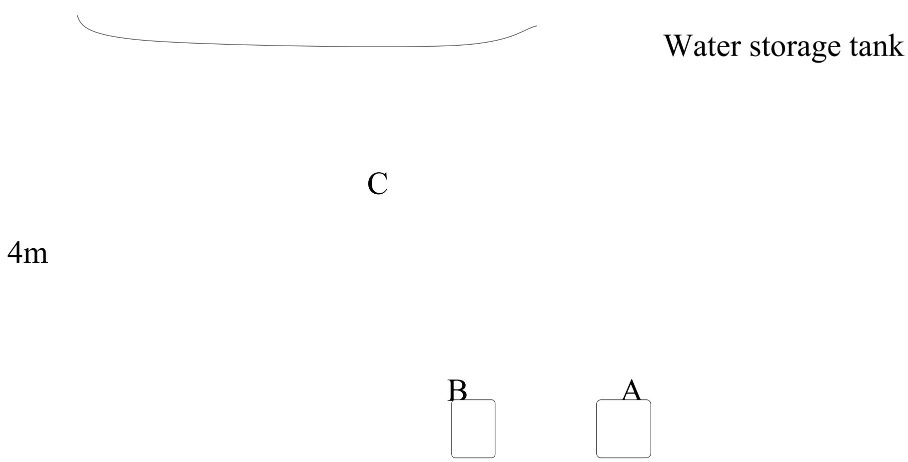
(880, 960)

(0, 100)

Depth (m)

i) Use the graph to find the pressure at a depth of 800m.
ii) Calculate the force exerted by the water on $2.0m^2$ of the outside surface of a submarine at a depth of 800m.
iii) State why the pressure is not zero at the surface of the water.
iv) The part of the submarine containing the crew contains air at normal atmospheric pressure. Explain why the outside walls of this part of the submarine are usually made from very thick steel.
v) Explain why at a depth of 100m the pressure in sea water is different from lake water.

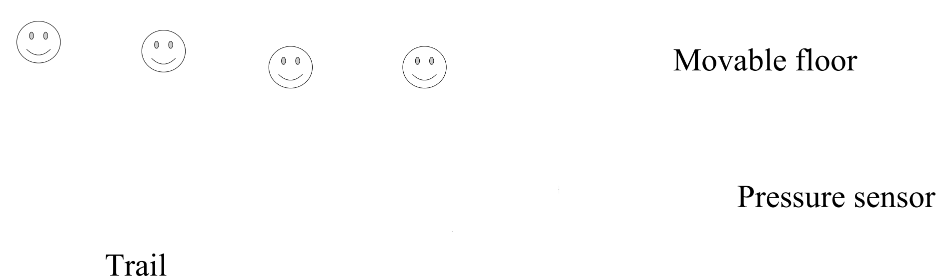
62. The diagram below shows a water storage tank supplying water to a tap at A.



i) If the water level in the tank is 4m above tap at A, calculate the pressure at A due to this water. (density of water = $1000kg/m^3$)
ii) The tap is moved from A to B. Explain why the water pressure at the tap is unchanged.
iii) The diagram is drawn to scale. An object becomes stuck in the pipe at C and the water is unable to flow to the tap. Calculate the pressure at C due to the water and explain your calculation.

iv) If the cross section area of the pipe is $1.2x10^{-3}m^2$, what force is acting on the object at C due to the water above it?

63. A pressure sensor attached to an airbag can be used to determine the weight of passengers in a train carriage. See diagram below.



In a trial using different number of passengers in a carriage the following results were obtained.

Numbers of passengers in a carriage	20	40	60	80	100	120
Pressure in MPa	8.8	11.2	12.2	14.0	15.0	16.8

i) Plot a graph of pressure (y-axis) against the number of passengers in the carriage.

ii) What is the pressure when we have 55 passengers in the carriage?

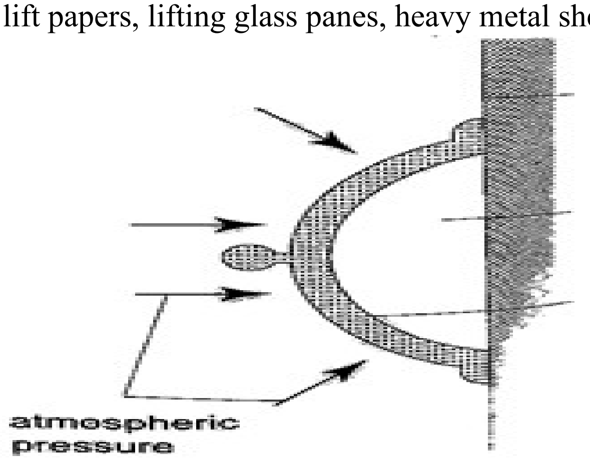
iii) Explain why

a. The graph does not pass through the point (0,0)

b. The points do not lie on a straight line

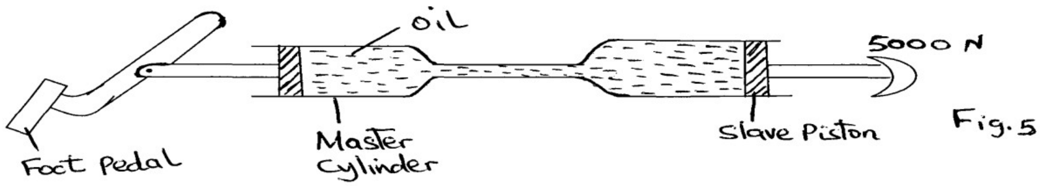
c. Similar readings would have been obtained if the pressure sensor had been placed at the other end of the airbag.

Rubber sucker– this is a shallow rubber cap. Before use it is moistened to get a good seal then pressed firmly on a smooth surface so that the air inside is pushed out. The atmospheric pressure will then hold it firmly against the surface as shown below. They are used by printing machines to lift papers, lifting glass panes, heavy metal sheets

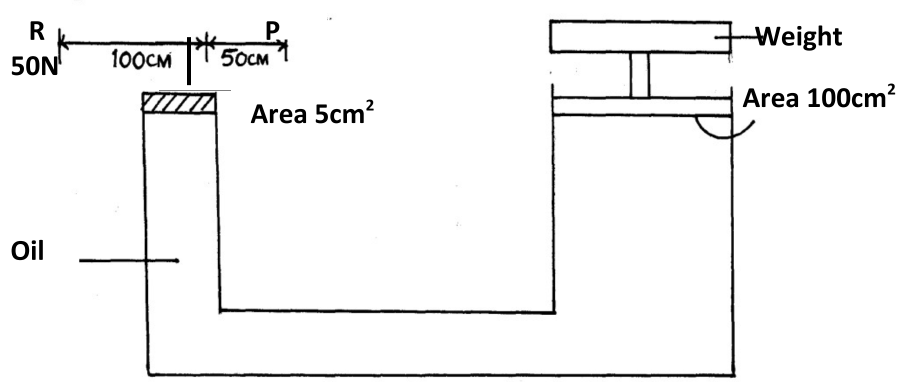


-Drinking straw– when a liquid is drawn using a straw air is sucked through the straw to the lungs. This leaves the space in the straw partially evacuated. The atmospheric pressure pushing down the liquid in the container becomes greater than the pressure inside the straw and this forces the liquid into your mouth.
-The syringe– they work in the principle as the straw. They are used by the doctors in hospitals for giving injections.

64. State **two** reasons why mercury is preferred as a barometric liquid and not water
65. The diagram in figure 5 below shows hydraulic brake system.



A force of 20N is applied on the foot pedal to a piston of area $50cm^2$ and this causes a stopping force of 5000N.
Determine;
(i) Pressure in the master cylinder.
(ii) Area of the slave piston.
66. The height of mercury column in a barometer density 13600kg/ m^{-3}, at a place is 64cm. What would be the height of a column of paraffin in barometer at the same place? (Density of paraffin = 8.0×10^2 kg /m^3).
67. The figure 3 shows hydraulic press system using a lever of negligible mass, on the ride of the small piston pivoted at a point P. A force of 50N is applied at R.



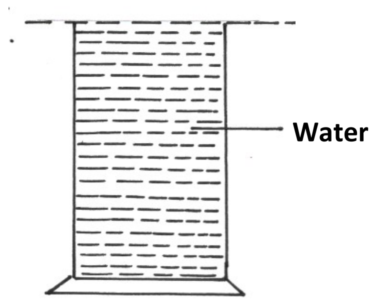
Calculate

(i) Force exerted by small piston on the liquid.

(ii) Pressure of liquid below the small piston.
(iii) The weight of object supported on the larger piston

68. Water tanks in houses are erected as high as possible. Explain.
- Water will flow at high pressure√[1]
Or- for water to have high potential energy √

69. The figure below is a gas jar completely filled with water and covered with a wire gauze.



a) State the observation when the set-up is suddenly inverted.
b) Explain the observation made in (a) above.

TOPIC 5: PARTICULATE NATURE OF MATTER

Matter is anything that occupies space and has mass. Matter commonly exists in three states i.e. solid, liquid and Gas
The process of sub-dividing matter into smaller units and smaller units continues indefinitely, suggesting that matter is not continuous, but is made up of even smaller parts e.g. A piece of paper can be cut endlessly until a stage when the small pieces cannot be cut into pieces. This suggests that the sheet of paper is made up of tiny particles

DEMONSTRATION OF DILUTION

APPARATUS: Beaker and potassium permanganate crystals
PROCEDURE
- Pour water into the beaker to half full.
- Dissolve the potassium permanganate crystals until the solution is purple.
- Transfer half of the solution to another beaker and add water
- Continue the process with other beakers, comparing the colour to each other.

OBSERVATION

The process of dilution can continue until the solution appears colourless. This suggests that the particles of potassium permanganate are spread evenly on water.
As water particles increase, the particles of potassium permanganate are spread further, making the purple colourless and less until it appears colourless.

CONCLUSION
Potassium permanganate is made up of tiny particles.

DISSOLVING A SOLID IN A SOLVENT

- ✓ 100g of salt is put into the flask and water added carefully using a pipette without shaking the salt until it is full.
- ✓ The stopper is then inserted to the mouth of the flask and shaken to dissolve the salt.

OBSERVATION
The volume of the solution of salt is less.
CONCLUSION
Particles of salt are able to occupy some spaces between the water particles.
This suggests that the particles of salt differ in size.
The particles of the solution pack more closely in the available space, thus reducing the volume.
This further suggests that particles of salt are broken down to fit into spaces between water particles.

BROWNIAN MOTION

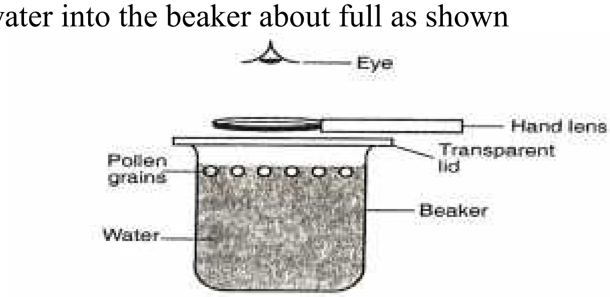
This is the random movement of particles of a substance in fluids. A fluid is anything that is capable of flowing, e.g. a gas or a liquid.
The particles in a fluid are in a constant random motion.

BROWNIAN MOTION IN LIQUIDS

DEMONSTRATION OF THE BROWNIAN MOTION

Apparatus: Beaker, hand lens, chalk dust, transparent lid.
PROCEDURE

- ➢ Pour water into the beaker about full as shown



- ➢ Sprinkle pollen grains or chalk dust on the surface of water (particles should be small in size, light and sprinkled evenly).
- ➢ Cover the beaker with a transparent lid and with the help of a hand lens observes what happens to pollen grains or chalk dust.

OBSERVATION

The pollen grains or chalk dust is in constant random motion.

CONCLUSION

The particles are hit continually by the movement of small invisible particles of water. The movement is random, suggesting that the particles of water are in constant random movement. This kind of movement is called **Brownian motion** a tribute to a scientist **Robert Brown** who first observed the effect.

BROWNIAN MOTION IN GASES

THE SMOKE CELL EXPERIMENT

DEMONSTRATION OF THE BROWNIAN MOTION IN AIR

Apparatus: Drinking straw, smoke cell, microscope and a bright light source

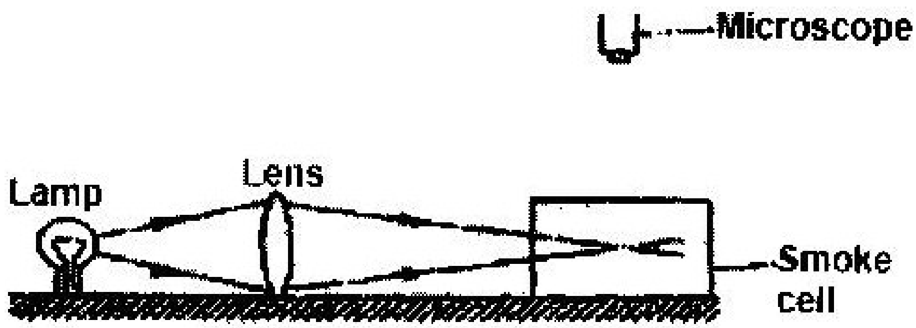


Figure 9

In this case, one end of the straw is burnt and let the smoke from the other end of the straw into the smoke cell as shown above. The smoke is then covered using a transparent glass lid. The smoke cell is covered to seal the content of the smoke cell. This ensures that the smoke molecules do not escape from the smoke cell. The lid is transparent to allow for easy visible of the smoke cell. The cell is illuminate with bright light. Therefore, the work of lamp in this case is to provide light which illuminates the content of the smoke cell. A hand lens is used to focus the light on the smoke particles in the smoke cell. The microscope is adjusted until bright specks are seen against the grey background. The work of the microscope is therefore to enlarge/magnify the smoke particles in the smoke cell for easy visibility.

OBSERVATION

In this experiment, the smoke particles (which are seen as bright specks) are seen moving in continuous random motion.

EXPLANATION

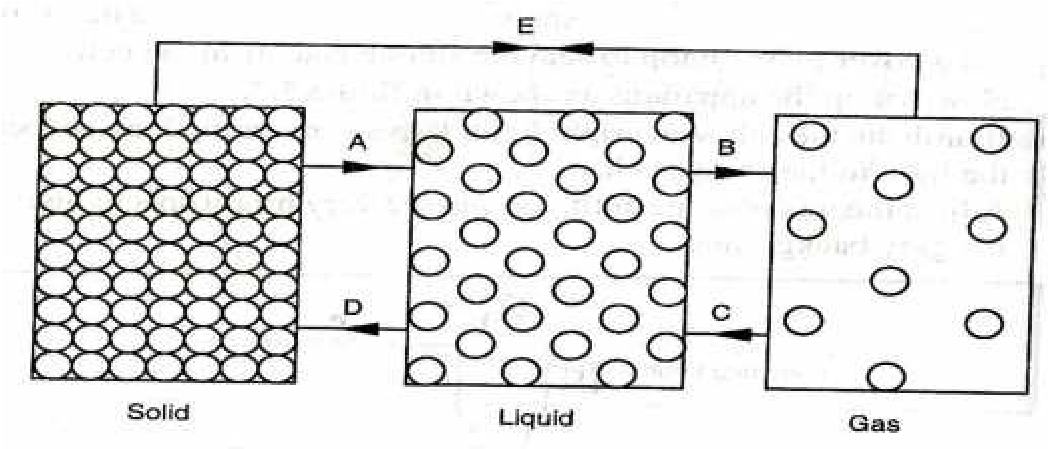
The smoke particles appear as bright specks since they scatter the light shining on them and appear as bright points. They move about in a continuous random movement because of uneven bombardment by the invisible particles or molecules in air. This suggests that air is made up of small particles which are in constant motion.

When this experiment is repeated at a higher temperature, the smoke particles move faster in a continuous random manner. This is due to increased kinetic energies of the molecules. The opposite is true when the temperature of the content is reduced.

CONCLUSION

From the experiments above, matter is made up of very small particles which are in constant random motion. This is called **kinetic theory of matter.**

ARRANGEMENT OF PARTICLES IN THE STATES OF MATTER



a. SOLID

- The particles of solids are closely packed together in an organised way.
- The closely knit structure is due strong attractive forces (cohesive forces) between the particles.
- In their fixed positions, they vibrate to and from so that increasing the temperature of the solid increases this vibratory motion.
- At a certain temperature the solid breaks away from this knit structure and the solid is said to have melted.

b. LIQUIDS

- The particles are further apart. They are not fixed as in solids but move about in Brownian motion.
- Liquids can break a solute put in it. It's easier to dissolve a solute in hot water because the particles have increased energy.
- The cohesive forces between the particles in liquids are weaker compared to those in solids. Due to this liquids can flow and take up the shape of the container in which they are put.
- When a liquid is heated molecules gain kinetic energy, they vibrate about and expand. The space between them widens further apart and the liquid changes into gaseous state by a process called **vaporization.**

c. GASES

- The particles are further apart and have increased random motion compared to those in the liquid state.
- The cohesive force between the particles is extremely small and as the particles move they collide with each other and with the walls of the container in which they are trapped. This produces gas pressure.

- Gases are easier to compress indicates that there exists a large intermolecular distance in gas than in liquids. Gas molecules or particles can lose some of their energy and fall back into the liquid state by a process known as **condensation.**

NOTE: Solids which when heated change directly into gas undergo the process called **sublimation.**

DIFFUSION

• This is the process by which particles spread from regions of high concentration to those of low concentration. Diffusion takes place in solids, liquids and gases.

• In solids, diffusion is exceedingly slow but occurs when two metals are placed in contact with each other e.g. lead and gold, metal block vibrating atoms breaks away from the substances to which they belong and enter the other substance to be trapped by its attractive forces. This process is speeded up by high temperature.

• Diffusion in liquids occurs at a faster rate than in solids.

• Diffusion in gases is faster due to their low density, high kinetic energy and weak cohesive forces.

DIFFUSION IN LIQUIDS

To investigate diffusion in liquids

Apparatus: Funnel, beaker, copper (II) sulphate solution.

PROCEDURE

- Pour water into the beaker until it is half full.
- Pour saturated copper (II) sulphate solution down the funnel slowly and notice how the two liquids settle.
- Remove the funnel carefully so that the liquids are not disturbed.
- Repeat the same steps for another set of apparatus but using warm liquids. Make observation.

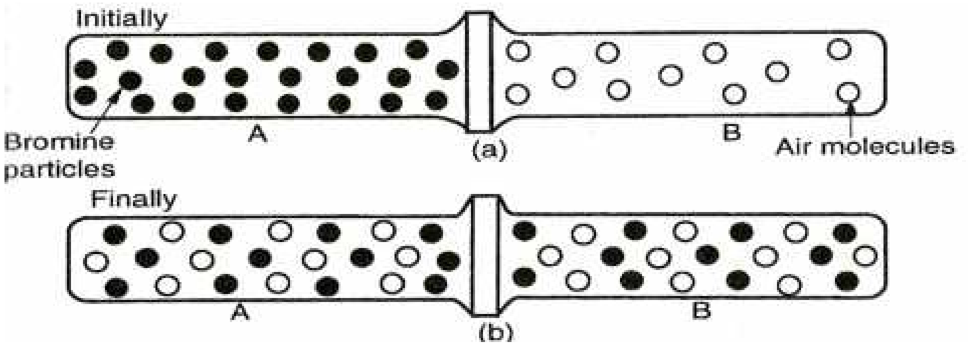
OBSERVATION AND EXPLANATION

• Initially, the water layer floats on top of the saturated copper (II) sulphate because it is less dense. After sometime, the boundary disappears and the liquids form a homogeneous pale blue mixture.

• Formation of the mixture is faster with hot liquids than because the movement of particles is faster due to increased energy. There is greater movement of water particles (molecules) from the water layer into copper (II) sulphate layer because it has greater concentration of water molecules than copper (II) sulphate particles.

• Similarly, there is a greater movement of particles from copper (II) sulphate layer into the water layer because of greater concentration of copper (II) sulphate particles than water molecules.

DIFFUSION IN GASES



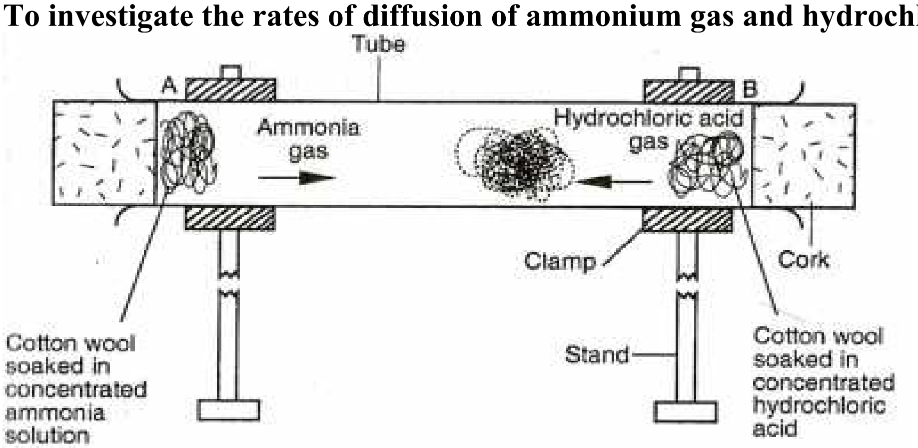
OBSERVATION AND EXPLANATION

- The bromine gas spreads into the gas jar B at a greater speed than it returns to gas jar A because of high concentration of bromine particles.
- Likewise, air spreads in gas jar A at a greater rate than it returns to gas jar B because of high concentration of air particles in B.
- A homogenous pale brown mixture forms in the two jars and because this happens in a very short time, it suggests that the random movement of particles is rapid (faster) than diffusion in liquids.

NOTE: Performing the same experiment with the jars held vertically instead of horizontally slows down the rate of diffusion because of the densities of the gases. The less dense gas diffuses much faster into the more dense gas.

RATES OF DIFFUSION

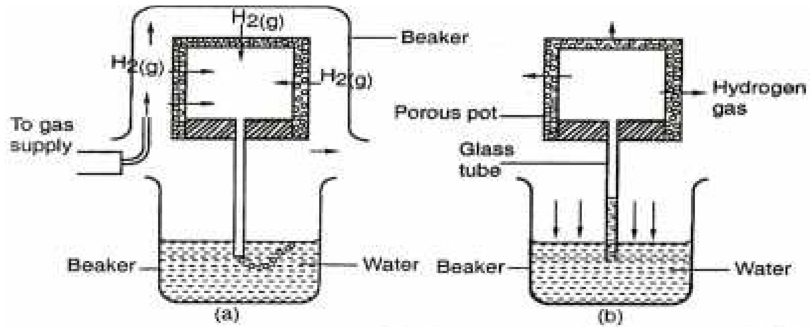
To investigate the rates of diffusion of ammonium gas and hydrochloric gas



OBSERVATION AND EXPLANATION

- **A** white deposit of ammonium chloride forms on the walls of the glass tube in the region nearer end B. This suggests that ammonia gas diffused at a higher rate than hydraulic acid gas.
- Different gases have different rates of diffusion. A gas of high density has heavier particles hence moves more slowly than lighter one.

DIFFUSION THROUGH POROUS MATERIALS



• The porous pot has very fine holes through which the hydrogen gas diffuses into the pot and air diffuses out.
• Hydrogen gas bubbles out of the glass tube as shown in the set up above.
• When the gas supply is stopped hydrogen gas diffuses out of the pot through the fine holes at a faster rate than air gets back to the pot. This decreases the gas pressure acting on the water surface in the beaker to push water up the tube.
NOTE: The beaker is used to confine the hydrogen gas around the porous pot.

QUESTIONS

1. Explain why rotten eggs broken at one end soon spreads the room.
2. Explain the cause of random motion of smoke particles as observed in Brownian motion experiment using a smoke cell.
3. Two identical tubes A and B held horizontally contain air and water respectively. A small quantity of coloured gas is introduced at one end of A while a small quantity of coloured water is introduced at one end of B. State with reason the tube in which the colour will reach the other end faster.
4. Distinguish between solid and liquid states of matter in terms of intermolecular forces
5. A bottle containing a smelling gas is opened at the front bench of a classroom. State the reason why the gas is detected throughout the room.
6. Motion of smoke particles can be studied by using the apparatus shown in figure 9 to observe the motion; some smoke is enclosed in the smoke cell and then observed through the microscope.

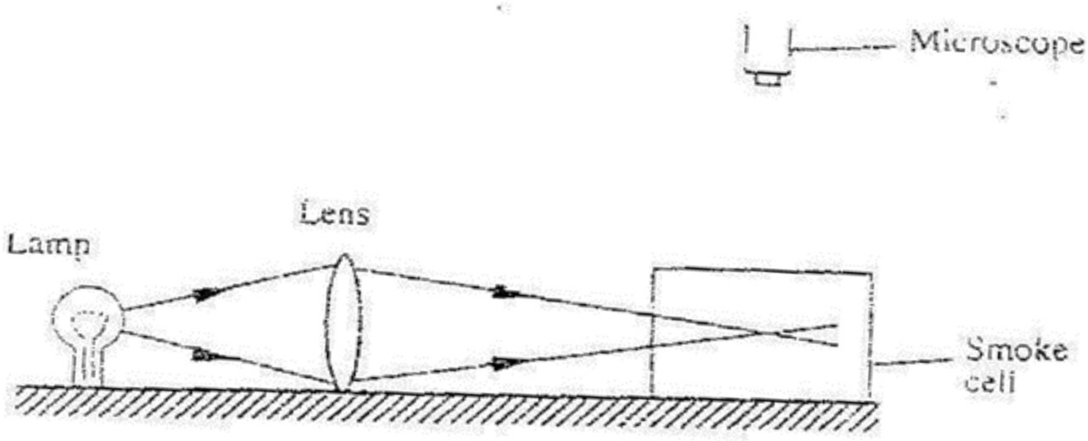


Figure 9

(a) Explain the role of the smoke particle, lens and microscope in the experiment
(b) State and explain the nature of the observed motion of the smoke particles
(c) State what will be observed about the motion of the smoke particles if the temperature surrounding the smoke cell is raised slightly.

SOLUTIONS

(a) The spreading is due to diffusion. The odour moves from a region of higher concentration to a region of lower concentration through diffusion.
(b) Air molecules are in constant random motion; smoke particles collide with these air molecules hence their random motion.
(c) A or tube with air; Gas molecules move faster/quicker than water molecules OR Diffusion of gases is Faster/more than in water/Grahams law the density of air is less than that of water
(d) In solids the molecules are held in position by intermolecular forces that are very large. In liquids the molecules are able to roll over one another since the forces are smaller
(e) The gas diffuse/ from the region of higher concentration to a region of low concentration.
(f) (a) Smoke particles show the behavior or movement of air molecule
Smoke particles are larger than air molecules/ visible and light enough to move when bombarded by air molecules; Lens Focuses the light from the lamp on the smoke particle; causing them to be observable; Microscope enlarge the smoke particles that they are visible/ magnifies smoke particles.
(b) Smoke particle move randomly / zigzag / haphazardly Air molecules bombard the smoke particles/ knock/ hit Air molecules are in random motion
(c)The speed of motion of smoke particles will be observed to be higher smocking particles move faster, speed increases, increased random motion

MORE QUESTIONS

1. Describe the motion solid molecules experience.
2. What type of motion do molecules in the liquid and gaseous state experience
3. Describe Brownian motion.

4. When food is being cooked in the kitchen, why is it possible to smell this food in other rooms in the house?
5. State the forms of energy possessed by particles in (a) solids (b) liquids (c) gases.
6. State the type of motions described by a molecule in (a) solid (b) liquid (c) gas.
7. What do you see when you use a microscope to study illuminated smoke floating in air?
8. Describe the main difference between molecules in the gaseous state and those in the liquid or solid state.
9. Describe and explain Brownian motion.
10. Explain why perfume can be smelt some distance away from the person wearing it.
11. A house in which a cylinder containing cooking gas is kept unfortunately catches fire. The cylinder explodes. Explain why.
12. Two identical containers A and B are placed on a bench. Container A is filled with oxygen gas and container B with hydrogen gas. The two gases have equal masses. The containers are maintained at the same temperature. State with reason the container in which the pressure is higher.
13. (a) A substance has molecules which are moving completely free and random manner.
    i) Is the substance a solid, liquid or gas?
    ii) Draw below a diagram to show the path followed by one of these molecules when it is moving randomly.
    iii) How can the speed of such a molecule be reduced?
    iv) What name is given to the temperature at which all molecular motion ceases?

    (b) The behavior of substances as they change from solid state to the liquid state can be described using kinetic theory of matter. This assumes that matter is made of small moving particles or molecules.
    i. What is the typical diameter of one of these molecules?
    ii. In the spaces in the table below describe the difference in solids and liquids.

	Solids	Liquids
Type of motion of molecules		
Position of molecules		
Spacing of molecules		

1. (a) A substance has molecules which are in a close packed regular arrangement undergoing vibrations about fixed positions.
    i) Is the substance a solid, liquid or a gas?
    ii) What is meant by `undergoing vibrations about fixed positions'?
    iii) How can the size of these vibrations be increased?
    iv) State the name given to the temperature at which the arrangement ceases to be close packed and regular.

    (b) Describe a laboratory experiment using a syringe which shows that molecules of water are closely packed. How can this closely packed arrangement are completely destroyed.

    (c) Matter exists in three states, solid, liquid, and gas. Complete the following table by writing in the state best described by each molecular property.

Molecular Property	**State**
1. Close packed	
2.Spacing very large	

3. Moving independently	
4. Very strong forces of attraction	
5. Vibrating about a fixed point	

2. A small amount of air is trapped in an open glass capillary tube by a pellet of mercury as shown below.

Glass capillary tube
Mercury pellet

Trapped air

i) Describe the spacing and motion of the molecules in the liquid mercury and then the trapped air.
ii) How does the pressure of the trapped air compare with that of the air outside the tube?
iii) What difference, if any, are there in the speed and spacing of the trapped air molecules compared with those of the outside air (Temperature of both samples of air is the same.)

2. (a) The diagram below shows an apparatus which may be used for observing Brownian motion

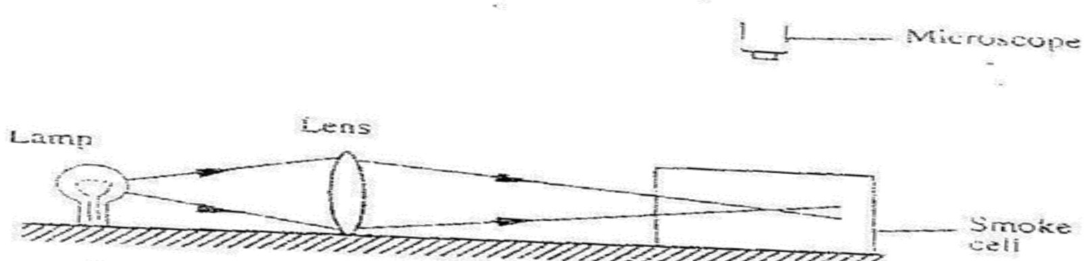


Figure 9

i) When the apparatus was being used, points of light were observed moving about in a random manner.
   a. What are these points of light?
   b. Why are they moving randomly?
   c. Name two ways by which this random motion could be made less vigorous.

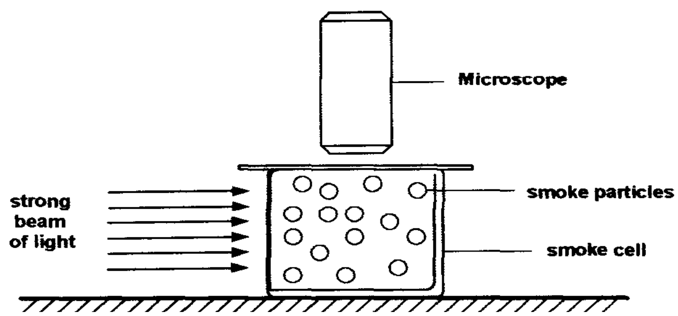
(b) A sealed packet of crisps bought in a shop at sea level was found to appear like a balloon when taken to the top of a mountain.

(i) Why did the packet appear to be inflated in this way?
(ii) Assuming there was no difference in temperature between sea level and the top of the mountain, what were the similarities and differences in motion of the air molecules inside the packet at sea level and on the top of the mountain.

3. (a) Some smoke is trapped in a small glass cell containing air and is brightly lit. When the mixture is viewed through a microscope, small bright specks which dance about in a random fashion can be seen.
   i) What are small bright specks?
   ii) Explain what makes them dance in a random fashion.
   iii) Complete the diagram below by adding lines to show the movement of the small speck shown.

• Bright speck

4. State three assumptions of the kinetic theory of gases.
5. Figure below shows apparatus used to observe the behaviour of smoke particles in a smoke cell.



   a) Explain what was observed
   b) Explain what happens if the temperature was raised.
6. State why diffusion is faster in gases than in liquids.

TOPIC 6: THERMAL EXPANSION

TEMPERATURE

This is the degree of hotness or coldness of a body. Temperature of a body is measured by an instrument called **a thermometer.**

Temperature is a basic physical quantity and is measured in degrees celcious (^{0}C) or Kelvin (K). The S.I unit of temperature is Kelvin (K) which is a scalar quantity.

MEASURING TEMPERATURE

A thermometer is an instrument used for measuring temperature. There are various types of thermometers in use. A thermometer is designed according to the purpose for which it is required. The following are some of the commonly used thermometers:

a) Liquid-in-glass thermometer.
b) Clinical thermometer
c) Six's maximum and minimum thermometer

(a) LIQUID-IN-GLASS THERMOMETER

A liquid-in-glass thermometer commonly in use is **mercury or coloured alcohol** as the thermometric substance.

The volume of the liquid changes uniformly with the change in temperature

The characteristics of the liquid in the bulb include;

i) Be easily seen (visible).
ii) Expand or contract uniformly and by a large amount over a small range of temperature.
iii) Not stick to the inside of the tube. (Should not wet the inside of the tube)
iv) Have a wide range of temperature.

THERMOMETRIC LIQUIDS

The most common in use is mercury and alcohol.

Mercury freezes at -39°C and boils at 357°C while alcohol freezes at -115°C and boils at 78°C. Alcohol is therefore suitable for measuring temperatures below - 39°C.

PROPERTIES OF THE TWO THERMOMETRIC LIQUIDS

ALCOHOL	MERCURY
- Low boiling point, 78oC	- High boiling point, 357oC
- Low melting point, -115oC	- Relatively higher melting point, -39oC
- Poor thermal conductor	- Good thermal conductor
- Expansion slightly irregular	- Expands regularly
- Wets glass	- Does not wet glass
- Coloured to make it visible	- Opaque and silvery

NB

Water is not used as a thermometric liquid because it undergoes anomalous expansion.

TEMPERATURE SCALE

The scale of a thermometer is obtained by selecting two temperatures called fixed points; the lower fixed point and the upper fixed point. The lower fixed point is the temperature of pure melting ice. It is taken to be 0^0C. The upper fixed point is the temperature of steam above pure boiling water at normal atmospheric pressure. It is taken to be 100^0C. The temperature of steam is used since impurities do not affect its temperature but will raise the boiling point of water. The temperature of boiling water itself is not used because any impurities in water would raise its boiling point. The temperature of steam is not affected by impurities in water.
The range between these two points is then divided into equal divisions. Each division is called **degree.**

FEATURES OF A COMMON THERMOMETER

The basic features of a common laboratory are as shown below.

- **Bulb-** Carries the liquid in the thermometer. It has a thin glass wall for effective heat transmission between the liquid and body whose temperature is taken.
- **Capillary bore –** Liquid expands and contracts along the capillary tube. It is narrow for high degree of accuracy.
- **Glass stem –** this is a thick wall surrounding the capillary bore. It also serves as a magnifying glass for easy reading of scale.

CELCIOUS AND KELVIN SCALE

They are the commonly used temperature scale. The celcious scale has the fixed points at 0ºC and 100ºC. In Kelvin scale, the temperature of pure melting ice is 273K while that of pure boiling water at normal atmospheric pressure is 373K.
The lowest temperature in the Kelvin scale (0K) is referred as **absolute zero.**
This is the temperature at which the energy of the particles in material is zero.

To change ºC to Kelvin

T = (ϴ – 273) K where ϴ is the temperature in ºC

EXAMPLE 1

Convert 25ºC in Kelvin

SOLN

T = (25 + 273)

= 298 K

To change Kelvin to ºC

ϴ = (T- 273) ^{0}C where T is the temperature in Kelvin

EXAMPLE 2

Convert 1 K

SOLN

ϴ = **1-273**

= **-272ºC**

ASSIGNMENT

1. Convert the following into Kelvin:

a) 35^0C b) -111^0C c) $-273\ ^0C$

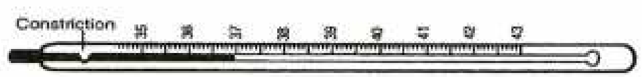
2. Convert the following into ^0C:

a) 123 K b) 323 K

NOTE: Temperature in Kelvin scale cannot have a negative value because the absolute zero, (0K), is the lowest temperature attainable.

(b) CLINICAL THERMOMETER

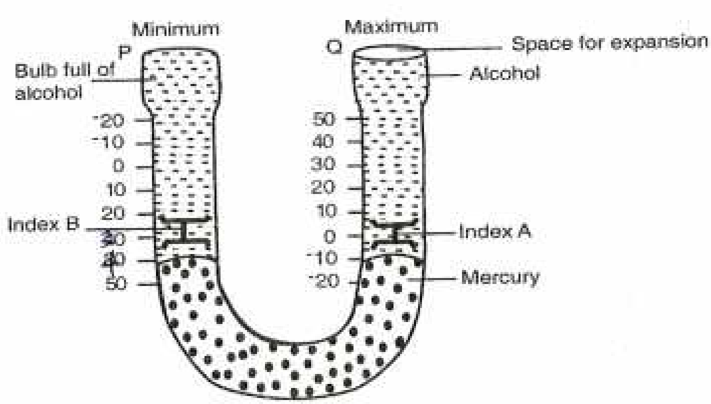
A clinical thermometer is an instrument used to measure the temperature of a human body. It uses mercury as its thermometric substance and has a narrow constriction in the tube just above the bulb.
The diagram below shows the main features of a clinical thermometer.



The **constriction** prevents the mercury level from falling down when it contacts with the human body.
The clinical thermometer has a short scale of temperature from 35°C to 43°C spread over its entire level. This is because the human body temperature falls slightly above or below 37°C which is the temperature of a normal and healthy person. Methylated spirit is used to sterilize the clinical thermometer. Boiling water is not used because its temperature is quite far away from the maximum temperature of the clinical thermometer. This can destroy the thermometer. The thermometer can be reset by a simple flick.

(c) SIX'S MAXIMUM AND MINIMUM THERMOMETER

This thermometer is used to record the maximum and minimum temperature of a place during a day. The thermometer consists of a U-tube connected to two bulbs. The U-tube contains mercury. The two bulbs contain alcohol.
The figure below shows the main features of a six's maximum and minimum thermometer.



Working of the Thermometer

When temperature raises alcohol occupying volume of bulb A expand and forces mercury in the U-tube to rise on the right hand side.
The mercury in turn pushes the steel index A upwards. The maximum temperature can be noted from the lower end of the steel index A.
On the other hand when the temperature falls, alcohol in the bulb A contracts and the mercury is pulled back rising u the left hand side of the U-tube. The index B is then pushed up. During contraction of the alcohol, index A is left behind (in the alcohol) by the falling mercury.
The minimum temperature is then read from the lower end of index B.
NOTE: To reset the thermometer, a magnet is used to return the steel indices to the mercury surfaces.

(d) THE BIMETALLIC THERMOMETER

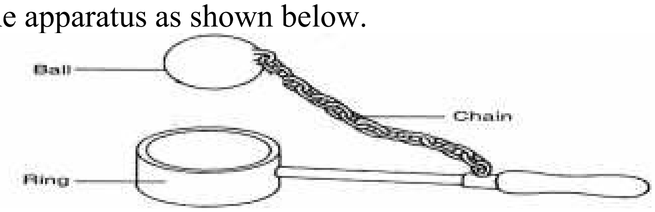
It is made up of a coiled bimetallic strip whose one end is fixed and the other end connected to a pointer. Commonly used metals are brass and invar. When the temperature rises brass expands more than invar. The strip thus curls forcing the pointer to move over a calibrated scale.

THERMAL EXPANSION AND CONTRACTION OF SOLIDS, LIQUIDS AND GASES

All substances increase in size when heated. This increase in size of a substance is called **expansion.** On the other hand when a substance is cooled it decreases in size. This decrease in size is called **contraction.**

EXPANSION IN SOLIDS

Thermal expansion and contraction in solids can be demonstrated using a ball and ring experiment. Set the apparatus as shown below.



NOTE: The ball should pass through the ring when both are at room temperature
- Heat the ball and try to pass it through the ring. Observe what happens.
- Leave it for sometime

OBSERVATION
- When both the ball and the ring are at the same room temperature**,** the ball just passes through the ring.
- When the ball is heated; it does not go through the ring but when left there for sometime, it goes through.

EXPLANATION
- When heated, the ball **expands** so that it cannot go through the ring.

When left on the ring for some time, the temperature of the ball decreases and it **contracts.**
- At the same time, the temperature of the ring increases and it expands so that the ball goes through.

WHY SOLIDS EXPANDS ON HEATING

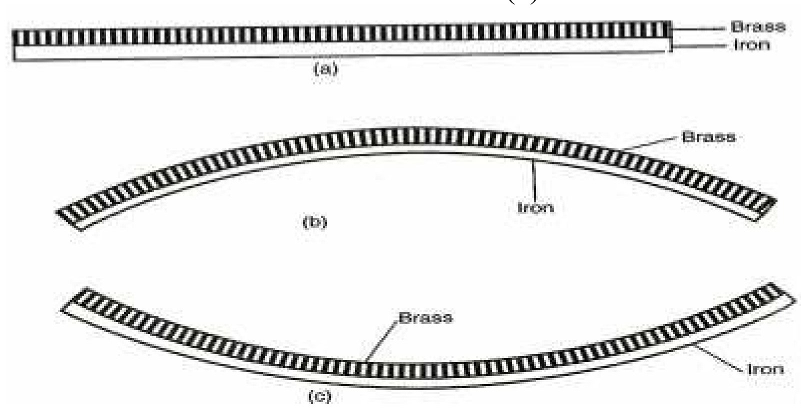
The molecules of a solid are closely packed together and are continuously vibrating in their fixed positions When a solid is heated the molecules gain more kinetic energy and therefore make larger vibrations about their fixed positions. This increase in vibration means that the molecules collide with each other with larger forces and the molecules increases and so the solid expand.

LINEAR EXPANSIVITY

The measure of the tendency of a particular material to expand is called its **expansivity** e.g. aluminium expands more than iron thus aluminium has higher expansivity than iron.
The knowledge of linear expansivity values is applied in the designing of materials to ensure that they are able to operate well under varying thermal conditions.
Ordinary glass expands at a higher rate than Pyrex glass. When hot water is poured into a tumbler made of glass it breaks but does break in Pyrex glass.
Concrete and steel are reinforced together because they are of the same linear expansivity. Hence cannot crack under varying thermal conditions.

THE BIMETALLIC STRIP

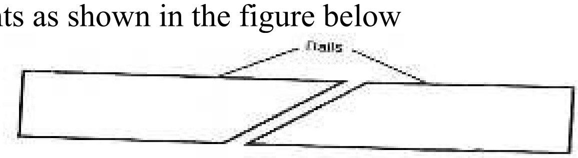
When two metals of different linear expansivity are riveted together they form a bimetallic strip. Brass and iron are used to make the bimetallic strip.
On heating the bimetallic strip, brass expands more than iron. The brass thus becomes longer than the iron for the same temperature range. Hence, the bimetallic strip bends with brass on the outside of the curve as shown in (b) below
On cooling, the brass contracts more than iron. It therefore becomes shorter than the iron and thus ends up being on the inner side of the curve as shown in (c) above



APPLICATIONS OF EXPANSION AND CONTRACTION IN SOLIDS

(a) RAILWAY LINES

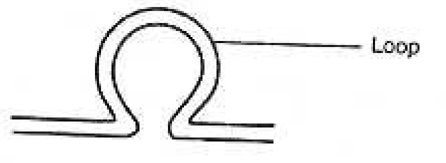
Gaps are left between the rails. Expansion for the rail is provided by overlapping the plane ends using overlapping joints as shown in the figure below



If these gaps for the expansion are not provided then during hot weather, they rails may buckle out, bend and cause derailment of the train leading to destruction and accidents.

(b) STEAM PIPES

Pipes carrying steam from boilers are fitted with loops or expansion joints to allow pipes to expand and contract easily when steam passes through and when it cools down.

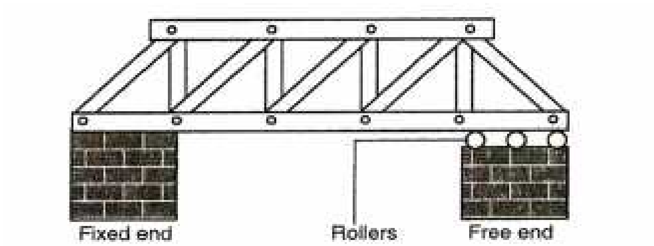


(c) TELEPHONE WIRES

They are loosely fixed to allow for contraction and expansion. During cold weather, they contract and when it is warm they expand.
Telephone or electricity wires appear to be shorter and taut in the morning.
However in hot afternoons, the wires appear longer and slackened.

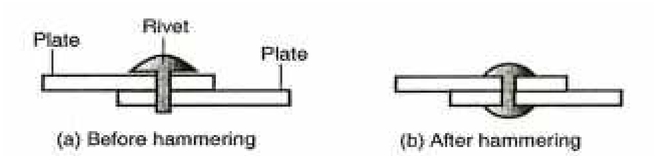
(d) STEEL BRIDGES

In bridges made of steel girders, one end is fixed and the other end placed on rollers to allow for expansion as shown



(e) RIVETS

Thick metal plates, sheets and girders in ships are joined together by means of rivets.
The rivet is fitted when hot and then hammered flat. On cooling, it contracts, pulling the two firmly together as shown

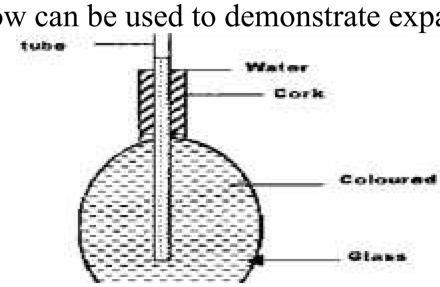


(f) ELECTRIC THERMOSTAT

A thermostat is used to maintain a steady temperature in some devices such as electric iron box, refrigerators, fire alarm and flashing unit for indicator lamp in motor cars.

EXPANSION AND CONTRACTION IN LIQUIDS

The experimental set up below can be used to demonstrate expansion of a liquid.



A glass flask is filled with coloured water and heated as shown above

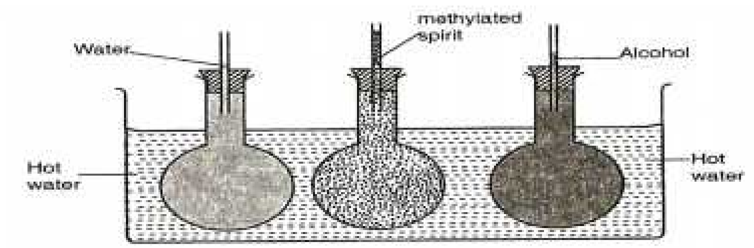
OBSERVATION

Immediately the level of coloured water on the tube drops slightly at first and then starts rising.

EXPLANATION

The initial fall of the level of the water is due to the expansion of the glass flask which gets heated first. The water starts expanding when heat finally reaches it and it rises up the tube.
NOTE: The water expands faster than the glass.
QUESTION
Explain why there is a drop in the level of the water initially followed by a steady rise in the level of water.

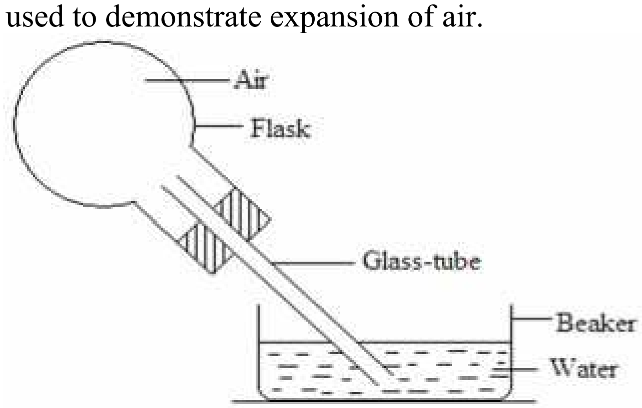
Different liquids expand more than others for a given temperature as shown in the diagram



In this case, methylated spirit expands most, followed by alcohol and finally water.

EXPANSION IN GASES

The experiment below can be used to demonstrate expansion of air.

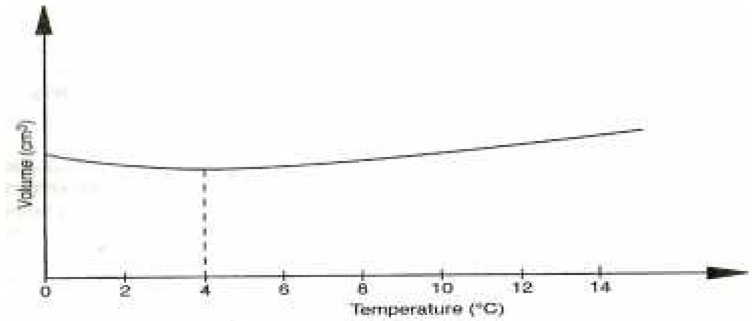


Invert the flask with glass tube dipped into the water as shown.
Warm the flask with your hands for some time and note what happens.
Remove your hand and let the flask cool while the tube is still inserted in water.

OBSERVATION AND EXPLANATION
When the flask is warmed the level of water column inside the glass tube drops indicating air expands. When the flask is warmed further, some bubbles are seen at the end of the glass tube. On cooling the air inside the flask contracts and water rises up the glass tube.

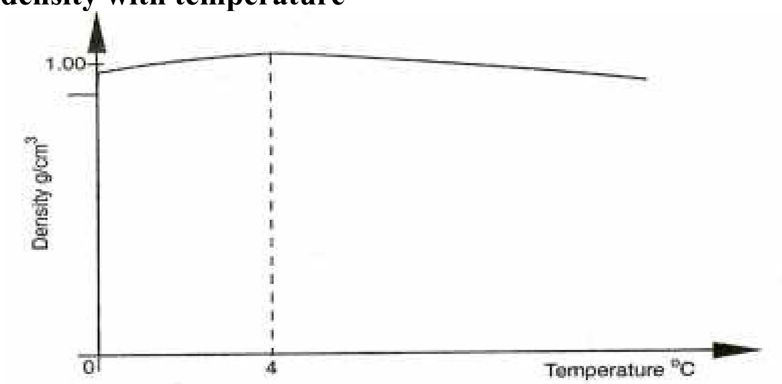
THE ANOMALOUS (UNUSUAL) EXPANSION OF WATER

Solids, liquids and gases expands when heated and contracts when cooled.
Water however shows an anomalous (unusual) behaviour in that it **contracts** when it is temperature is raised from 0ºC to about 4ºc.
When ice is heated from say -20ºC, it expands until its temperature reaches 0ºC and it melts with no change in temperature. The melting is accompanied by **contraction.** The water formed will still contract as its temperature rises from
0ºC as shown



Above 4^0C, the water expands with increase in temperature. Since volume of a given mass of water is minimum at 4ºC, water at this temperature has a maximum density, slightly higher than $1g/cm^3$.

A sketch of the variation of density with temperature



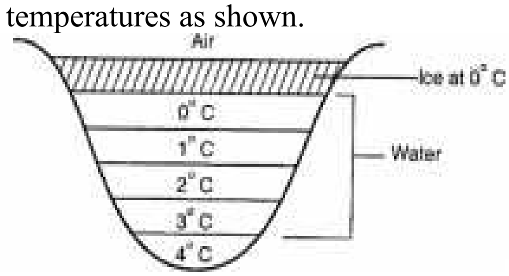
At the melting point of water (º0C) there is a drastic increase in the volume, resulting in a large decrease in density as the ice forms.

EFFECTS OF ANAMALOUS EXPANSION OF WATER

(a) Freezing of lakes and ponds

Water in lakes and ponds usually freezes in winter. Ice is less dense than water and floats on water. Since ice a bad conductor of heat it insulates the water below against heat losses to the cold air above.

Water remains at 40C being the most dense, remains at the bottom of a lake while ice being less dense floats on layers of water at different temperatures as shown.



Fish and other aquatic animals and plants can therefore survive by living in the liquid layers below the ice.

(b) Icebergs

Since the density of ice ($0.92g/cm^3$) is slightly less than that of water it floats with only a small portion above the water surface. The rest and bigger portion rests under water. A big mass of such submerged ice is known as **an iceberg.**

It poses a great danger to ships as navigators cannot see the submerged part.

(c) Weathering of Rocks

When water in a crack in a rock freezes, it expands. This expansion breaks the rock into small pieces.

(d) Water pipes

Water pipes bursts when the water flowing through the pipes freezes

QUESTIONS

1. One property of a liquid that is considered while construction a liquid – in – glass thermometer is that the liquid expands more than the glass for the same temperature change. State any other two properties of the liquids that are considered
2. Explain why a glass container with thick walls is more likely to crack than one with a thin wall when a very hot liquid is poured into them.
3. Figure 1 shows a circuit diagram for controlling the temperature of a room.

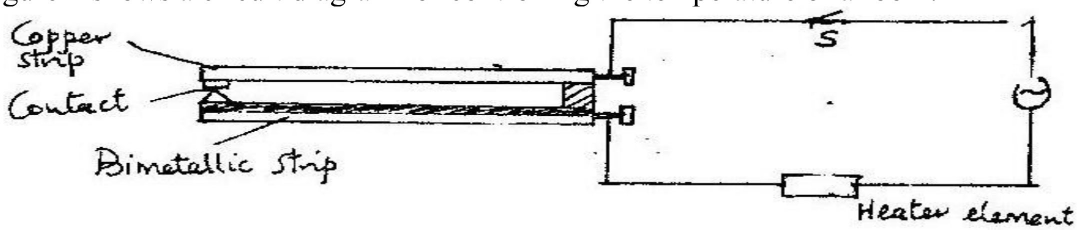


Fig. 1

Describe how the circuit controls the temperature when the switch is closed

4. Fig 2 shows a fire alarm circuit. Explain how the alarm functions.

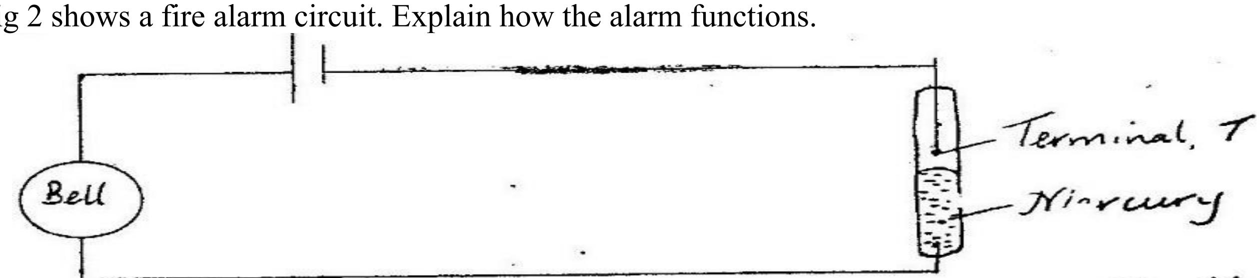


Fig. 10

5. Figure 3 shows a bimetallic strip at room temperature. Brass expands more than invar when heated equally.

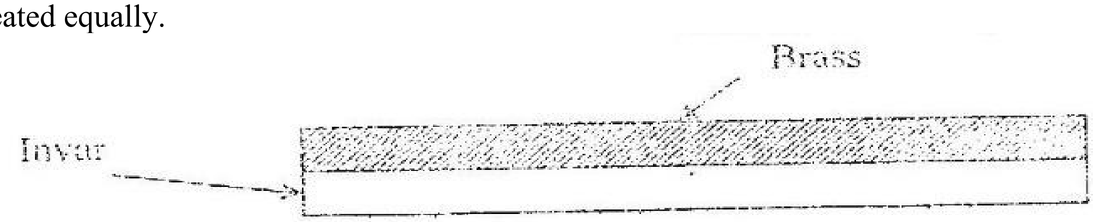
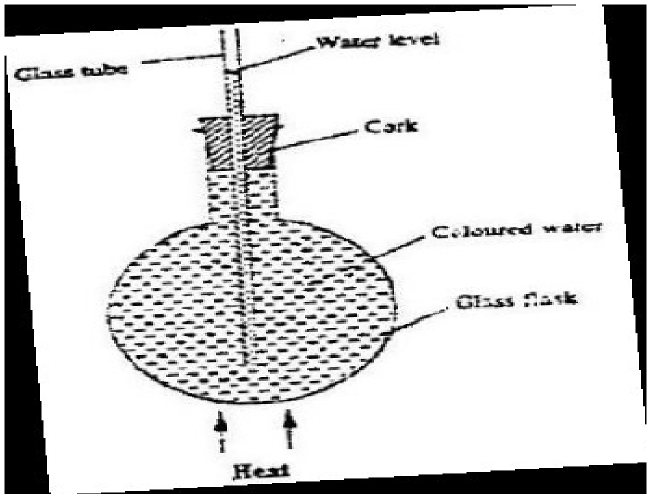


Fig. 5

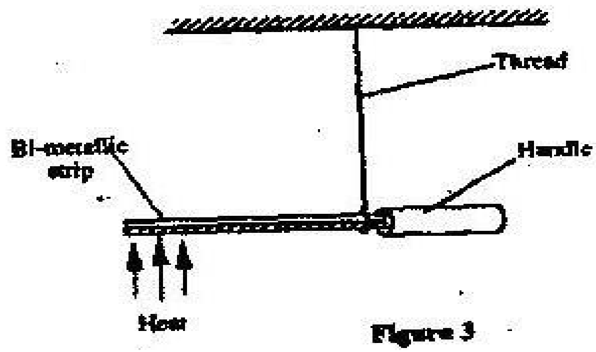
Sketch the bimetallic strip after being cooled several degrees below room temperature.

6. In the set up shown in Figure 5, it is observed that the level of the water initially drops before starting to rise.



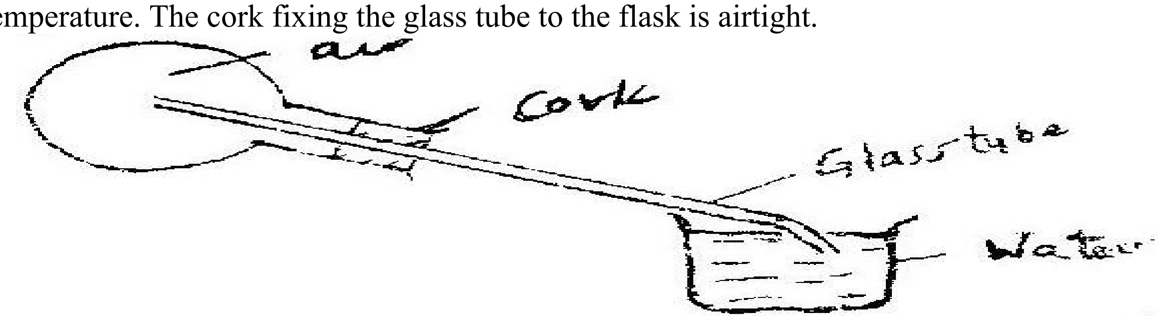
Explain this observation.

7. Figure 6 shows a bimetallic strip with a wooden handle, suspended horizontally using a thin thread.



The strip is heated at the point shown. Explain why the system tips to the right

8. A clinical thermometer has a constriction in the bore just above the bulb. State the use of this constriction.
9. Fig. 7 shows a flask fitted with a glass tube dipped into a beaker containing water at room temperature. The cork fixing the glass tube to the flask is airtight.



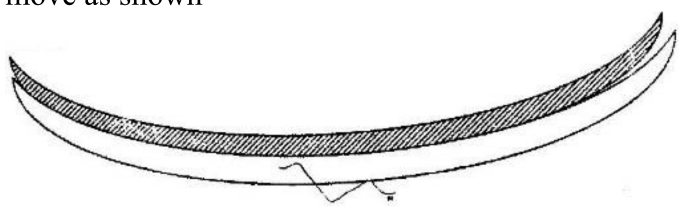
Explain what is observed when ice- cold water is poured on the flask.

10. The melting point of oxygen is given as -281.3^{0}C. Covert this temperature to Kelvin

SOLUTIONS

1. The liquid expand uniformly, expansion is measurable (large enough), thermal conductivity

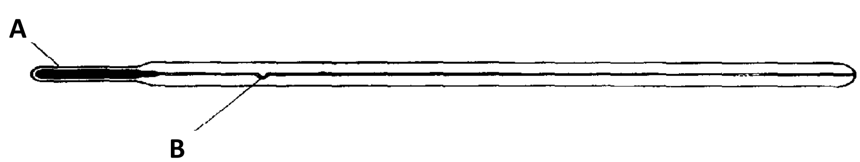
2. Glass is a bad conductor of heart, the difference in temperature between the inside and the outside cause unequal expansion.
3. Bimetallic strip bends and straightens or the metals expand differently. Current flows, heating takes place, temperature rises, strip is heated and bends way from contact; disconnects heater; temperature; drops reconnected heater or completes circuit.
4. When mercury is heated (during a fire); it expands and makes contact, completing the circuit to ring the bell. Since the strip is bimetallic when temperature rises the outer metal expands more than the inner metal; causing the strip to try and fold more; this causes the pointer to move as shown



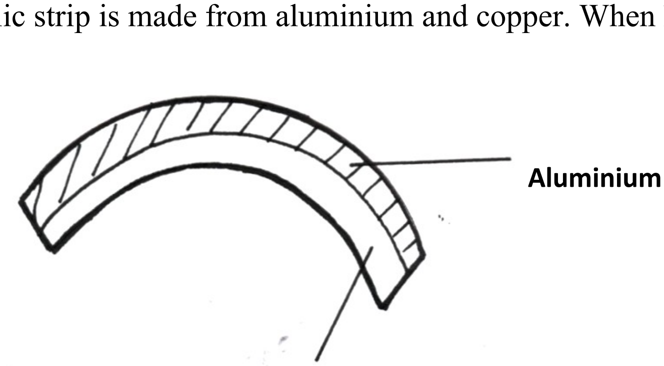
5.
6. Glass flask initially expands / Heating increases the volume of the flask; hence the level drops. Eventually water expands more than glass, leading to the level rising.; Cold water causes air in the flask to contract // reduces pressure inside flask or when cold water is poured it causes a decrease in volume of air the flask or pressure increases in the flask // volume of the flask decreases.
7. On heating, the bimetallic strip bends; this causes the position of the centre of gravity of the section to the left to shift to the right causing imbalance and so tips to the right.
8. Prevents/ holds, traps breaks mercury thread/ stops return of mercury to bulb When thermometer is removed from a particular body of the surrounding
9. Water rises up the tube into the flask or water is sucked into the tube or bubbles are seen momentarily.
10. 273+ -281.3 = 8.3K

MORE QUESTIONS

1. Figure 5 shows a clinical thermometer which is not graduated.



   a) Name the parts indicated with letters: **A** and **B.**
   b) Mark the appropriate scale range in degrees Celsius
2. A bimetallic strip is made from aluminium and copper. When heated, it bends as shown below.

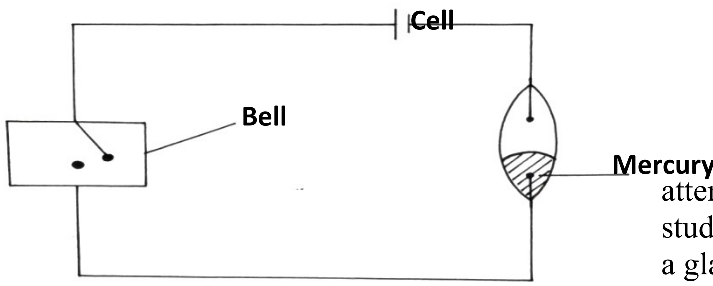


Copper

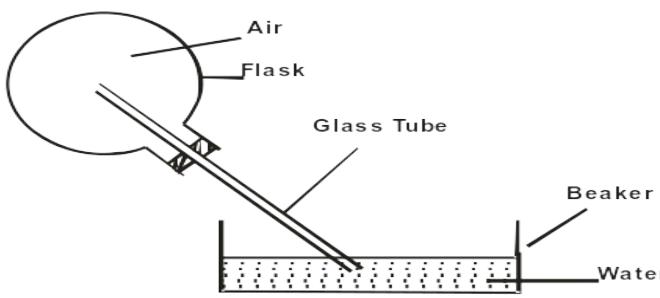
Sketch a diagram showing the strip when cooled below room temperature.

3. Explain why fish can survive under water when the surface is already frozen.
4. Explain the purpose of the constriction in a clinical thermometer.
5. It is not advisable to fix electrical cables tightly during the day. Give a reason for this.

6. The diagram below shows circuit of a fire alarm. When fire breaks it rings the bell to alert people that there is fire. Name two properties of mercury that makes it suitable to be used.



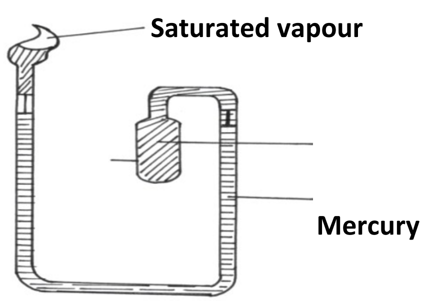
7.
8. In an attempt to prepare a cup of tea, a student placed boiling water into a glass tumbler. The glass tumbler broke into pieces. Explain this observation.
9. Figure 5 shows a flask fitted with a tube dipped into a beaker containing water at room temperature. The cork fixing the glass tube is tight.



State with reason what would be observed if cold water is poured on to the flask

10. Explain why steel is selected for use to reinforce a concreter beam
11. State **two** properties of mercury that make it a suitable thermometric liquid.

12. The diagram below shows a six's maximum and minimum thermometer.



i) What is the thermometric liquid in the thermometer?
ii) Why is it necessary for the vapour in bulb B to be saturated?
iii) Explain how the thermometer indicates maximum and minimum temperature.

iv) Indicate on the figure the two points where the reading of the temperature shown by the thermometer can be made.

13. Explain why a lemon juice bottle always has space between the top of the liquid and the cap.
14. Explain the difference between heat and temperature.
15. Convert 450^0C to Kelvin.
16. The figure below shows a bimetallic strip.

Invar

Brass

This strip is at room temperature. Sketch the bimetallic strip after being cooled several degrees below room temperature. Explain your answer.

17. A metallic disc is thin and has a hole passing through its centre. Describe what happens to the size of the hole when the disc is heated uniformly.
18. Give a reason why a concrete beam reinforced with steel does not crack when subjected to changes in temperature.
19. Describe the thermal expansion of a solid using kinetic theory of matter.
20. Explain the application of expansion in telephone and electric overhead cables.

21. Describe how a bimetallic thermometer works.

22. Explain why aquatic animals are able to survive under water when the surface is already frozen.
23. When a mercury thermometer is used to measure the temperature of hot water, it is observed that the mercury level first drops before beginning to rise. Explain this observation.
24. The coefficient of linear expansion of lead is 2.7 $x10^{-5}$per ^{0}C. Explain this statement.

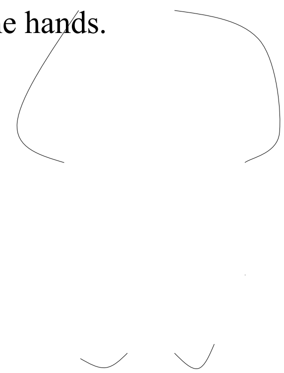
25. Compare the expansion of brass and iron.
26. Air in a bulb may be used as a thermometric substance. State:
    (i) One property of air that would enable the temperature to be measured.
    (ii) One limitation of such a thermometer.
27. What is meant by absolute zero temperature?
28. Explain why a thick glass container is more likely to crack than a thin one when boiling water is suddenly poured in.
29. One property of a liquid that is considered while constructing a liquid in glass thermometer is that the liquid must expand more than the glass for the same temperature range. State any other two properties of the liquid that are considered.
30. Describe and explain the features of a thermometer which will make it: (a) sensitive (b) Quick acting.

31. Why would you crawl close to the flow in a smoke filled room when trying to move out?

32. State three properties of a liquid for it to be considered in constructing a glass thermometer.

33. Sketch a volume against temperature graph for water that cools from 10^0C to - 4^0C

34. The figure below shows a flask fitted with a glass tube dipped into a beaker containing water at room temperature. The cork fixing the glass tube to the flask is air tight. The flask is warmed with the hands.



State and explain the observations made.

35. (a) Explain why in warm coastal regions, a cool breeze often blows from the sea to the land during the day time.

(b) Describe and explain what happens at night in question (a).

(c) Careful measurements are made on the density of pure water as shown in the table below.

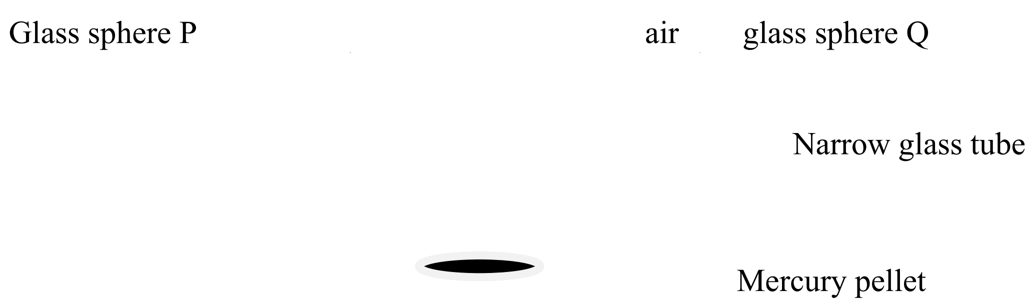
State	**Temperature ^{0}C**	**Density (kg/m^3)**
Liquid	8.0	999.85
Liquid	6.0	999.94
Liquid	4.0	999.97
Liquid	2.0	999.94
Liquid	0.0	999.84
Solid	0.0	916.59

(i) Use the density data above to describe how the volume of the liquid changes as it cools from 8^0C to 0^0C.

(ii) Describe the change in volume of water as it changes from liquid to solid.

(iii) Describe what happens to a sealed glass bottle full of water if it were placed in the freezing compartment of a refrigerator.

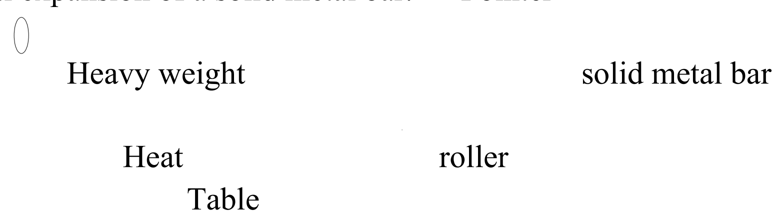
36. (a) Two glass spheres contain equal volumes of air at the same temperature and pressure. The spheres are connected by a narrow glass tube containing a mercury pellet as shown below.



(i) Describe how the air molecules exert a pressure on the walls of the glass spheres.

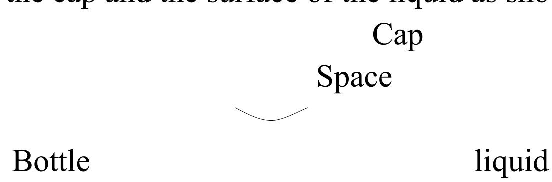
(ii) Describe and explain using the ideas of molecules what happens to the mercury pellet when sphere Q is gently heated while sphere P is kept at its original temperature.

(b) The diagram below shows an experiment which can be used to demonstrate the thermal expansion of a solid metal bar.



i. Describe what happens when the bar is heated.
ii. Explain what happens in (i) using kinetic theory of matter.
iii. Give an example of an everyday situation where allowance must be made for the expansion of a solid. Explain how this allowance is made for the expansion.

37. (a) When liquids are stored in a sealed bottle, they are not completely filled out, but a space is left between the cap and the surface of the liquid as shown below.



(i) Describe what happens to the contents of the bottle when the temperature is increased slowly and uniformly.

(ii) Explain what happens in (i) in terms of the expansion of liquids and solids.

(iii) Give a use of the above effect.

(iv) Describe and explain what happens to the gas in the space above the liquid using kinetic theory.

(c) A cylindrical copper rod is heated. State and explain what happens to the density of copper as the rod is being heated.

38. a) The diagram below shows a long silver rod, a light pointer and a pivot.

(i) Describe how this apparatus can be used to measure the expansion of the silver rod as its temperature increases.

(ii) State a problem of repeating the above experiment using a polythene rod of the same shape and size as the silver rod.

(iii) State two extra pieces of apparatus that would be needed

39. (a) Place in ticks in the table below to show which liquid is better in each case.

Characteristic	**Mercury**	**Alcohol**
Expands more evenly		
Expands more		
A better conductor of heat		
Useful at higher temperatures		
Useful at lower temperatures		

(b) In terms of the forces of attraction between the particles, the particle spacing and their motion describe and explain the change in volume that occurs on boiling.

TOPIC 7: HEAT TRANSFER

HEAT AND TEMPERATURE

Heat is a form of energy which passes from a body at high temperature to a body at a lower temperature. When a body receives heat energy its temperature increases whereas the temperature of a body that gives away energy decreases.

Thermal equilibrium- Condition when if two bodies at the same temperature are in contact, there is no net flow from one body to the other.

The SI unit of heat is joules.

Heat cannot be measured directly by an instrument as temperature is measured by a thermometer.

MODES OF HEAT TRANSFER

Heat can travel through a medium as well as in a vacuum. There are three (3) modes of heat transfer namely;

i) Conduction – takes place in solids.
ii) Convection – takes place in fluids (liquids and gases).
iii) Radiation – takes place in gases (vacuum)

1. CONDUCTION

In stirring a hot tea the handle of a spoon becomes warm. The mechanism to this is explained below,

- Heat energy entering the spoon from the hot end increases vibrations of the atoms at this ends. These atoms in turn collide with neighbouring atoms, increasing their vibrations and hence passing the heat energy along.
- Metals have free electrons which travel throughout the body of the metal. Heat energy injected at the hot end of the metal spoon increases the vibration of the particles at the end. The free electrons in that region gain more kinetic energy and because they are free to move, they spread heat energy to the other parts of the spoon.

THERMAL CONDUCTIVITIES OF VARIOUS CONDUCTORS

Different materials have different thermal conductivities. Metals are generally good conductors of heat. Non-metals are poor conductors of heat (insulator).
Solids that are good conductors of heat use both atom vibration and free electrons to conduct heat.
Solids that are poor conductors of heat like glass, wood, rubber make use of atom vibration as a mechanism to conduct heat because they have no free or mobile electrons.
The table below shows some of the good and poor conductors in decreasing order of thermal conductivity.

Good conductors	Poor conductors
Silver	Concrete
Copper	**Glass**
Aluminium	Brick
Brass	**Asbestos paper**
Zinc	Rubber

NOTE: During thermal condition, heat flows through the materials without the material shifting or flowing. Conduction is therefore transfer of heat as a result of vibration of particles.

CONDUCTIVITY OF WOOD AND IRON RODS

The following set up is used;

Observation and explanation
The paper gets charred (blackened) on the region covering the wooden rod. This is because the wood does not conduct heat from the paper. Wood is said to be a bad conductor of heat while iron is a good conductor.

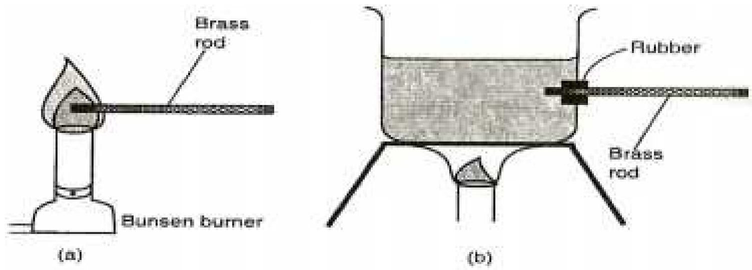
FACTORS AFFECTING THERMAL CONDUCTIVITY

Thermal conductivity in materials depends on the following factors;

(a) Temperature difference (ϴ) between the ends of the conductor.
(b) The length of the conductor.
(c) The cross-sectional area (A) of the conductor.
(d) The nature of the material (K)

(a) <u>Temperature difference</u>

To demonstrate how temperature difference (ϴ) affects thermal conductivity, the following set up is used.



Observation

It will be observed that the rod placed in the flame becomes too hot faster than the one placed in the boiling water.

Explanation

The rate of heat flow (thermal conduction) increases with increase in temperature.
Thermal conduction in metals is by two mechanisms i.e. vibration of atoms and by free electrons. A high temperature difference between the ends of the conductors sets the atoms into vibrations more vigorously and the vibrations are passed more quickly to the cooler end. The electrons on the other hand gain a lot of kinetic energy causing them to spread the heat energy to cooler parts of the metal within a short time.

(b) <u>Length of the conductor</u>

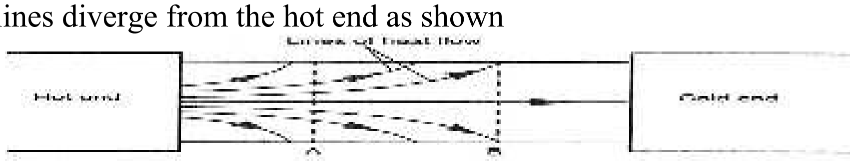
Consider the set up below

Observation

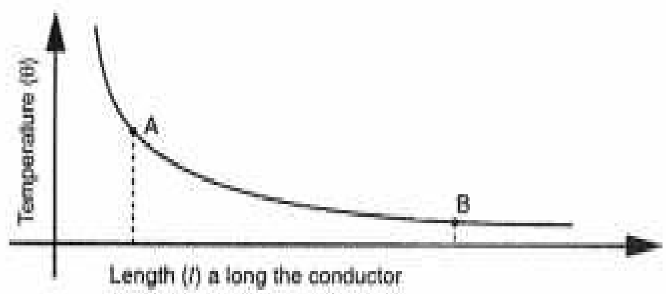
It will be observed that the end of metal B held in hand becomes too hot earlier than metal A.
Thermal conductivity increases with decrease in length.

Explanation

Heat travels within a conductor along imaginary lines called **lines of heat flow.**
These lines diverge from the hot end as shown



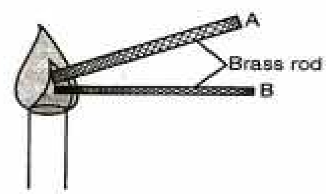
The graph of temperature (ϴ) against length (l) is as shown.



When the heat energy gets to the surface of the metal it is easily lost to the surroundings.
The lines of heat are more divergent near the hot end than they are far away (position A and B).
The slope of the graph in the above figure is steeper at A (near the hot end) than at B further away. This indicates that the shorter the length of the material, the higher the rate of heat flow.

(c) <u>The cross-sectional area of the conductor</u>

Consider the set up below,



Observation

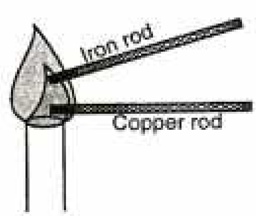
The end of metal A held in the hand becomes too hot earlier than metal B.
Thermal conductivity increases with increase in area of cross-section of the conducting material.

Explanation

The number of free electrons per unit length of the thicker length A is more than those in the thin metal rod B.

(d) <u>The nature of the material K</u>

To demonstrate how the type of the material K affects thermal conductivity, consider the diagram below,



Observation

In this case, it is observed that end of copper rod held in the hand becomes too hot earlier than iron rod.
This shows that thermal conductivity depends on the nature of the material.

Explanation

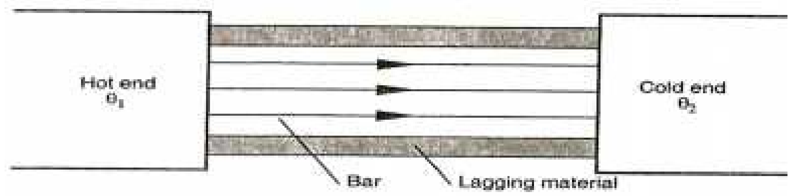
Different materials have different strength of force bonding the atoms within the material. The number of free electrons also differs from one material to another material.

Materials with many free electrons are better conductors of heat e.g. copper has more free electrons than iron.

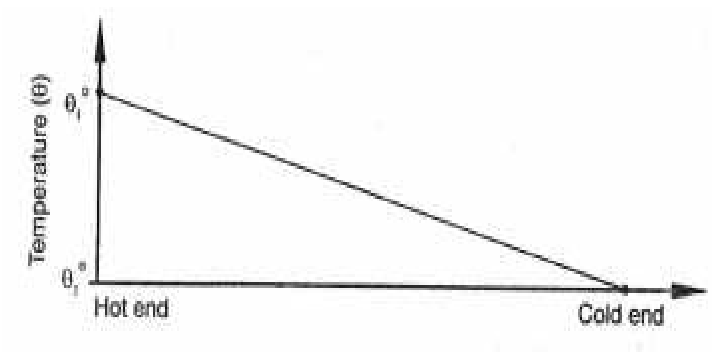
$$\textbf{Rate of heat flow} = \frac{\textbf{thermal conductivity x cross-sectional area x temperature difference}}{\textbf{Length L}}$$

LAGGING

This is the covering of good conductors of heat with insulators to reduce heat loss through surface effects. For example, iron pipes carrying hot water from boilers are covered with thick asbestos material.
The figure below shows lines of heat flow in a lagged metal bar.

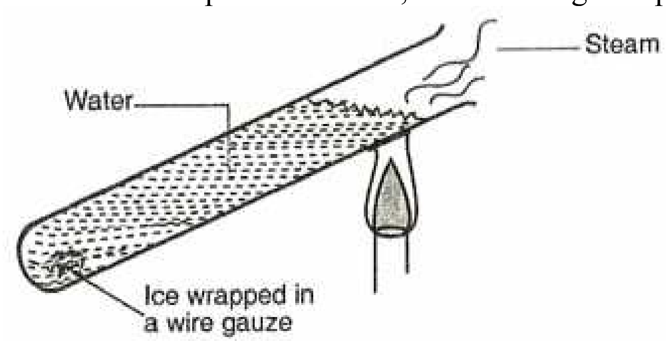


A graph of temperature (ϴ) against the position along the lagged conductor is as shown below.



THERMAL CONDUCTIVITY IN LIQUIDS

To demonstrate that water is a poor conductor, the following set up considered,



Observation and explanation

It will be noted that water at the top of the boiling tube boils while ice remains unmelted. This shows that water is a poor conductor.
NOTE: The boiling tube is made of glass (poor conductor of heat) which limits possible conduction of heat down the tube.
The ice is wrapped in wire gauze to ensure it does not float. The fact that the wire gauze is a good conductor of heat and yet ice remained unmelted shows that there is very little heat conduction in water, unable to melt the ice.

Water is heated at the top to eliminate possibility of heat transfer to the ice by convection. Although liquids are in generally poor conductors of heat, some liquids are better heat conductors than others e.g. mercury is a better conductor of heat than water.

Why Liquids Are Poor Conductors of Heat

Pure liquids have molecules further apart from each other. Although molecules move about within the liquid, they are slow to pass heat to other regions compared to the free electrons in metals. This is because there are large intermolecular distances between liquid molecules. There are also fewer and rare collisions between the molecules.

Electrolytes e.g. salt solution, are better conductors of heat than pure liquids because of increased compactness of the particles.

Mercury is a metal existing as a liquid at room temperature. Bromine, the only non-metal existing as a liquid at room temperature, is a poor conductor.

THERMAL CONDUCTIVITY IN GASES

Since thermal conductivity is by means of vibration of atoms and presence of free electrons, gases are worse conductors of heat because of large intermolecular distance.

A match stick held within the unburnt gas region of a flame cannot be ignited by the heat from the hot part of the flame. This is because gas is a poor conductor of heat.

APPLICATIONS OF GOOD AND POOR CONDUCTORS

- Cooking utensils, soldering irons and boilers are made of metals which conduct heat rapidly. For cooking utensils, the handles are made of insulators such as wood or plastic. Metal pipes carrying hot water from boilers are lagged with cloth soaked in a plaster of Paris to prevent heat losses.
- Overheating of integrated circuits (ICs) and transistors in electronic devices can drastically affect their performance such components are fixed to a heat sink (a metal plate with fins) to conduct away undesired heat. The fins increase the surface area of heat sink and conduct more heat away to the surrounding.
- Fire fighters put on suits made of asbestos material to keep them safe while putting out fire.
- Birds flap their wings after getting wet as a means of introducing air pockets in their feathers. Air being a poor conductor reduces heat loss from their bodies.
- In modern buildings where desired inside temperatures is to be stabilised, double walls are constructed. Materials that are good insulators of heat and can trap air put between the walls. Examples of such materials that are glass, wool (fibre glass) and foam plastic Air on its own may not effectively give the desired insulation because it undergoes convection. Double glazed windows used for the same purpose have air trapped between two glass sheets.
- In experiment involving heating water or liquid, the beaker is placed on the wire gauze. The gauze is heated and spreads the heat to a large area of the beaker. If the gauze is not used, heat from the Bunsen burner may concentrate on a small area and may make the beaker crack.

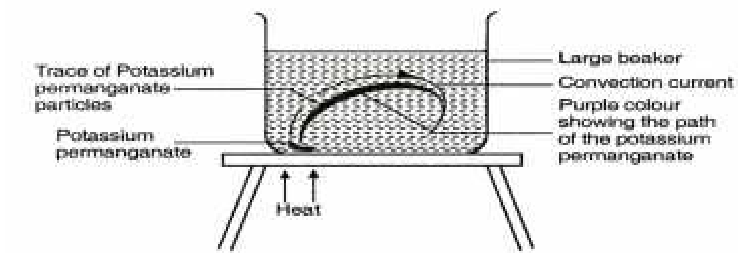
2. CONVECTION

Convection is the process by which heat is transferred through fluids (liquids and gases). The heat transfer is by actual movement of the fluid called **convection currents,** which arise out of the following;

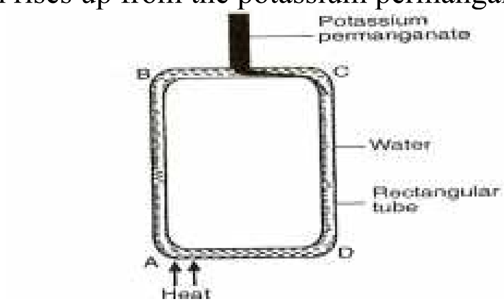
Natural convection – It involves change in density of the fluid with temperature.
Forced convection – Mixing of hot and cold parts of the fluid through some external stirring like a fan or pump.

CONVECTION IN LIQUIDS

To demonstrate convection in liquids the set up below is used



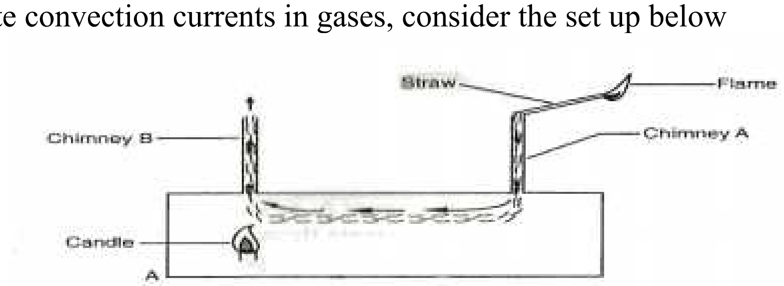
Observation
A purple colourisation rises up from the potassium permanganate, forming a loop.



Observation
The colourisation arising from the potassium permanganate flow in clockwise direction
From the experiments, it is clear that when a liquid is heated, it rises while cold liquid replaces it.
Explanation
When a liquid is heated, it expands and this lowers its density. The less dense liquid rises and its place is taken by more dense colder liquid. This movement of liquid forms **convection currents**

CONVECTION IN GASES

To demonstrate convection currents in gases, consider the set up below



Observation
Smoke is sucked into the box through chimney A and exists through chimney B.
When the candle is put off, the smoke is not drawn into the box.
This shows convection currents are set up when air or gas is heated.
Explanation

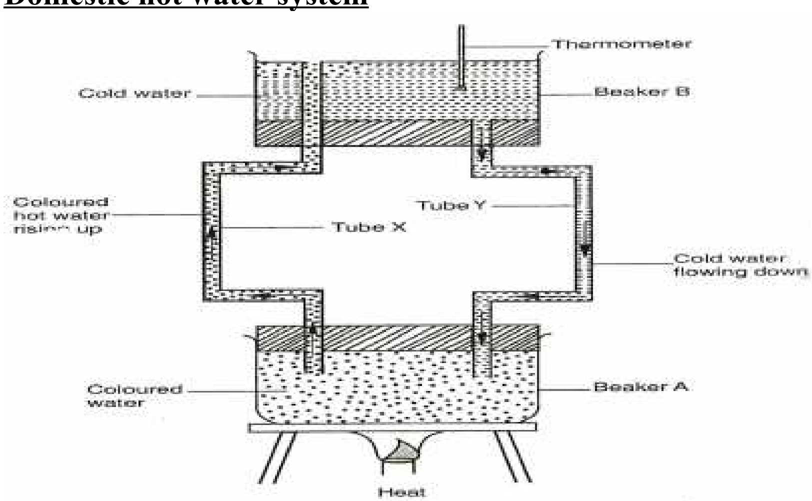
The candle heats up the air above it, which expands and rises up because of lower density. Cold heavier air particles is drawn into chimney A, carrying along the smoke which replaces the air that is escaping through chimney B.

MOLECULAR EXPLANATION OF CONVECTION IN FLUIDS

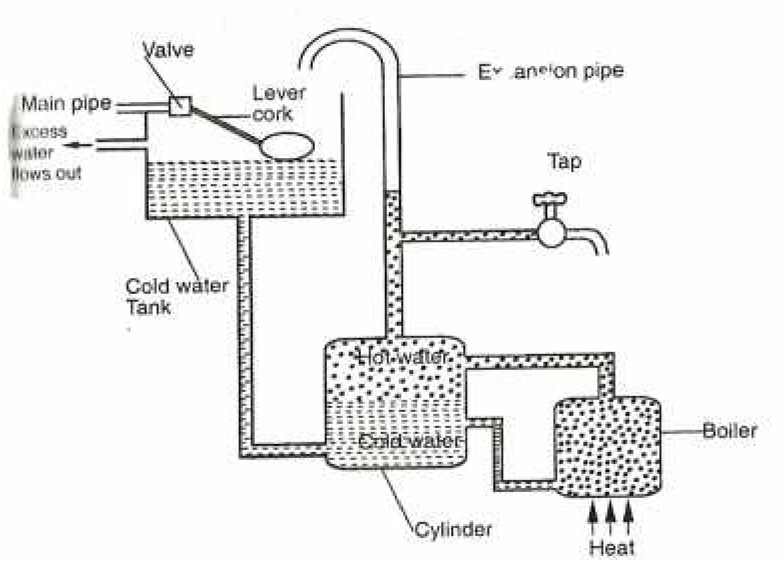
Molecules in fluids are further apart and have negligible cohesive force. Heating a fluid increases the kinetic energy of the vibrating molecules and their random movement.
As the fluid rises, these molecules pass energy to the molecules in the colder regions which have less energy. Because the molecules are further away from the heating source, their temperature is reduced.
Pressure near the heating source decreases because of the depletion of molecules as they rise. Colder molecules move into the low pressure zone to fill up the void being created.
This movement of molecules constitutes convection currents. Convection currents are set up much faster in gases than in liquids because of relatively low cohesive force in gases.

APPLICATION OF CONVECTION IN FLUIDS

(a) Domestic hot water system



Initially, the two beakers A and B have cold water. Water in beaker A is coloured to distinguish it from that in beaker B. When the water in beaker A is heated, it is observed to rise up through tube X and emerges on top of cold water in beaker B. The cold water flows down from beaker B to beaker A.
As long as heating continues, there will be movement of hot water into beaker B and cold water will flow down into beaker A. Thermometer will show increase in temperature for water in beaker B.
The commercial domestic hot water system utilizes the same principle of operation. The hot water rises up because of the effective lowering of density.
The force of gravity helps the cold water to flow down from the cold tank.



The hot water tap and expansion pipe are connected to the upper region of the cylinder. The expansion pipe is an outlet for excess water that could have resulted from overheating.
Once the cold water flows down the cylinder, the main pipe allows more cold water to flow into the tank. When filled to capacity, the ball cork floating on water closes a valve i the main pipe, stopping further in flow of cold water.
An overflow pipe lets out water from the cold tank when the valve is not sufficiently functional.
Lagging is done on the pipe that conveys hot water to minimise heat losses.

(b) Ventilation

This is the supply of fresh air into the room. Air expelled by the room occupants is warm and less dense. It rises up and escapes through the ventilation holes.
Cold fresh air flows into the room to replace the rising warm air. The room gets continuous flow of fresh air.
NOTE: Some devices are fitted with air conditioning devices which cause forced convection of air, giving out cold dry air and absorbing warm moist air.

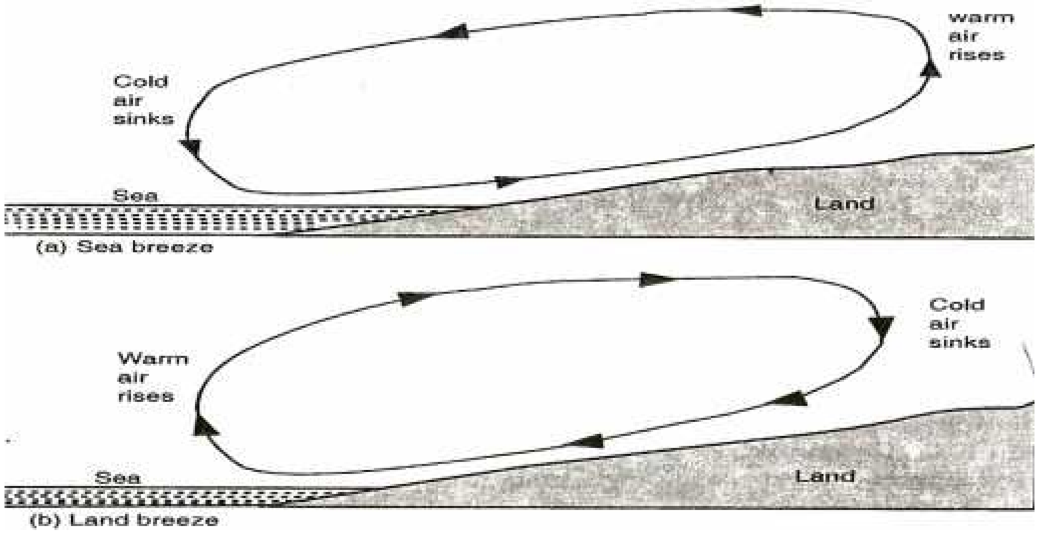
(c) Car Engine Cooling System

Heat conduction and convection play a very crucial role of taking away heat from a car engine that would reduce its efficiency.
The engine is surrounded by a metal water jacket that is connected to the radiator. The metal surface conducts heat away from the engine. This heats up the water, setting up convection currents. The hot water is pumped into the radiator which has thin copper fins that conduct away heat from water.
Fast flowing air past the fins speeds up the cooling process.

(d) Land And Sea Breezes

This is a natural convection of air, and occurs at sea shores because of temperature difference between the mass of water and the land.
The mass of water takes longer time than land nearby land by the same temperature from the sun.
Water also takes a longer time to cool than the land after being raised at the same temperature.

During the day, the land heats up much faster than the sea. The air just above the land gets heated up and rises because of reduced density. Cold air above the sea blows towards the land to replace the void created by warm air rising. This is called **sea breeze.**
In the evening, temperature of the sea water is higher than that of the land. The air above the sea gets heated up and rises. Cold air from the land blows to the sea. This is called **land breeze.**



3. RADIATION

Heat from the sun to the earth reaches us by radiation. Thermal radiation is heat transfer through a vacuum.
All bodies absorb and emit radiation. The higher the temperature of the object, the greater the amount of radiation A body emitting thermal radiation can also emit visible light when it is hot enough.
An electric bulb in a room produces both light and radiant heat. The radiant heat is absorbed by the materials in the room, which in turn give out radiant heat of lower energy.

NATURE OF RADIANT HEAT

To demonstrate the radiant heat;
Consider light rays travelling from sun light to hand lens as shown,

OBSERVATION
When light rays are focused onto the paper, it burns out.
EXPLANATION
Radiant heat, like light can be concentrated to a point using a lens. Thermal radiation is a wave like light and can be reflected. Because of the nature of production, radiant heat is an electromagnet wave which causes heating effect in objects that absorb it.
Radiation can also be described as the flow of heat from one place to another by means of electromagnetic waves.

EMISSION AND ABSORPTION OF RADIATION

To compare radiation from different surfaces (shiny and black surfaces),
Consider the set up below,

The two surfaces are heated to a certain temperature say 80^0C. The temperatures of the two tins taken after sometime

Observation

After sometime, it is noted that the temperature recorded by T_B is lower than that recorded by T_S.

Explanation

The experiment shows that black surfaces are better emitters than shiny surfaces.

A graph of temperature against time for temperatures recorded by each thermometer

The graph shows water in a shiny tin lost heat less rapidly than the blackened tin (good emitter).

To Compare Absorption of Radiant Heat by Different Surfaces

Set up the apparatus as shown

Observation

The cork fixed on the dull/black surface falls off after the wax, melts, while the cork polished/shiny plate remains fixed for a longer time.

Consider also the set up below,

Observation

The thermometer T_B immersed in water in the blackened tin records higher reading than that of thermometer T_S, when the heater is placed mid-way between tin A and tin B.

A graph of temperature (ºC) against time (minutes) is as shown,

The graph shows that temperature of water in the polished tin does not increase as fast as temperature of water in blackened tin.

EXPLANATION

Black surfaces are good absorbers of radiant heat than polished surfaces.

NOTE: Good absorbers of radiant heat also **good emitters** while **poor absorbers** of heat are also **poor emitters.**

Poor emitters of heat are also good reflectors.

APPLICATIONS OF THERMAL RADIATION

(a) Kettles, cooking pan and iron boxes have polished surfaces to reduce heat lose through radiation.
(b) Petrol tanks are painted silvery bright to reflect away as much heat as possible.
(c) Houses in hot areas have their walls and roofs painted with bright colours to reflect away heat, while those in cold areas have walls and roofs painted with dull colours.
(d) In solar concentrators, the electromagnetic waves in form of radiant heat are reflected to a common point (focus) by a concave reflector. The temperature at this point can be sufficiently high to boil water.
(e) **The green house effect-** A green house has a glass roof through which radiant heat energy from the sun passes. This heat is absorbed by objects in the house, which then emit radiation of lower energy that cannot penetrate through glass. The cumulative effect is that temperature of the houses increases substantially. Greenhouses are used in providing appropriate conditions for plants in cold regions.

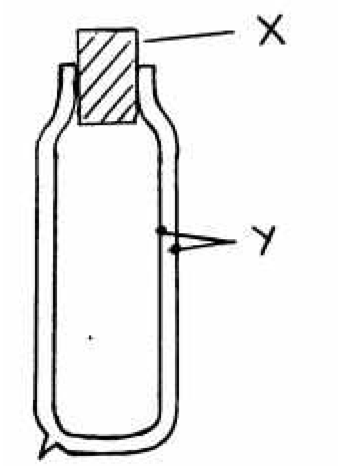
NOTE: Carbon dioxide (CO2) and other air pollutants in the lower layers of the atmosphere show the same properties of glass, raising the temperature on earth to dangerous levels.

(f) **Solar heater**

The solar heater uses solar energy to heat water. The figure below shows the solar heater,
The solar heater consists of a coiled blackened copper pipe on an insulating surface. Radiant heat from the sun passes through glass and is absorbed by black copper pipes that contain water, which is heated up. Copper pipes are used because they are good conductors and they are painted black to increase their absorbing power.
Lower energy emitted after absorption of radiant energy does not escape because it cannot penetrate the glass. The temperature of the air above the pipe thus increases boosting the heating of water. A good insulating material is used at the base.

(g) <u>THERMOS FLASK (VACUUM FLASK)</u>

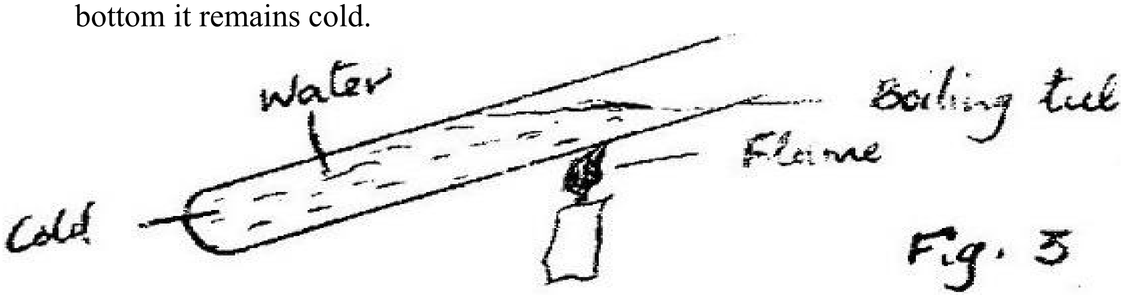
A thermos flask is designed such that heat transfer by conduction, convection and radiation between the contents of the flask and its surrounding is reduced to a minimum.



The vacuum is a double walled glass vessel with a vacuum in the space between the walls. This minimises the transfer of heat by conduction and convection.
The inside of glass walls, in the vacuum side, is silvered to reduce heat losses by radiation (Poor emitter and absorber). The felt pads on the sides and at the bottom support the vessel vertically. The heat loss by evaporation from the liquid surface is prevented by a well fitting cork.

<u>QUESTIONS</u>

1. In the set up shown in figure 1, water near the top of the boiling tube boils while at the bottom it remains cold.



Give a reason for the observation

2. When a Bunsen burner is lit below wire gauze, it is noted that the flame initially burns below the gauze as shown in Figure 2 (i).After sometime, the flame burns below as well as above the gauze as shown in Figure 3(ii).

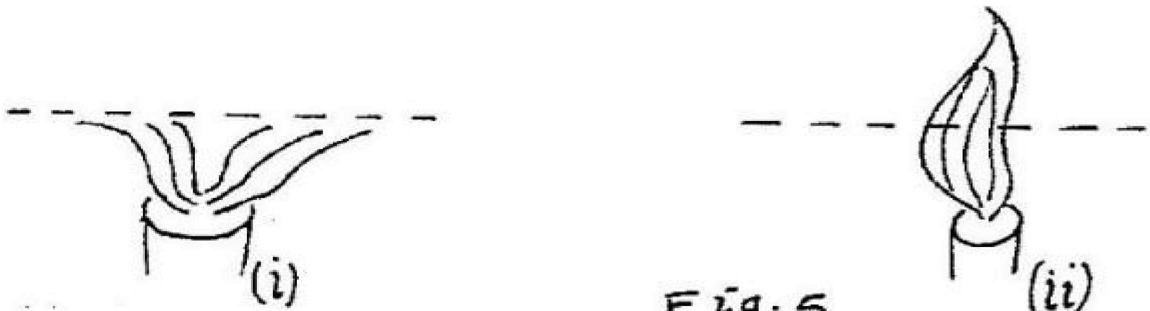


Fig. 5

Explain this observation

3. Two identical aluminum rods as shown in figure 3. One rests on metal block the other on the wooden block. The protruding ends are heated on Bunsen burners shown.

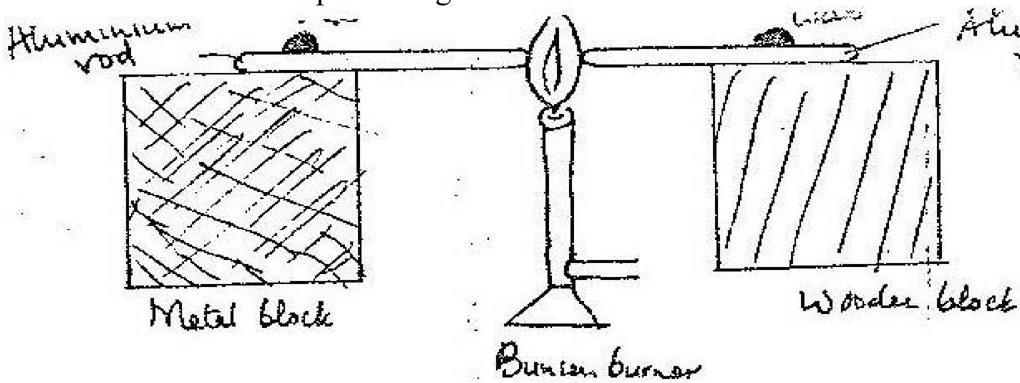


Fig. 4

State with reason on which bar the wax is likely to melt

4. Fig. 4 shows a hot water bath with metal rods inserted through one of its sides. Some wax is fixed at the end of each rod. Use this information to answer questions below

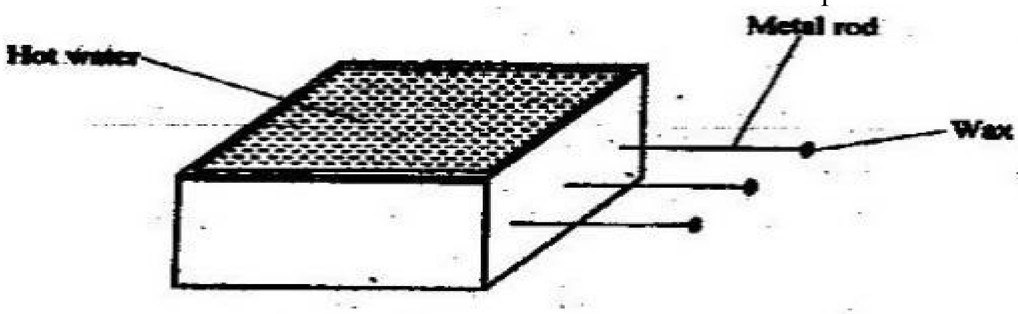
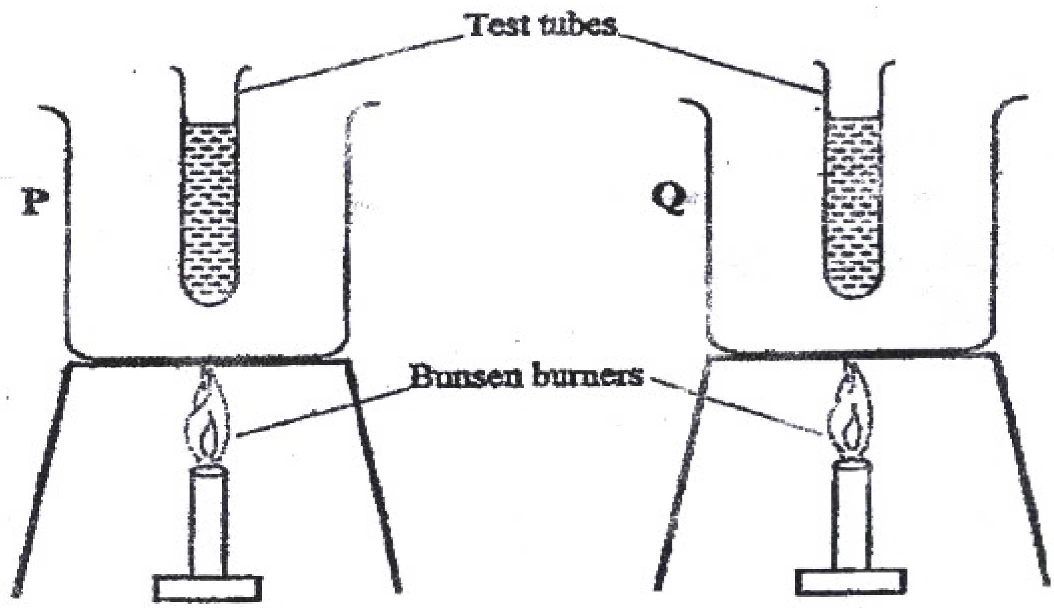


Figure 3

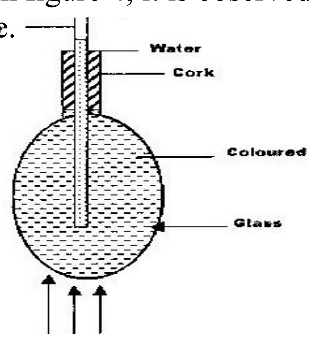
What property of metals could be tested using this set-up?

5. Two identical empty metal containers P and Q are placed over identical Bunsen burners and the burners lit. P is dull black while Q is shiny bright. After each container attains a temperature of 100^0C the burners are turned off. Identical test tubes containing water are suspended in each container without touching the sides as shown



(i) Explain why the container Q may become hot faster than P.
(ii) Explain why the water in test- tube in P becomes hot faster than in Q

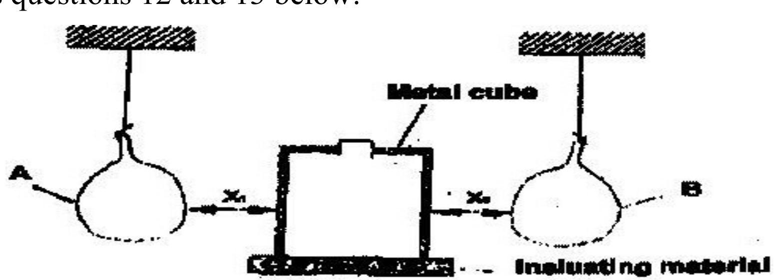
6. In a vacuum flask the walls enclosing the vacuum are silvered on the inside. State the reason for this.
7. Give a reason why heat transfer by radiation is faster than heat transfer by conduction.
8. A wooden bench and a metal bench are both left in the sun for along time. Explain why the metal bench feels hotter to touch.
9. An electric heater is placed at equal distances from two similar cans A and B filled with water at room temperature. The outer surface of can A is shiny while that of can B is dull black. State with reasons, which of the cans will be at higher temperature after the heater is switched on for some time.
10. In the set up shown in figure 4, it is observed that the level of the water initially drops before starting to rise.



Explain this observation.

11. In a vacuum flask the walls enclosing the vacuum are silvered on the inside. State the reason for this

Figure 4 shows two identical balloons A and B. The balloons were filled with equal amounts of the same type of gas. The balloons are suspended at distances X_1 and X_2 from a metal cube filled with boiling water and placed on an insulating material. Use this information to answers questions 12 and 13 below:



12. State the mode by which heat travels from the cube to the balloons
13. The face of the cube towards A is bright and shiny and the face towards B is dull black. State with reason the adjustments that should be made on the distances X_1 and X_2 so that the rate of change of temperature in both balloons is the same.
14. Temperature scale in clinical thermometer ranges from 35^0c to 43^0c. Explain.
15. State one application of expansion in gases
16. Why is it that boiling is not used for sterilization of clinical thermometer?
17. Describe ONE advantage and ONE Disadvantage of anomalous behavior of water.
18. (a) Draw a well labeled diagram of a vacuum flask
    (b) Stating the specific parts in the flask explain how heat loss is reduced through:
    (i) Conduction
    (ii) Convection
    (iii) Radiation

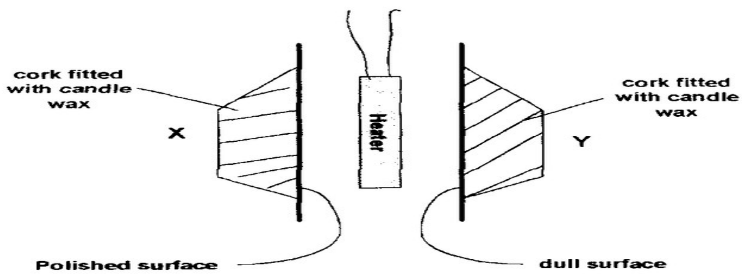
SOLUTIONS

1. Water/ or glass are poor conductor of heat
2. Initially the wire gauze conducts heat away so that the gas above does not reach the ignition temp/point. Finally the wire gauze becomes hot raising the temp of the gas above ignition point.
3. Wooden Block; Wooden block is a poor conductor of heat all the heat goes in melting the wax.
4. Heat conductivity/ rates of conduction/ thermal conductivity
5. Dull surface radiate faster than bright surface P- Looses more of the heat supplied by burner than Q or Q shinny surface is a poorer radiator/ emitter of heat thus retains more heat absorbed Or P- Dull surface is a better radiator/ emitter i.e. retains less of the heat absorbed. Heat travels from container to test tube by radiation so the dull surface P, gives more heat to the test tube.
6. Reduce/ minimize the transfer of heat by radiation OR Reduce the loss of heat OR gain of heat by radiation.
7. Radiation is at the electromagnetic waves Φ infrared while conduction involves particles, which move at lower speed
8. This is because metal is a good conductor, so that heat is conducted from outer parts to the point touched; while wood is a poor conductor
9. Can B is a good absorber of radiation/better absorber of radiation or heat.
10. Glass flask expands first (creating more volume for water) Water then expands using the tube.
11. To reflect heat outwards or inwards hence reduce heat loss by radiation.
12. - x^2 is made larger than X_1

13. - Since B receives radiation at a higher rate, it must be moved further from source for rates to be equal.
14. Since the quantity of water in A is smaller, heat produces greater change of temperature in A; a decrease in density causing the cork to sink further.

MORE QUESTIONS

1. Figure below shows two corks **X** and **Y** fixed on a polished plate and a dark plate with candle wax



Explain the observation, when the heater is switched on for a short time.

2. What feature of a vacuum flask minimizes heat loss by radiation? Explain how this is achieved.
3. Explain why fuel carrying tankers are painted white or silvery.
4. When a thermometer is immersed in ice cold water, the mercury thread is observed to rise before dropping steadily in the capillary tube. Explain.
5. Figure below shows two glass bulbs **C** and **D** of the same size. Bulb **C** is painted dull black while **D** is polished. A hot metal ball is placed equidistant from the two bulbs.

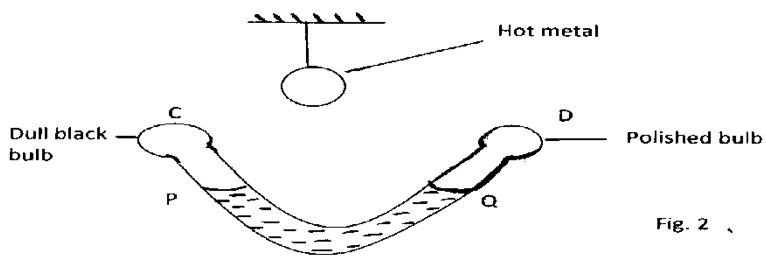
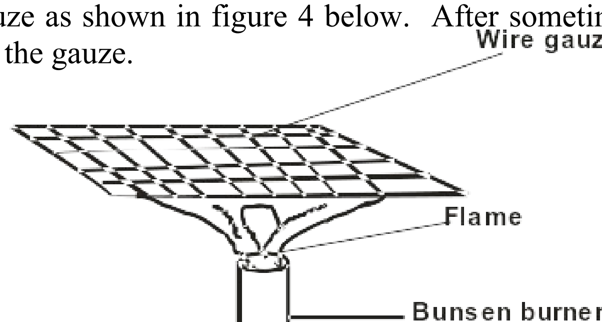


Fig. 2

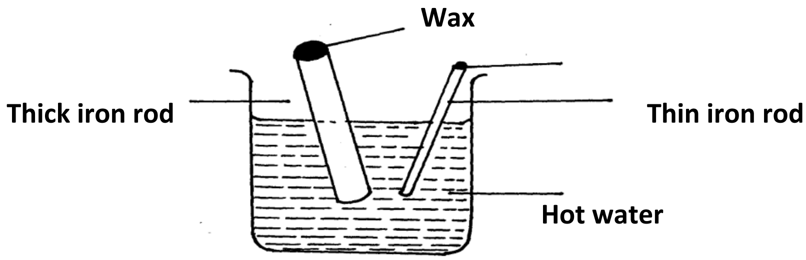
State and explain what will happen to the levels of the liquid in the manometer.

6. When a Bunsen burner is lit below wire gauze, it is noted that the flame initially burns below the gauze as shown in figure 4 below. After sometime the flame burns below as well as above the gauze.



Explain this observation

7. State the reason why it is colder during the night when the sky is clear than when it is cloudy.
8. The figure below shows an experiment carried out by form one students.



(i) The students dipped two iron rods of the same length but different thickness into a beaker of hot water at the same time. What was the experiment about?
(ii) State and explain the observations made after about 10 minutes.
(iii) If the **two** rods were much longer, state and explain any difference from C (ii) above that would be made in the observation.

TOPIC 8: RECTILINEAR PROPAGATION AND REFLECTION AT PLANE SURFACES

Light is a form of energy. It enables us to see the surrounding objects. Light itself is not visible but its effect is felt by the eye.
Light is also very essential as a source of energy for the process by which plants their own food (photosynthesis).

SOURCES OF LIGHT

Luminous (incandescent) source – these are objects that produce their own light e.g. sun, stars, burning candles, wood or charcoal, electric bulbs, television screens, glow worms e.t.c.
Non-luminous source – these are objects which do not produce light of their own. They are seen when light falling on them from luminous sources is reflected (bounces off their surfaces) e.g. the moon, planets, plants, people, books, walls, clothes e.t.c.

RAYS AND BEAMS OF LIGHT

A source of light produces pulses of energy which spread out in all directions.
The path along which light energy travels is referred to as **a ray of light.** Rays are represented by lines with arrows on them to show the direction of travel.
A stream of light energy is called **a beam.** It is also considered to be a bundle of rays of light.
Beams of light can be seen;

- In the morning as the sunlight breaks through the clouds or leaves.
- When a spotlight is shown in a smoky room or a car driven along a dusty road at night with its headlamps on.
- When sunlight streams into a smoky dark room through a small opening

TYPES OF BEAMS OF LIGHT

a) Diverging beam
b) Converging beam
c) Parallel beam

Diverging beam – These are beams of light that appear to spread out (diverging) e.g. light from a spotlight.
Converging beams – these are beams which appear to collect (converge) to a point.
Parallel beam – are those beams which appear to be perfectly parallel to each other e.g. a beam of light from the sun reaching the earth's surface.

OPAQUE, TRANSLUCENT AND TRANSPARENT OBJECTS

OPAQUE – these are objects that do not allow light to pass through them at all e.g. brick walls, metals, wood, stones e.t.c.
TRANSLUCENT – these are objects that allow light to pass through but we cannot see through e.g. glass panes used in toilets and bathroom window and greased paper.
TRANSPARENT – these are objects which allow light to pass through and we see clearly through them e.g. car wind screen and ordinary window panes.

RECTILINEAR PROPAGATION OF LIGHT

Light does not need a material medium to carry it. In a vacuum, the speed of light is 3.0×10^8m/s. Light from the sun reaches the earth having travelled mostly through a vacuum.

When light falls on an opaque object, it casts a shadow of the object with sharp edges on a screen behind it. This suggests that light travels in a straight line.

TO INVESTIGATE HOW LIGHT TRAVELS

Apparatus: three cardboards, source of light.
Arrange the apparatus as shown

The cardboards are arranged such that holes are exactly in line.

OBSERVATION

When the holes in the three cardboards are in line, the eye can see the lamp.
However when the middle cardboard is displaced, the eye can no longer see the lamp.

EXPLANATION

When the holes in the cardboards are in a straight line, light travels through the holes and the lamp is seen from the other side. When one of the cardboards is displaced, the beam of light is cut off and since light cannot bend to follow the displaced hole, the lamp cannot be seen.

CONCLUSION

Light travels in a straight line. This property is known as **rectilinear propagation of light.**

SHADOWS

Shadows are formed when an opaque object is on the path of light. The type of shadow formed depends on;

i. The size of source of light.
ii. The size of opaque object.
iii. The distance between the object and the source of light.

a) To study the formation of shadows by a point source of light

Consider the set up below,

Observation and Explanation

A uniformly and totally dark shadow is seen on the screen. This shadow is called **umbra (**Latin for shade)
The shadow has a sharp edge, supporting that light travels in straight lines.

b) To study the formation of shadows by extended (larger) source of light

Consider the set up below (source of light made larger)

Observation

The centre of the shadow remains uniformly dark as before, but smaller in size.
The shadow is edged with a border of partial shadow called **penumbra.**

Explanation

The centre of the shadow still receives no light at all from the source. Light from some parts of the extended source of light reaches the centre parts of the shadow on the screen, but light from other parts is cut off by the opaque object, resulting in a partial shadow at the edges.

NOTE: Extended light source produce light that is much softer and without sharp edges.

Application

It is used in frosted light bulbs and lamp shades to provide a more a more pleasant lighting with less sharp edges.

c) To study the formation of shadows by extended (larger) source of light when object distance is changed

Consider the set ups below,

i. Object moved closer to source

ii. Object moved away from the source

Observations

When the ball is moved closer to the source, a ring of penumbra is formed. No umbra is seen.
When the ball is far away from the source, there is umbra surrounded by penumbra.

Explanation

The centre of the shadow receives light from the extended source. Since the object (ball) is smaller than the source of light, its umbra does not reach the screen because of the distance. When the object is moved away from the source, the tip of the umbra reaches the screen.

ECLIPSE

An eclipse is a phenomenon of shadow formation which occurs once in a while.

It's the total or partial disappearance of the sun or moon as seen from the earth.
Eclipses are explained in terms of relative positions of the earth, the moon and the sun.

THE PHASES OF THE MOON

At any given moment, about half the surface of the moon is lit by the sun while another half is in darkness.
The lighted part is bright enough to be seen easily at night from the earth and can be seen at day time. The darkened part is usually invisible.
When we look at the moon, we normally notice only the shape of the lighted part.

a) SOLAR ECLIPSE (ECLIPSE OF THE SUN)

When the moon, revolving around the earth, comes in between the sun and the earth, the shadow of the moon is formed on the earth. This is called **eclipse of the sun.**
Depending on the position of the moon, some parts of the earth lie in the region of umbra and some in the region of penumbra. Total eclipse occurs in the regions of umbra and partial eclipse in the regions of penumbra.

b) ANNULAR ECLIPSE

Sometimes the umbra of the moon is not long enough to reach the earth because sometimes the distance between the moon and earth varies (the moon's orbit is elliptical). When the moon is further away from the earth, its disc is slightly smaller than the sun's disc. So when a solar eclipse occurs, the moon is not large enough to cover the sun totally. A bright ring of sunlight can be seen round the edge of the dark disc of the moon. This is called **Annular or ring eclipse.**

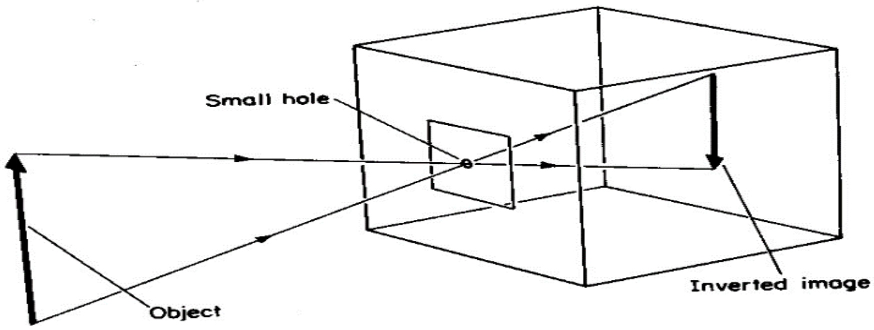
c) LUNAR ECLIPSE (ECLIPSE OF THE MOON)

The moon is a non luminous object. It can only be seen when light from the sun is incident on it. When we look at the moon, we see only the shape of the lighted portion. When the earth comes in between the sun and the moon, **lunar eclipse** occurs. Depending on the position of the moon, a total or partial eclipse of the moon will occur. Total lunar eclipse will occur if the moon is in the region of umbra and partial eclipse will occur if any part of the moon is in the region of penumbra as shown,

A lunar eclipse occurs when the moon passes through the earth's umbra.

PINHOLE CAMERA

A pinhole camera consists of a box with pinhole on one side and a translucent screen on the opposite side. Light rays from an object pass through the pinhole and form an image on the screen as shown



The image formed is **real** and is **inverted.** A pinhole camera has a large depth of focus i.e. objects that are far and near form focused images on the screen.

CHARACTERISTICS OF IMAGES FORMED ON THE PINHOLE

Consider the sets below;

When the object is near the pinhole, the image is **larger.**
When the object distance is increased from the pinhole the image is **smaller.**
When more holes are added close to the first pinhole, images of each point are seen overlapping on the screen.
If the camera was made in such a way that it could be elongated by moving the screen farther away from pinhole but keeping the distance between the object and pinhole fixed, it could be seen that the image enlarges when length of the camera is increased and diminishes when the length of the camera is reduced.

- Length of camera **decreased**, image **smaller**
- Length of camera **increased**, image **bigger** (larger)

MAGNIFICATION

Magnification is the change in size of an image to that of the object or it's the ratio of the height of the image and that of the object.

Magnification, m= $\frac{\text{Image distance, } v}{\text{Object distance, } u}$

Also,

Magnification, m= $\frac{\text{Height of the image, } h_i}{\text{Height of the object, } h_o}$

Hence, magnification, m = Image distance, v = Height of the image, h_i

Object distance, u Height of the object, h_o

$$= \frac{h_i}{h_o} = \frac{v}{u}$$

EXAMPLE 1

The distance between the pinhole and screen of a pinhole camera is10cm. The height of the screen is 20cm.At what distance from the pinhole must a man 1.6m tall stand if a full length is required

SOLN

$$\frac{h_i}{h_o} = \frac{v}{u}$$

But, hi=20cm, ho=1.6m and v=10cm

$$\text{Magnification, } m = \frac{20}{160} = \frac{10}{u}$$

$$\text{Hence, } u = (160 \times 10) / 20$$

$$= 80 \text{ cm or } 0.8 \text{ m}$$

EXAMPLE 2

An object of height 5m is placed 10m away from a pinhole camera. Calculate

a) The size of the image if it's magnification is 0.01
b) The length of the pinhole camera.

SOLN

$$\text{a) Magnification, } m = \frac{h_i}{h_o} = \frac{v}{u}$$

$$0.01 = \frac{h_i}{5}$$

Thus, hi =0.05m (image is 0.05m high)

$$\text{b) } \frac{h_i}{h_o} = \frac{v}{u}$$

$$\frac{0.05}{5} = \frac{v}{10}$$

Hence, v =0.1m (length of pinhole camera is 0.1m)

<u>EXERCISE</u>

1. The length of pinhole camera is 25cm. An object 2m high is placed 10cm from the pinhole. Calculate the height of the image produced and its magnification.
2. a) A pinhole camera of length 20cm is used to view the image of a tree of height 12m which is 40m from the pinhole. Calculate the height of the image of the tree obtained on the screen.
   b) If the pinhole is moved by 10m towards the tree, what will be the height of the tree on the screen?

TAKING PHOTOGRAPHS WITH A PINHOLE CAMERA

The pinhole camera can be used to take still photographs if it is modified as follows,

i. The box should be painted black to eliminate reflection of light.
ii. The translucent screen should be replaced by a light-tight lid with a photographic film fitted on the inside. The film should be fitted in a dark room.

iii. The pinhole should be covered with a thin black card which acts as a shutter as shown,

REFLECTION OF LIGHT (PLANE SURFACES)

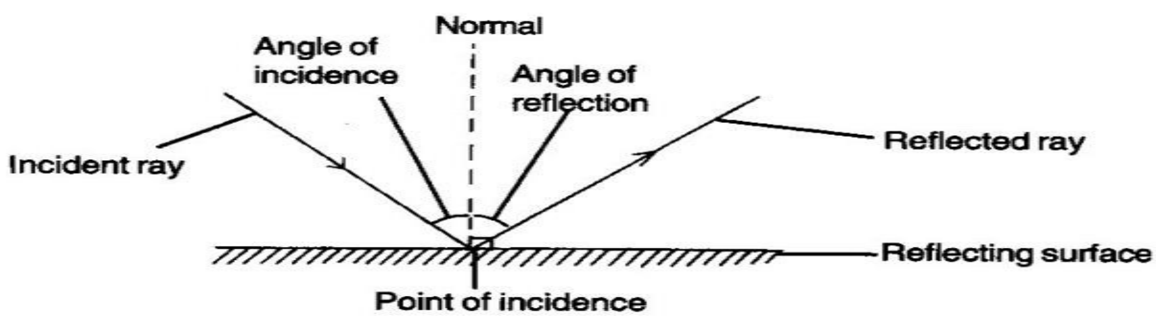
All objects, except self luminous objects, become visible because they bounce light back to our eyes. This bouncing off light is called **reflection.**
There are two types of reflection namely **regular** and **diffused** reflections.
When light is reflected by a plane smooth surface, the reflection is **regular (**specular) and when reflection occurs at a rough surface it is called a **diffused** reflection. Plane mirrors forms images while shiny sheet of papers cannot. This is because with papers, there is irregular/diffused reflection while image formation requires regular/specular reflections only.

REFLECTION BY PLANE MIRRORS

A plane mirror is a flat smooth reflecting surface which forms images by regular reflection. It is often made by bounding a thin polished metal surface to the back of a flat sheet of glass or silvering the back side of the flat sheet of glass.
The silvered side is normally coated with some paint to protect the silver coating. If the clear and the silvered surfaces are in parallel plane, the mirror is called a **plane mirror.**
If the surfaces are curved, the mirror is called **curved mirrors.**
The silvered side of the mirror is shown by shading behind the reflecting surface.

DEFINITION OF TERMS USED IN REFLECTION

Consider the set up below,



Incident ray – is the ray that travels from the source to the reflecting surface.
Angle of incident (i) – is the angle between the incident ray and the normal.
Normal – is the line drawn perpendicularly at the point where the incident ray strikes the reflecting surface.
Reflected ray – is the ray that bounces from the reflecting surface.
Angle of reflection (r) – is the angle between the reflected ray and the normal.

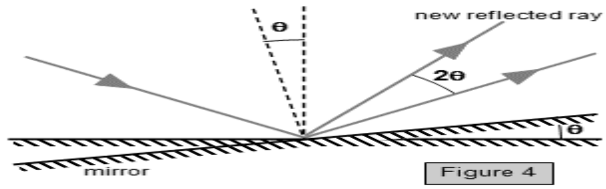
LAWS OF REFLECTION

(i) The incident ray, the reflected ray and the normal at the point of incidence all lie on the same plane.
(ii) The angle of incidence, i, equals the angle of reflection, r.

Experiments to show the laws of reflection (exp. 8.6) KLB

ROTATION OF A MIRROR THROUGH AN ANGLE

Consider the mirrors below,



In figure (a), the angle of incidence is 30^0. The angle of reflection is also 30^o.
Therefore the angle between the incident ray and the reflected ray is 60^o i.e., ($30^o + 30^o$).
In figure (b), mirror m_1 is rotated by an angle 10^o to the new position m_2. The normal BN moves through an angle 10^o. Angle between the two normals is 10^o.
In figure (c), for the same incident ray AB, the new angle of incident = $30^o +$ 10^o =40^o. The new angle of reflection = 40^o. Hence the new angle between the angle of incidence and the angle of reflection = $40^o + 40^0$=80^0.
In figure (d), the angle between the two reflected rays BC and BD =20^o.
For the same incident ray, the angle of rotation of the reflected ray is twice the angle of rotation of the mirror.

EXAMPLE 3

A ray of light is incident along the normal in a plane mirror. The mirror is then rotated through an angle of 200. Calculate the angle between the first reflected ray and the second reflected ray.

SOLN

Angle of rotation of reflected rays = 2 x angle of rotation of the mirror
=2 x 20^0
=40^o

EXAMPLE 4

The figure below shows a ray incident at an angle of 25o at position 1.
The mirror is turned through 6^0 to position 2. Through what angle is the reflected ray rotated.

SOLN

Rotation change the angle of incidence from 25^o to (25+6) =31^0.
Hence the angle of reflection is 31o from the new normal. The total change in the angle of reflected ray is 12^o

EXAMPLE 5

A suspended plane mirror makes an angle of 20^o with a wall. Light from a window strikes the mirror horizontally. Find;
a. Angle of incidence.
b. The angle between the horizontal and the reflected ray

<u>FORMATION OF IMAGES BY PLANE MIRRORS</u>

Images formed are far behind the mirror as the object is in front of the mirror i.e. image distance is equal to object distance from the mirror

<u>Characteristics of images formed by plane mirrors</u>

- Image formed is the same size as the object.

- The image is formed far behind the mirror as the object is in front of the mirror.
- Images formed are **laterally inverted** e.g. when you raise your right hand, the image raises its left hand.

  Virtual images – are formed by rays that appear to come from the image. Such images are not formed on the screen as they are only imaginary.

EXAMPLE 6

A girl stands 2m in front of a plane mirror.

a) Calculate the distance between the girl and her image
b) If the mirror is moved 0.6m to the girl, what will be the distance between her and image.

SOLN

a) 2+2 = 4m
b) Object distance =2-0.6 =1.4m

   Total distance = 1.4 + 1.4 = 2.8m

IMAGES FORMED BY MIRRORS AT AN ANGLE

When an angle θ is 90º, the number of images formed, n, is 3, i.e.

$$n = \frac{360}{90} - 1 = 3 \text{ images}$$

When the angle θ is 60º, the number of images formed, n, is 5, i.e.

$$n = \frac{360}{60} - 1 = 5 \text{ images}$$

In general if the angle between two placed mirrors is θ, then the number of images formed, n, is given by,

$$n = \frac{360^\circ}{\theta} - 1$$

EXAMPLE 7

Two plane mirrors are kept inclined to each other at 120º. Calculate the number of images formed by the mirrors.

SOLN

$$n = \frac{360}{120} - 1 = 2 \text{ images}$$

EXAMPLE 8

At what angle would the two mirrors inclined to form 17 images.

SOLN

$$17 = \frac{360}{\theta} - 1$$

$$\mathbf{18\theta} = 360^0$$

$$\theta = 20^\circ$$

Mirror Parallel To Each Other

When the mirrors are parallel i.e. θ= 0º, the number of images is given by,

$$n = \frac{360^\circ}{0^\circ} - 1 = \infty \text{ (infinite number of images)}$$

In this case, each image acts as an object in the second and first mirror as illustrated below;

EXAMPLE 9

Two parallel plane mirrors are placed 30cm apart. An object placed between them 10cm from one mirror. Determine the image distance of two nearest images formed by each mirror.

SOLN

Image distance = object distance

Image distance on mirror 1= 10cm

Image distance on mirror 2 = 20cm

EXAMPLE 10

Two plane mirrors inclined at an angle 60^o to each other. A ray of light makes an angle of 40^o with mirror M_1 and goes on to strike mirror M_2.

Find the angle of reflection on the second mirror M_2.

The angle of reflection = 10^o

APPLICATIONS OF PLANE MIRRORS

1. **The kaleidoscope**

A kaleidoscope or mirror scope is a device used to produce a series of beautiful symmetrical images. Two plane mirrors are placed at an angle of 60^o inside a long tube.

The bottom of the tube is a ground glass plate for admitting light. On this plate is small scattered small pieces of brightly coloured glass, which act as objects.

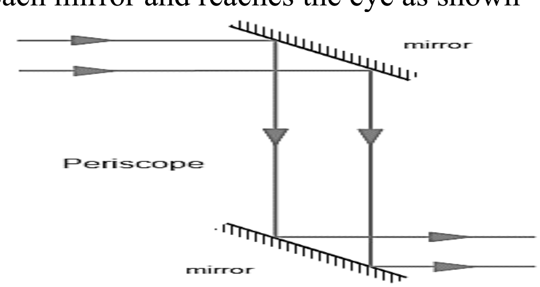
When one looks down the tube, five images of the object are seen which together with the object form a symmetrical pattern in six sectors as shown below

The instrument is used by designers to obtain ideas on systematic patterns.

2. **The periscope**

This is an instrument used to view objects over obstacles. It is used in submarines and also to watch over crowds. The images seen with the aid of the instrument are **erect** and **virtual.**

A periscope uses two plane mirrors kept parallel to each other and the polished surfaces facing each other. Each plane mirror makes an angle of 45^o with the horizontal. Light from the object is turned through 90^0 at each mirror and reaches the eye as shown

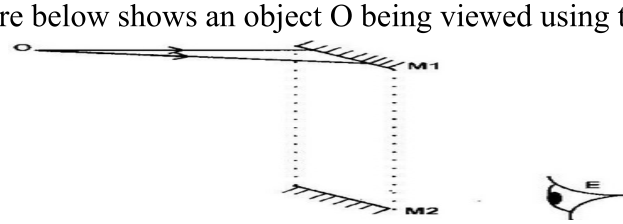


The rays from the object are reflected by the top and then reflected again by the bottom into the observer. The image formed is **virtual, upright** and **same size as the object.**

3. **Barber shops and saloon**
4.

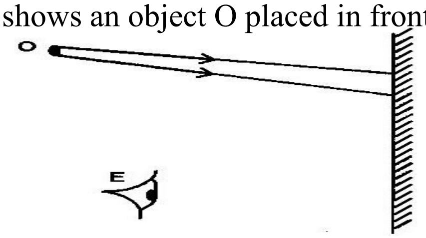
QUESTIONS

1. What is meant by a virtual image?
2. The figure below shows an object O being viewed using two inclined mirrors M_1 and M_2.



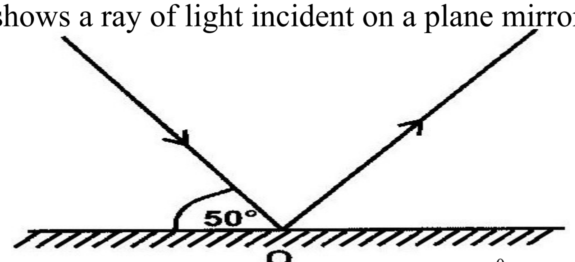
Complete the diagram by sketching rays to show the position of the image as seen by the eye E

3. The figure below shows an object O placed in front of a plane mirror



On the same diagram, draw rays to locate the position of the image 1 as seen from the eye E.

4. The diagram shows a ray of light incident on a plane mirror at point O.

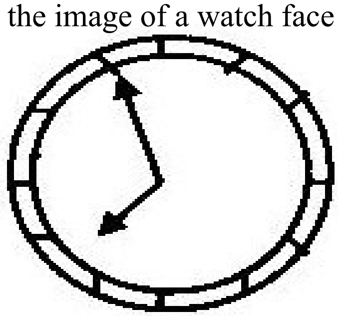


The mirror is rotated clockwise through an angle of 30^0 about an axis perpendicular to the paper. Determine the angle through which the reflected ray rotated.

5. A luminous point object took 3 s to move from P to Q in front of a pinhole camera as shown below.

What is speed in cm/s of the image on the screen?

6. The diagram shows the image of a watch face in a plane mirror



What is the time shown on the watch face?

7. (a) Give two main reasons why concave mirrors are unsuitable as driving mirrors
(b) State one disadvantage of a convex mirror as a driving mirror
8. Explain why a concave mirror is suitable for use as a make up mirror.
9. In the space provided below, sketch a labeled diagram to show how a pinhole camera forms an image of a vertical object placed in front of the pinhole

10. A building standing 100m from a pinhole camera produces on the screen of the camera an image 5 cm high 10 cm behind the pinhole. Determine the actual height of the building.

11. What property of light is suggested by the formation of shadows?

12. State the reason why when a ray of light strikes a mirror at 90o, the reflected ray travels along the same path as the incident ray.

13. Figure 1 shows two point objects A, and B, placed in front of a mirror M

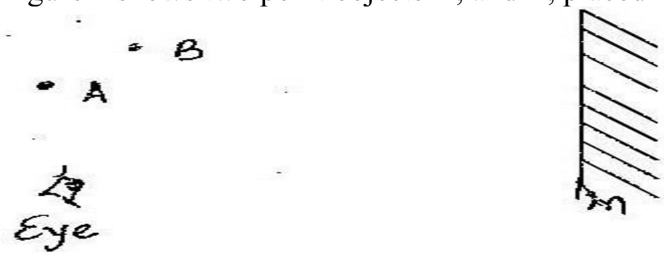


Fig. 4

Sketch a ray diagram to show the positions of their images as seen by the eye.

14. What is meant by virtual image?

15. Figure 2 shows a ray of light incident on plane mirror at point O.

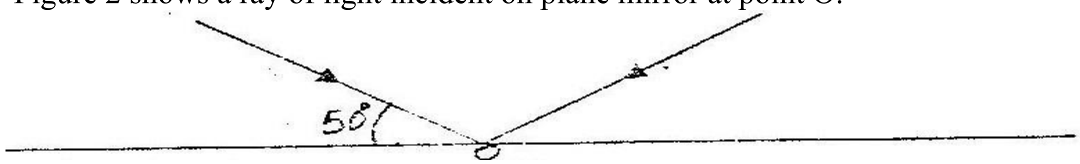


Fig. 6

The mirror is rotated clockwise through an angle 300 about an axis perpendicular to the paper. Determine the angle through which the reflected ray rotated.

16. Fig. 3 shows an object O being viewed using tow inclined mirrors M1 and M2. Complete the diagram by sketching rays to show the position of the image as seen by the eye.

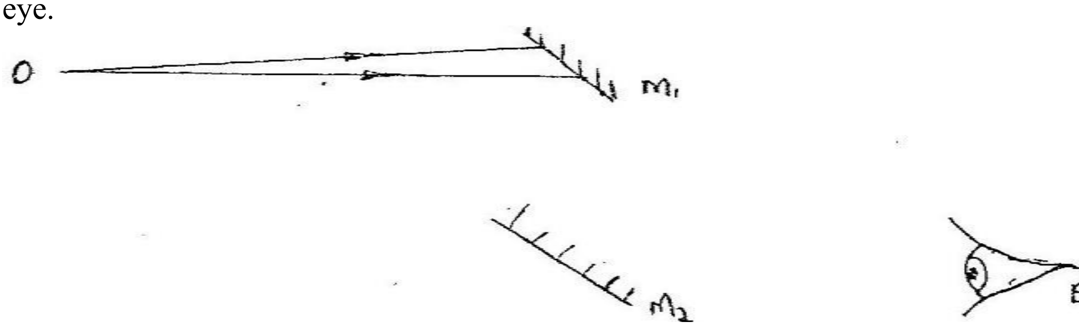


Fig. 6

Sketch the same diagram, the path of the ray until it leaves the two mirrors. Indicate the angles at each reflection

17. In a certain pinhole camera, the screen is 10cm from the pinhole. When the camera is placed 6m away from a tree, a sharp image of the tree 16cm high is formed on the screen. Determine the height of the tree

18. Figure 4 shows three point sources of light with an opaque object placed between them and the screen.

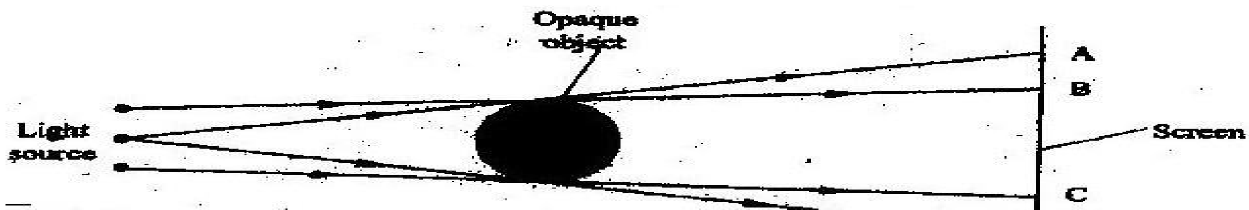


Figure 1

Explain the nature of the shadow formed along B and C.

19. State the number of images formed when an object is between two plane mirrors placed in parallel.

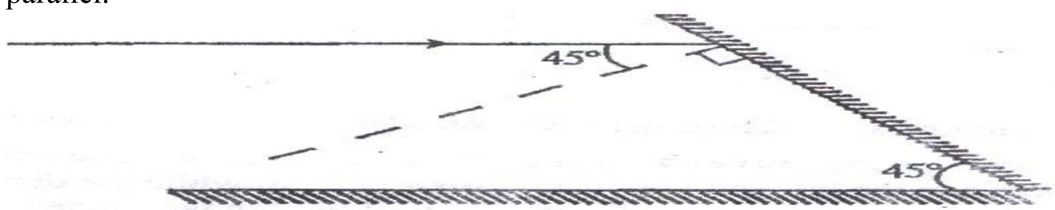


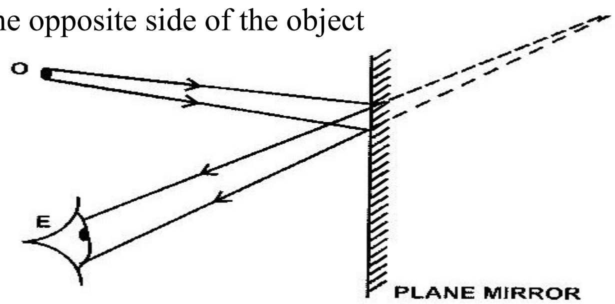
Figure 1

20. Figure 5 shows a ray of light incident on a mirror at an angle of 450. Another mirror is placed at an angle of 450 to the first one as shown .Sketch the path of the ray until it emerges

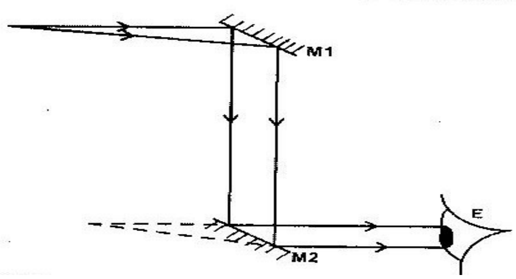
SOLUTION

(a) - Image that cannot be formed on screen.
- Always on the opposite side of the object

(b)

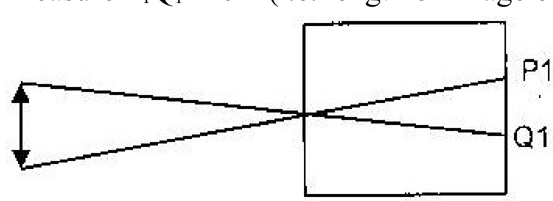


(c)



(d) Angle of rotation of reflected ray = 2(angle of rotation of mirrors)
$= 2x\ 30^0$
$=60^0$

(e) Measure P_1Q_1 in cm (i.e. length of image on the screen as shown below)



Divide this value by 3 seconds i.e. velocity = distance / time

(f) 4:05 p.m

(g) a) -Key form real inverted images

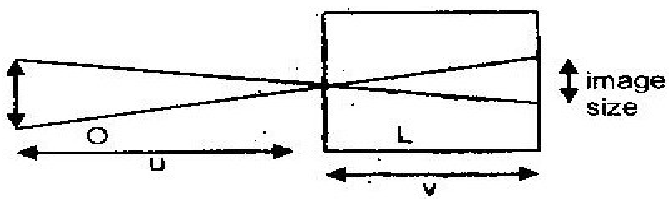
-Highly magnified images which give a wrong perception of object distance.

-Small field of view.

b) Very small images, giving the illusion that the objects are far away.

(h) Can from magnified, erected images.

(i)



Where O = object; h = pin-hole; u- Object distance; v- Image distance

(j) u =100m

h_i = 0.5cm

TOPIC 9: ELECTROSTATICS 1

This is the study of static charges. There are two types of charges i.e. **negative charge** and **positive charge.**
When a plastic ruler is brought near to small pieces of paper, it will be noted that it cannot be able to attract the small pieces of paper. This is because the ruler is electrically neutral.
When the ruler is rubbed against fur or hair the static charges becomes active. In this case, between the ruler and fur or hair they interchange charges whereby one becomes positively charged and the other negatively charged. Because of this the ruler is able to attract the small pieces of paper.
The SI unit of charge is coulomb (C). Millicoulombs and micro-coulombs are also used.
1000 millicoulombs = 1 coulomb
1000000 micro-coulomb = 1 coulomb

Origin of Charge

Matter is made up of atoms. An atom has particles known as protons, electrons and neutrons. Protons are **positively** charged, electrons are **negatively** charged and neutrons are neutral. Protons and neutrons are found at the centre and nucleus of the atom while electrons are found moving around the energy levels.
The nucleus has positive charge due to the charges on the protons. Electrons in the outermost orbit are weakly held by the nucleus and can be transfer easily from one material to another by rubbing.
The material that gains electrons becomes **negatively** charged and that which loses electrons becomes **positively** charged. A negatively or positively charged atom is called **an ion.**
Materials like polythene and plastic they acquire electrons when they are rubbed hence they become **negatively charged** while materials like acetate, Perspex and glass have their electrons removed from their surface when rubbed and they become **positively charged.**
In general origin of charge is based on the atom of any given substance; each atom contains protons, electrons and neutrons.

Basic Law of Charges

This law is based on the relationship between charges when they are brought near to each other. It states that **unlike charges attract while like charges repel.**

CHARGING MATERIALS

Materials can be charged by the following methods;

a. Induction
b. Contact
c. Separation

a) INDUCTION

This is the ability in which a body which is charged finds to influence another adjacent to acquire an opposite.

A positively charged material, when it is brought near to another uncharged material, it will influence another body to acquire some charge.

The positive charges in B which has been repelled are removed by the process of **earthing.**

Earthing is the process through which electrons are made to the ground or from the ground through a conductor.

In the above case when a conductor is connected to B, electrons will flow from the ground to neutralise the positive charges.

After the positive charges have been neutralised, the conductor in B is removed fast while the two bodies are maintained adjacent to one another. This is to enable the electrons in B to remain within that body but if you remove body A while the conductor is connected with B, those electrons in B will escape to the ground.

When body A and B are separated as far as possible the negative charges will distribute uniformly.

b) CHARGING BY CONTACT

In this method two bodies are brought directly into contact, because of this some charges are able to cross over between their surfaces.

In this method, one of the bodies must be charged. That charge will influence the other body to acquire some charge.

NOTE: When a body is charged by contact method, it acquires charges that are similar to the ones on the charging rod.

In the diagram above body A was charged positively and because of this charge when it is in contact to body B it attracts negative charges and repel with positive charge.

When the two are made to be in contact the negative charge in body B crosses to body A to neutralise part of its positive charge.

If this process continues with time the number of positive charges in A will reduce and the number of the positive charges in B will increase.

Finally when the two bodies are separated the positive charges in B will distribute uniformly.

c) CHARGING BY SEPARATION

In this case two uncharged bodies are brought near to charged material. By the process of induction the two bodies will acquire an opposite charge because of attraction and repulsion.

The positive charge in A influence negative charges in X because of attraction while it influences positive charges in Y because of repulsion.

NOTE: In order to sustain the two opposite charge in X and Y in the two bodies, they are first separated while the position in body A is maintained. Finally when they are separated the two bodies will distribute uniformly as shown.

THE ELECTROSCOPE

This is an instrument which works on the principle of electrostatic charges. It is also used for investigating the effects of electric charges.
The gold-leaf electroscope consists of a thin gold or aluminium leaf of plate connected to a metal rod that has a brass cap at the top as shown,

The cap acquires the charges through induction or contact and spreads it through the rod to the plate and leaf.
The cap is circular to ensure uniform distribution of charges.
Both the leaf and the plate show the presence of charges by repelling each other, making the leaf to diverge. The absence of charges is also shown when leaf divergence decreases.
Metal casing is for protecting the leaf from the effects of draught. The casing has a glass window through which observations are made.
The rod is supported by passing it through a plug of good insulating material such as rubber. The insulator stops charge given to the cap from spreading onto the case and leaking away. The casing may be a terminal connected to the earth.
When the electroscope is touched by a finger or connected to the earth by a wire, electrons either flow to the earth, depending on the charge on the electroscope.
The process of losing to or gaining charges from the earth through a conductor is called **earthing.**

- **Charging an Electroscope by Contact Method**

In this method, a charged body is brought into contact with the cap of the electroscope as shown in the figure below,

Because the positive charge on the rod are in contact with the negative charge at the cap, the two charges neutralise i.e. negative charges move to the rod and positive charge move to the cap.
It will be observed that at the leaf, the leaf diverges because of like charges at the point (positive charges).
The more positive charges at the leaf will make the leaf to diverge at a greater angle. If the process is continued, the electroscope will charge to a maximum point in which the leaf cannot diverge any further.
NOTE: The charged material coming into contact with the cap of the electroscope is an insulator. Only charges on the rod's surface coming into contact with the cap are used in neutralizing the charges induced on the cap.

- **<u>Charging Through Induction</u>**

In this method a charged body is brought near to the cap of the electroscope and because of attraction the cap is going to have opposite charge while at the leaf is going to have same charge because of repulsion as shown,

The positive charges at rod attract the negative charge at the cap and repel positive charge at the leaf. The positive charges at the leaf repel one another thus making the leaf to diverge through an angle.
In order to eliminate the charges at the leaf, one is required to earth the cap by the use of a finger or a wire while maintaining the position of the charging rod as shown;

Through earthing electrons are going to flow from the ground through the cap down the leaf to neutralise the positive charge hence making the leaf to fall.
These electrons when they are passing through the cap, they are not affected by the negative charge at the cap. This is because the negative charge at the cap and the positive charge on the rod are strongly attached because of attraction.
While maintaining the position of the rod removes the finger or the earth wire first in order to avoid the negative charge at the cap not to escape down to the ground.
Finally remove the positive charged rod away from the cap. Because of like charges at the cap they will repel one another in order to distribute uniformly on the cap and the leaf.
The negative charges which move to the leaf diverge once more indicating electroscope has been charged.

<u>ASSIGNMENT</u>

Use a negatively charged rod to explain how to charge an electroscope using induction method.

<u>USES OF THE ELECTROSCOPE</u>

(a) <u>To detect the presence of charge on a body</u>

-The material to be tested is placed on or close to the cap of the electroscope. If it is not charged, the leaf does not diverge.

(b) <u>To test the sign of charge on a charged body</u>

-Charge an electroscope negatively by contact method. Slowly bring a negative rod to be tested close to the cap of the electroscope. The leaf **diverges more.** It does so because the negative charges on the rod repel more charges from the cap to the plate and the leaf. Similar charges in the plate and the leaf are repelled more.

-When a strong positively charged rod is brought from high position towards a negatively charged electroscope, the leaf divergence first decreases then increases as the rod approaches the cap. The leaf divergence reduces slightly first because the positive on the rod attract negative charges on the leaf and plate, making the electroscope neutral. On moving the rod, much lower, the leaf divergence increases again to higher position. This is because the strong positively charged rod attracts more electrons from the plate and leaf, making them more positive. Hence, they repel further.

NOTE:

The same observations are made when a negatively charged rod is brought towards a positively charged electroscope. On moving a neutral conductor close to a charged electroscope, leaf divergence decreases. Charges on the electroscope induce opposite charges on the conductor.

Charge on the electroscope	Charge brought near the cap	Effect on the leaf divergence
+	+	Increase
-	-	Increase
+	-	Decrease
-	+	Decrease
+ or -	Uncharged	Decrease

An increase in divergence of the leaf is therefore the only sure way of confirming the kind of charge on a body.

(c) To test the quantity of charge on a charged body

-Small bodies have few charges compared to big ones of the same kind.

(d) To test for insulation properties of a material

-Materials like copper, iron, aluminium, zinc and graphite make the leaf divergence decrease. Materials like plastic, glass, charcoal and wood do not affect the divergence of the leaf. For metals and graphite, the leaf decreases in divergence because they allow electrons to flow between the electroscope and the earth. Such materials are called **conductors.** In conductors, electrons freely move from one atom to another. Such electrons are called **free electrons.**

For materials like plastic, glass, wood there is no change in leaf divergence because they do not allow electrons to flow between the electroscope and the earth. In these materials, electrons are not free to move and are strongly bound to their nuclei. These materials are called **insulators**. There are other materials like silicon and germanium which conduct under special conditions. This conductivity is between conductivity of insulators and conductors. Such materials are called **semi-conductors.**

CHARGES IN AIR

Air can also be charged. It is shown by heating air above a charged electroscope. It is observed that the leaf divergence decreases.

When fuel burns, chemical reactions yield ionised products. The ions move and collide with air molecules making air to be ionised. Ionisation produces both negative and positive charges.

The ions carrying opposite charge to the electroscope are attracted to the cap of the electroscope, resulting in the discharge of the electroscope.

APPLICATION OF ELECTROSTATIC CHARGES

- **Electrostatic precipitator**

It is used in industries to reduce pollutants. The figure below shows a common precipitator used in chimneys.

It consists of a cylindrical metal plate fixed along the walls of the chimney and a wire mesh suspended through the middle. The plate is charged positively at a potential of about 5000V while the wire mesh is negatively charged.
A strong electric field is set up between the plates, which ionises the particles of the pollutants. These are attracted to the plate.

- **Spray painting**

The can is filled with paint and nozzle charged. During spraying, the paint droplets acquire similar charges and therefore spread out finely due to repulsion.
As they approach the metallic body they induce opposite charges which in turn attract them to the surface. Therefore little paint is used.

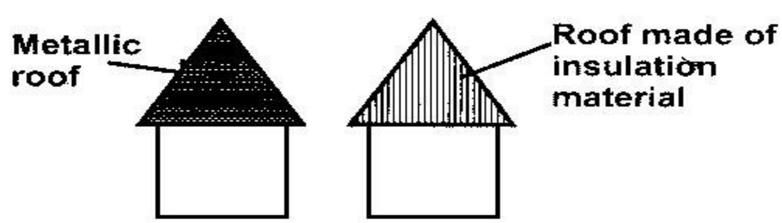
- **Finger printing and photocopying**

DANGERS OF ELECTROSTATICS

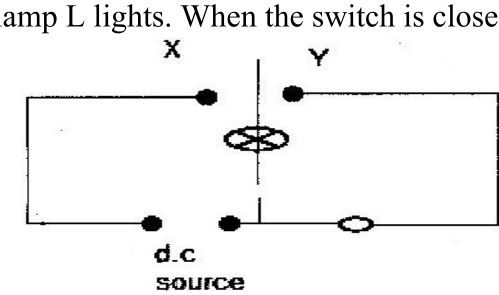
When a liquid flows through a pipe its molecules become charged due to rubbing on the inner surface of the pipe. If the liquid is inflammable it can cause sparks and explode.
Similarly, explosive fuel carried in plastic cans can get charged due to rubbing which may result in sparks and even explosion.
It is therefore advisable to store fuels in metal cans so that any charges generated continually leak.

QUESTIONS

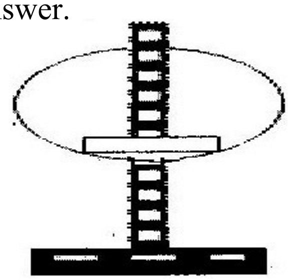
1. Explain why fuel tankers have a loose chain hanging under them to touch the ground as they move?
2. Why do some motor tyres contain graphite?
3. Two isolated and insulated spheres A and B carry the same positive charge. Sketch the electric lines of force of their field when placed close to each other but not touching some.
4. State the observation on the leaves of a positively charged electroscope when a negative charge is brought near it.
5. The fig shows sketches of two types of houses built in a lighting prone area. State with reasons, which house is safer to stay in during lighting and thunderstorms?



6. The diagram below shows a circuit with a capacitor C and a lamp L. When the sketch is closed at Y, the lamp L lights. When the switch is closed at X, L does not light. Explain the observation.



7. In the clothing and textile industries the machines experiences electrostatics forces at certain points. Suggest one method of reducing these forces.
8. State two other factors to be considered in constructing a capacitor other than the surface area of the plates.
9. State the precaution that is taken when charging a metal object.
10. (a) (i) State coulombs law of electrostatic force
    (ii) Define capacitance
    (b) Describe how the type of charge on a charged metal rod can be determined
    (c) The fig. Shows hollow negatively charged sphere with a metal disk attached to an insulator placed inside. State what would happen to the leaf of an uncharged electroscope if the metal disk were brought near the cap of the electroscope. Give a reason for your answer.

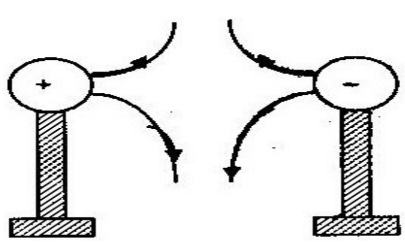


    (d) State two ways of charging the magnitude of the deflection of the leaf of an electroscope.
11. Explain why the leaf of an uncharged object is brought near the cap.
12. A glass rod can be charged positively by rubbing it with silk. Explain what happens when the glass rod is being charged.
13. State the law of electrostatic charges.
14. A positively charged rod is brought near the cap of a leaf electroscope. The cap is the earthed momentarily by touching with the finger. Finally the rod is withdrawn. The electroscope is found to be negatively charged. Explain how this charge is acquired.

SOLUTIONS

1. To induce/effect earthing process thus allows unnecessary charges to leak to the ground, causing neutralization of the charges. This prevents the formation of sparks which can cause explosion

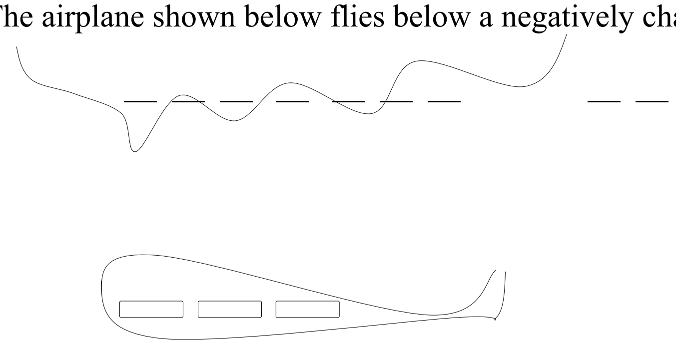
2. Graphite has free and mobile electrons. This causes neutralizations of the electrostatic charges.
3.



4. The leaf in the electroscope falls
5. Metal roofed house. Because there is less resistance of the flow of charges to the ground so if struck by lighting it would conduct it to the ground. The other one would burn or have the people inside struck by the lightening.
6. At x the capacitor is charged only once and the keeps charging and discharging in opposite directions hence current keeps alternating at the a.c frequency. This lights the bulb continuously.
7. Earthing the machines/using spikes.
8. Material used between the two plates of the capacitor.
9. Well insulated / avoid touching
10. a)Ability to store charge given by the quantity of charge it can store per unit p.d
b) Bring it near a charged electroscope (say +vely). If not, charge the electroscope – vely and bring the rod near. If divergence is observed then they have the same charge. Note that if decrease in divergence is observed in both cases then the rod is simply a conductor and it's not charged.
c) Nothing would happen to the leaf of the electroscope. This is because in a hollow charged conductor, the charged conductor and not inside
d) - Earthing or using another
- Charged body
14. Like charges repel unlike charges attract.
15. On earthing negative charges flow to the leaves from earth to neutralize positive charges when the rod is withdrawn the leaves are left with net negative charge.

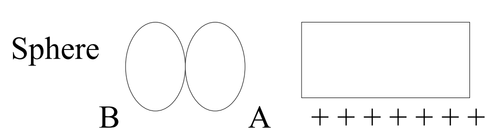
MORE QUESTIONS

1. (a) The airplane shown below flies below a negatively charged thunder cloud.



(i) On the diagram draw on the positions and signs of the induced charges on the aircraft
(ii) Explain, in terms of the movement of electrons, the distribution of the charges as shown in (i)
(iii) What would happen to the induced charges when the air craft flies away from the cloud?

2. Two identical uncharged conducting spheres, each of which is on an insulating support, are placed as shown below. The spheres are electrically in contact.



A positively charged rod is now moved close to the set up. The sphere B is then moved a distance away to the left. Finally the charged rod is removed.

(i) What type of charges do the sphere A and B acquire.

(ii) Explain how the charges were acquired.

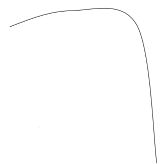
(iii) In what way, if any, would the final arrangement of he charges have been different if initially the charged rod would have been negatively charged?

3. (a) The diagram below shows sphere A and B which are conductors.

\+ + + + A B

\+ +

Insulators



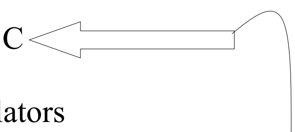
Sphere A is charged to a high positive charge and B is connected to the earth and close to A. Draw a diagram showing the resulting change distribution on B.

(b) B is replaced by the earthed metal needles C which is the same distance from A as was B.

\+ + + + A C

\+ + + +

Insulators



Draw a diagram to show the charge distribution on C, and explain why in this case A loses its charge more quickly.

(d) Lightning conductors with pointed tops are put on high buildings to prevent them from being damaged by lightning but it is foolish to walk across an open space carrying an open umbrella in thundery conditions. State the physical reasons for the above statement.

4. Given an earthed gold leaf electroscope and a positively charged Perspex rod describe using diagrams how you would charge the leaf electroscope, include, observations and explanations.
5. Why is it difficult to clean nylon carpets?
6. A charge polythene rod is brought close to, but not touching, the lap of an uncharged electroscope.
    a. State what happens to the leaf. Why?
    b. The polythene rod is then removed. State and explain what happens.
7. A charged Perspex rod is firmly slid across the edge of the metal cap of a leaf electroscope.
    a. State and explain what happens to the leaf.
    b. The Perspex rod is then removed. State and explain what happens to the leaf.
8. A Van-der- Graff generator is charged to a maximum, a point at which the machine starts sparking. A student approaches the dome with a pointed metal pin in her hand. Explain why the machine stops sparking?
9. While standing on an insulator and touching the charged dome of a van- der –Graff generator a student aimed the pointed end of a pin at a candle flame.

To Van der Graff dome. Candle flame

Pin

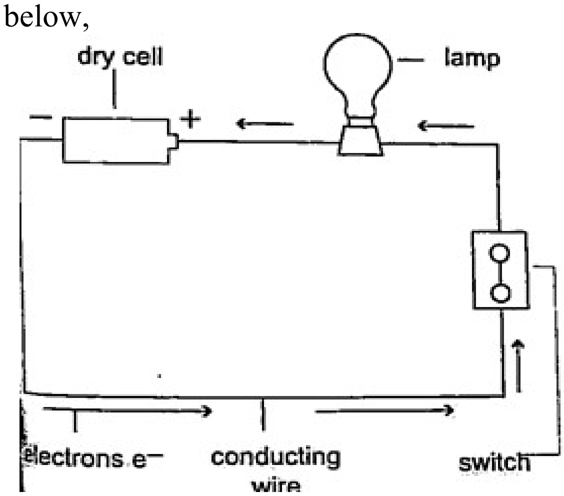
Describe and explain what happens to the candle flame.

CELLS AND SIMPLE CIRCUITS

Electrical energy is commonly used in various applications e.g. in operating devices like televisions, radios, telephones, computers and high speed trains.
We also use electrical energy in producing heat and light. The transfer of energy is due to the flow of electrons.
The complete path along which the charges flow is called **electric circuit.**

A SIMPLE ELECTRIC CIRCUIT

A simple electric circuit consists of a dry cell, a torch bulb, a switch and connecting wires connected as shown below,



It is observed that when the switch is closed, the bulb lights.

EXPLANATION
The bulb lights because charges are flowing through it in a given time. The rate of flow of charges (charge per unit time) is called **an electric current.**
The SI unit of current is ampere (A).
From definition,
Current, $I = \frac{Q}{t}$ where I is current, Q is charge in coulombs and t is time in seconds.

EXAMPLE 1

Calculate the amount of current flowing through a bulb if 300 coulombs of charge flows through it in 2.5 minutes.

SOLN
$I = Q$

$$= \frac{300}{2.5 \times 60}$$

$$= 2.0\ A$$

EXAMPLE 2

A charge of 180 Coulombs flows through a lamp every minute. Determine the current flowing the lamp.

SOLN

$$I = Q/t$$

$$= \frac{180}{1 x 60}$$

$$= 3A$$

EXAMPLE 3

A battery circulates charge round a circuit for 1.5 minutes. If the current is meld at 2.5 A, what quantity of charge passes through the wire.

SOLN

Charge, $Q = It$

$= 2.5 \times 1.5 \times 60$

$= 225\ C$

EXAMPLE 4

If the current in a circuit is 2A, calculate:

a) The charge that crosses a point in the circuit in 0.6s.
b) The number of electrons crossing the point per second. Take $e=1.6 \times 10^{-19}$C.

SOLN

a) $I = Q/t$

$Q = It$

$= 2 \times 0.6 \quad =1.2C$

b) $I = Q/t = ne/t$

$1.2/0.6 = (n \times 1.6 \times 10^{-19})/0.6$

$N = 1.2/ (1.6 \times 10^{-19})$

$= 7.5 \times 10^{18}$ electrons.

EXAMPLE 5

A charge of 180C flows through a conductor for 3 minutes. Calculate the current flowing through the conductor.

SOLN

$I = Q/t$

$= 180/ (3 \times 60)$

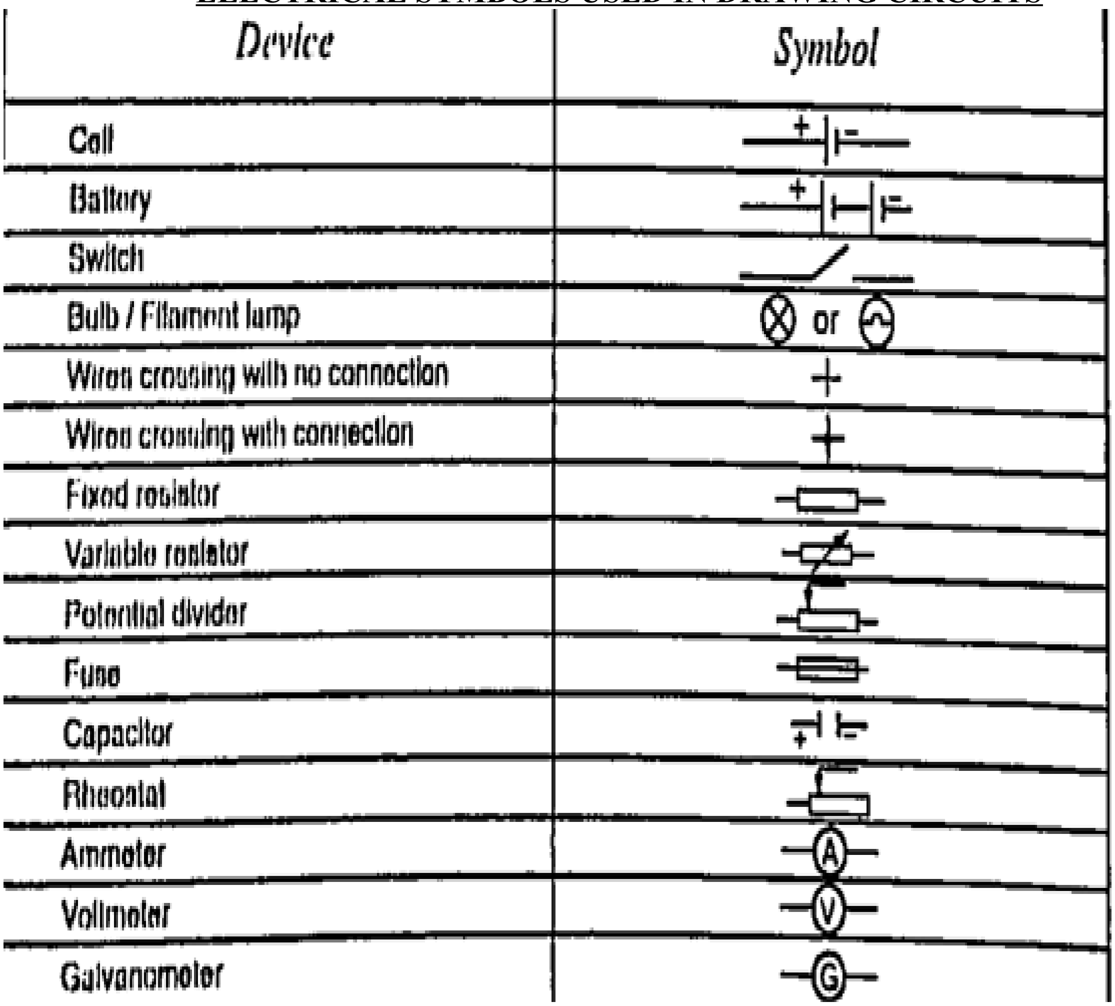
$= 1A$

An electric current circuit like the one shown above allows charges to move in a complete path when the switch is closed. This circuit is said to be **closed circuit.** Therefore, a closed circuit is one in which the switch is closed such that the current flows in a complete loop.

Copper wire readily allows electric charges (mainly electrons) to flow. The wires may be covered by an insulating material like rubber to prevent the user from electric shock if the current is too high.

The cell is the source of electrical energy in the circuit and maintains the flow of charges round the circuit.
When the gap is introduced, by opening the switch the charges stop flowing.
The circuit is then said to be **open (broken circuit).** Loose connection of wires or components in the circuit opens the circuit.
For clarity and neatness, symbols are used in representing an electrical circuit as shown,
The arrow heads indicates the direction of electric current.

ELECTRICAL SYMBOLS USED IN DRAWING CIRCUITS



Device	Symbol
Cell	
Battery	
Switch	
Bulb / Filament lamp	or
Wires crossing with no connection	
Wires crossing with connection	
Fixed resistor	
Variable resistor	
Potential divider	
Fuse	
Capacitor	
Rheostat	
Ammeter	A
Voltmeter	V
Galvanometer	G

DEVICE	**USE**
• Cell	-Provides the driving force for charges
• Battery	-More than one cell
• Switch	-Opens or closes the electric current
• Bulb/filament	-Shows the brightness of the current flowing
• Wires crossing with no connection	-Used for connection
• Wires crossing with connection	-Used for connection
• Fixed resistor	-Provides resistance to the flow of current
• Variable resistor	-Increase or decrease the amount of current

- Potential divider - Controls the amount of current in the circuit
- Fuse -Control the amount of current passing in a circuit
- Capacitor -Used to store charge
- Ammeter -Measuring amount of current in a circuit
- Voltmeter -Used to determine the potential difference between two points in a circuit.
- Galvanometer - To detect the direction of the flow of current
- Rheostat - Controls the amount of current in circuit

ELECTROMOTIVE FORCE AND POTENTIAL DIFFERENCE

The purpose of a cell/battery in a circuit is to provide energy to cause charges to flow.
This is measured in terms of potential difference (p.d) in volts. The force that pushes electrons around the circuit is voltage.
Potential difference-is the voltage measured across a cell/battery when supplying current. It can also be defined as the voltage across the cell/battery in a closed circuit. Remember, a closed circuit is the one in which the switch is closed such that current flows in a complete loop.
Therefore, in a closed circuit, the voltmeter readings will give the potential difference of the battery.
Electromotive force (e.m.f)
It is also measured in volts.
Electromotive force is the voltage across a cell/battery when it is not supplying current. It can also be defined as the voltage across the cell/battery in an open circuit.
Therefore, in an open circuit, the voltmeter readings will give the electromotive force (e.m.f) of the battery.
Electromotive force (e.m.f) is slightly greater than potential difference because some of the energy is used in drilling current across the cell itself.
The difference between electromotive force (e.m.f) and potential difference (p.d) is called **lost volts.** The voltage is lost because of the opposition to the flow of charges within the cell (internal resistance).

ARRANGEMENT OF CELLS

We have two types or forms of arrangement of cells

a) Series arrangement
b) Parallel arrangement

CELLS IN SERIES

This is when cells are connected such that the positive terminal of one is joined to the negative terminal of another one. Two or more cells connected in series make a battery, i.e. the figure shows two cells in series, Suppose three cells each of e.m.f 1.5V are connected in series, then the total e.m.f of the circuit is the sum of the e.m.f of the three cells. In series arrangement of cells, a positive terminal of one cell is connected to the negative terminal of the next cell. The current flowing through the circuit will be higher and hence the bulb would be brighter than when it would have been a single cell.

ADVANTAGE

Higher voltages can be achieved since the effective (total) voltage is the sum of each voltage.

EXAMPLE 6

5 cells of electromotive force (e.m.f) 1.2V are connected in series. What is the effective voltage?

SOLN

$V_T = (5 \times 1.2)$ V

$= 6$V

DISADVANTAGE

Current is supplied for only a short time. This is because the cells produce a higher resistance to the flow of the current.

CELLS IN PARALLEL

This is when cells are placed side by side. The positive terminals is connected together and the negative terminals also connected together as shown,

In this case, the bulb uses an e.m.f equivalent to the e.m.f of one cell. The current flowing in the circuit will also be lower. The advantage this method of connection has over series connection is that it can supply current for a longer time. The total voltage is equal to that of a single cell in a parallel connection.

EXAMPLE 7

4 cells of e.m.f 1.5V each are connected in parallel. What is the effective e.m.f?

SOLN

$V_T = 1.5$ V

ADVANTAGES

- The current is supplied for a long time since resistance is low.
- It produces more current compared to series connection.

DISADVANTAGE

- Lower voltages are produced.

NOTE: The ammeter is always connected in series while the voltmeter is connected across the cells. (Parallel)

To investigate the current flowing in a circuit when devices are arranged in series and parallel

Consider the two set ups below,

(a) Series arrangement of bulbs (b) parallel arrangement of bulbs

In (a), the bulbs have been connected in series. In this case, the current flowing through the bulbs is the same and is equal to the circuit current. The sum of the voltage drop across the bulbs is equal to the total circuit voltage. When one bulb is faulty, the remaining bulbs will stop working since the circuit will be incomplete.

In (b) where the bulbs have been connected in parallel, the voltage drop across the bulbs is the same and is equal to the voltage supplied by the cell. The sum of the current through the individual bulbs is equal to the circuit current. The advantage of this method of connection is that when one of the bulbs is faulty the remaining bulbs will still be working.

EXPLANATION

The same current flows through the devices connected in series. If one of the devices is disconnected, it introduces an open circuit. Electrical devices connected in series offer greater opposition to flow of current.

For devices connected in parallel, the current flowing in one does not affect the current flow in other devices. If one of the devices causes an open circuit, current will still flow in other devices. This method is commonly used in wiring of lighting circuits in houses.

In domestic electrical wiring (lighting circuit), bulbs are connected in parallel as shown below,

S_1 S_2 S_3

To the Supply

B_1 B_2 B_3

The three bulbs can be switched on or off independently and if one bulb blows off, it does not affect other bulbs.

EXAMPLE 8

Study the figure below and answer the questions

Explain what happens, indicating the path of current when;

a) S_1 is closed while S_2 and S_3 are open.
b) S_2 is closed while S_1 and S_2 are open
c) S_1 and S_2 are closed while S_3 is open
d) S1 and S3 are closed while S2 is open
e) S_2 and S_3 are closed while S_1 is open

SOLN

a) B_2 lights because it is in a closed circuit while B_1 and B_3 does not light.
   Path of current; O P R S U
b) B_1 and B2will light because they are in closed circuit. The bulbs are less bright since they are in series.
   Path of current; O P R S T U
c) Bulb B_2 lights brightly. B_1 does not light since it is short-circuited. B_3 is in an open circuit.
   Path of current; O P R S U
d) B_1 does not light (open circuit).B_2 and B_3 are in closed parallel circuit. They light with the same brightness.
   Path of current is; O P R S U and O P Q R S U
e) The three bulbs light. B_1 is brighter than B_2 and B_3.B_2 and B_3 share the current flowing through B1.
   Path of current; O P R S T U and O P Q R S T U

CONDUCTORS AND INSULATORS

Conductors – These are materials which can conduct electricity. They allow electric charges to pass through them e.g. copper, silver and aluminium.
Insulators – These are materials which do not allow electric charges to pass through them e.g. plastic, rubber and dry wood. They cannot be used in connection of circuits.
Conductors can either be good or poor. Examples of good conductors are copper, silver and aluminium. An example of poor conductor is graphite.
Generally metals are good conductors of electricity. They have large number of free electrons moving randomly within them. When a cell is connected across the ends of a conductor, the free electrons move in a given direction.
When electrons are made to drift in a given direction, current is said to be flowing through the conductor. Current is taken to flow in the direction opposite to that of electron flow. Poor conductors (e.g. graphite) have fewer free electrons.
Insulators have their electrons tightly bound to their nuclei of their atoms.
Because they cannot conduct electric current, insulators are used as cover materials for good conductors.
Semi-conductors – Their electrical properties fall between conductors and insulators e.g. silicon and germanium.
Electrolytes – These are liquids which are good conductors of electric charge e.g. dilute sulphuric acid, sodium chloride solution and potassium hydroxide.

SOURCES OF ELECTRICITY

The main sources of electricity presently are chemical cells, batteries, generators and solar cells/panels. Other sources include:

(i) Thermocouples
(ii) Some crystals when under pressure (piezo effect)

CHEMICAL CELLS

A chemical cell provides the energy needed to drive an electric current in a circuit. It consists of two different metals called **electrodes** and a conducting liquid called **electrolyte.** The chemical energy stored in the cell is converted into electrical energy when an electric current flows in the circuit. Chemical cells are classified as either **primary cell** or **secondary cell.**
Primary cells cannot be renewed once the chemicals are exhausted while **secondary cells** can be renewed by recharging.

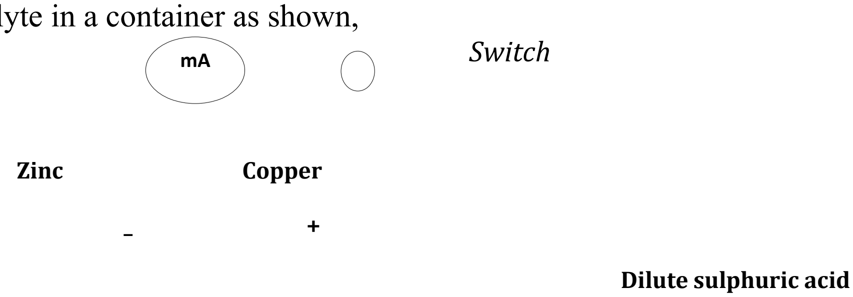
1) PRIMARY CELLS

In primary cells, chemical energy is directly changed into electrical energy.
Consider the set up below,

The voltmeter pointer deflects showing existence of an electromotive force (e.m.f) across the two plates. The voltmeter drops after a short time.
The two metal plates used must have different rates of reaction when immersed in the lemon fruit. In this case zinc is more reactive than copper thus when immersed in an acid such as citric acidic in lemon, an e.m.f is set up at the ends of the metals.

SIMPLE PRIMARY CELL

Simple primary cells consist of zinc and copper plates as electrodes and dilute sulphuric acid as the electrolyte in a container as shown,



Working of a simple cell

Dip zinc and copper plates into a beaker containing dilute sulphuric acid.
Connect the two plates to a bulb. Observe what happens to the bulb immediately when it is connected.
Allow the set up to run for sometime and note what happens to the bulb.

OBSERVATION

When the bulb is connected it lights brightly but dims after sometime. Bubbles form around the copper plate.
When potassium dichromate is added into the container, the bubbles on the copper plate disappear and the bulb brightness is restored.

EXPLANATION AND DEFECTS OF A SIMPLE CELL

The hydrogen ions in the electrolyte pick up electrons and form an insulating layer of hydrogen gas bubbles around the copper plate making it difficult for the electrons to flow. This is what causes the bulb to be dim. The process by which hydrogen bubbles form around the copper plate is called **polarisation.**

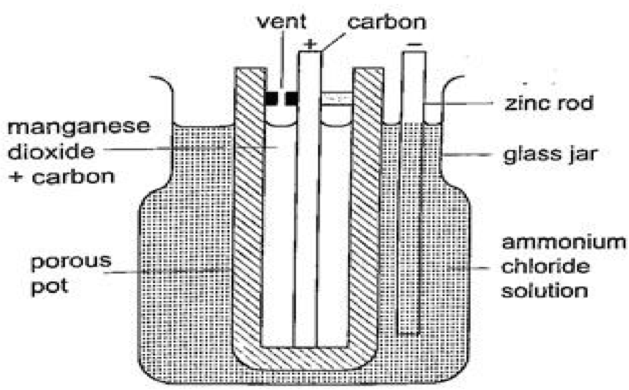
Polarisation can be minimized by adding **a depolarizer** e.g. potassium dichromate. A good depolarizer should not react with the electrolyte.

When zinc reacts with sulphuric acid, it dissolves and exposes hidden impurities of carbon and iron. These impurities form small cells called **local cells.** These local cells cause the zinc to be used up even when current is not being supplied.

This defect is called **local action.** It is minimized by applying a layer of mercury on the zinc plate. This process is called **amalgamation.** In this process mercury dissolves off zinc leaving the impurities buried in the electrode. It can also be minimized by use of **pure zinc.**

THE LECLANCHE' CELL

The leclanche' **cell** is an improvement of the simple cell. The defects of polarisation and local action have been minimized.



The carbon rod (positive terminal) is surrounded with manganese (IV) oxide mixed with carbon powder. **The manganese (IV) oxide** acts as a depolarizer, reacting with the hydrogen gas formed on the carbon rod to produce water. This process however is slow and hence large currents should not be drawn steadily for a long time. **Carbon powder** increases the effective area of plate, which in effect reduces opposition to the flow of current.

The zinc plate is dipped in ammonium chloride solution, which converts zinc to zinc chloride when the cell is working. Local action is still a defect in this cell.

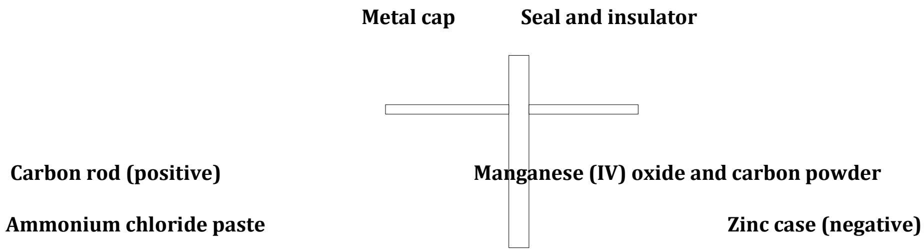
The cell is used for purposes where current is not drawn from it for a very long time e.g. in operating bells and telephone boxes. It has a longer life span than the simple cell.

THE DRY CELL

This is referred as a dry cell because it has no liquid. The ammonium chloride solution in the leclanche' cell is replaced with ammonium chloride jelly or paste.

Manganese (IV) oxide and carbon powder act as a depolarizer. The hydrogen gas produced is oxidized to form water, making the cell to become wet after being used up.

The zinc case acting as a negative electrode gets eaten away by ammonium chloride to form zinc chloride. Local action is still a defect in this cell. The cell cannot be renewed once the chemical action stops.



NOTE: Large currents should not be drawn from the dry cell within a short time. Shorting its terminals can also ruin it.

The cells must be stored in dry places. They are used in radios, torches, calculators, e.t.c

ASSIGNMENT

Write advantages and disadvantages of dry cells

2) SECONDARY CELLS

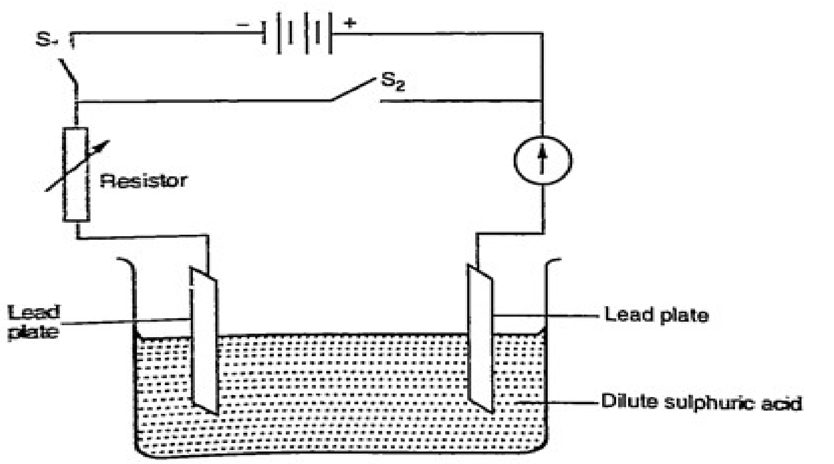
A secondary cell stores electrical energy in a chemical form. It must first be charged with electricity.

The chemical reactions in a secondary cell are reversible i.e electrical energy produced during charging is changed to chemical energy and stored in the cell.

When the cell is in use the stored chemical is once again changed to electrical energy.

MAKING A SIMPLE SECONDARY CELL

Dip two clean plates into a beaker containing dilute sulphuric acid. Connect the circuit as shown below,



Close the switch and allow the current to flow for sometime.

OBSERVATION

The lead plate connected to negative terminal of the battery becomes coated with a chocolate brown colour. The other plate remains grey. Gas bubbles are seen on the plates.

EXPLANATION

Sulphuric acid is electrolysed, giving off oxygen at the anode and hydrogen at the cathode. The oxygen reacts with the lead to give lead (IV) oxide, which is deposited at the anode.

Hydrogen gas formed at the cathode has no effect.

LEAD-ACID ACCUMULATOR

This is the most reliable, long lasting and cost-effective of the secondary cells.
A 12V lead acid accumulator has six cells connected in series. Each cell has several plates made in the form of a lattice grid, the positive plate carrying lead (IV) oxide and the negative plates having spongy lead.
The plates are very close to one another and are prevented from getting into contact (short circuiting) by having insulating sheets separating them.
The surface area and the number of plates in a given cell determine the current carrying capacity of the battery. The charge (electrical energy) stored is directly proportional to the surface area of the plates.
The container used in the construction of the lead acid accumulator must be mechanically strong, highly acid proof with insulating properties.
As electrical energy is taken from the cell, sulphuric acid reacts with lead (IV) oxide and lead to form lead sulphate (white solid). This makes the density of sulphuric acid to fall. When the density of sulphuric acid falls, the cell cannot provide any more electrical energy and is said to be **discharged.** To regain energy, the cell is recharged by connecting a direct current (d.c) source When connected in this manner, chemical reactions are reversed. The density of sulphuric acid is restored. The lead sulphate is converted to lead and lead (IV) oxide. The charging is complete when hydrogen and oxygen bubbles are freely released from the plate.

CAPACITY OF LEAD – ACID ACCUMULATOR

The capacity of the lead-acid accumulator is the total amount of current that can be drawn in a given time from the battery. This is the total amount of charge,

$Q = It$ expressed in Ah.

Lead-acid accumulators give strong current over along time compared to other cells because of an effective low internal resistance.

EXAMPLE 9

A battery is rated at 30Ah. For how long will it work if it steadily supplies current of 3A?

Amount of charge, $Q = It$ but $I = 3A$ and $Q = 30Ah$

$30 = 3t$

$T = 10hrs$

Maintenance of Accumulators

i) The level of the electrolyte should be checked regularly and maintained above the plate.
ii) The accumulator should be charged when the e.m.f of the cell is below 1.8V and when the relative density of the acid is below 1.12.
iii) Large currents should not be drawn from the battery for a very long time.
iv) The accumulator should not be left in a discharged condition for a long period.
v) Shorting or overcharging the accumulator the accumulator should be avoided.
vi) The terminals should always be kept clean and greased.
vii) The accumulator is not placed directly on the ground but not on an insulator.

ALKALINE ACCUMULATORS

The electrolyte in this case is an alkaline solution such as potassium hydroxide.
The common types are nickel-cadmium and nickel-iron accumulators.

Advantages of Alkaline Accumulators over Lead-Acid Accumulators

- Large currents can be drawn from them.
- Can be kept in a discharged condition for a very long time before the cells are ruined.
- They require little attention to maintain.
- They are lighter (portable).

Disadvantages

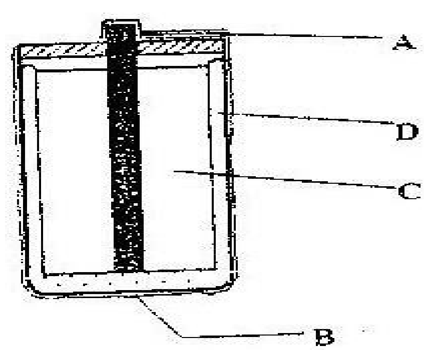
- They are very expensive.
- They have a lower e.m.f per cell.

Uses of Alkaline Accumulators

They are used in ships, hospitals and buildings where large currents might be needed for emergency.

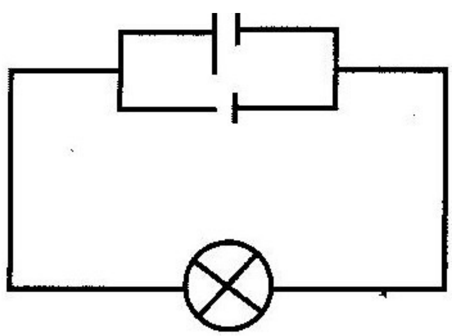
QUESTIONS

1. In a simple cell, the zinc plate gets negatively charged and the copper plate gets positively charged.
    a) Name the electrolyte in the cell.
    b) Explain how :(ii) Zinc gets negatively charged. (ii)Copper gets positively charged.
    c) State what constitutes the current when a wire is used to connect the zinc and the copper plate externally?
2. A student wishes to investigate the relationship between current and voltage for certain device X. In the space provided, draw a circuit diagram including two cells, rheostat, ammeter, voltmeter ad the device X that would be suitable in obtaining the desired results.
3. In large current circuits large resistors in parallel are preferred to low resistors in series explain
4. Fig 1shows the features of a dry cell



    a) State the polarities of the parts labeled A and B. Page 110 of 162
    b) chemical substance in the parts labeled C and D
5. State one advantage of an alkaline cell over a lead – acid cell.

6. A car battery requires topping up with distilled water occasionally. Explain why this is necessary and why distilled water is used.
7. A current of 0.5A flows in a circuit. Determine the quantity of charge that crosses a point in 4 minutes.
8. State the reason why a voltmeter of high resistance is more accurate in measuring potential differences, that one of low resistance.
9. A student learnt that a battery of eight dry cells each 1.5V has a total e.m.f of 12V the same as a car battery. He connected in series eight new dry batteries to his car but found that they could not start the engine. Give a reason for this observation
10. Distinguish between a primary cell and a secondary cell.
11. What current will a 500Ω resistor connected to a source of 240V draw?
12. A current of 0.08A passes in a circuit for 2.5 minutes. How much charge passes through a point in the circuit?
13. In large circuits, large resistors in parallel are preferred to low resistors in series. Explain.
14. State two advantages of an alkaline battery over a lead acid battery.
15. A current of 0.5A flows in a circuit. Determine the quantity of charge that crosses a point in 4 minutes.
16. State the purpose of manganese dioxide in a dry cell. (1 mark)



17. A student wishes to investigate the relationship between current and voltage for a certain device X. In the space provided, draw a circuit diagram including two cells, rheostat, ammeter, voltmeter and the device X that would be suitable in obtaining the desired results.
18. State one advantage of an alkaline cell over a lead acid cell
19. Explain clearly the precautionary measures you would take to maintain the efficiency of an accumulator?
20. State the advantage of Nickel-cadmium battery over the lead -acid type
21. Draw a well labeled diagram of a dry cell
22. When ammeter is connected between the two plates of a simple cell, the pointer deflects along the scale. Explain

SOLUTIONS

1. Dry cells have a very high internal resistance hence give very little current that start a vehicle.
2. Secondary cells are rechargeable while primary are not.
3. Q = it =0.08 x 2.5 x 60 =12c.
4. When connected in parallel, the total effective resistance is much less. The heating effect is reduced.
5. Large amounts of current can be drawn from them without damaging them while in lead acid batteries.
6. Q = It

   = 0.5 x 4x60

   = 120C

7. The overall resistance of cells and bulb is least and hence more current flows
8. Each will provide about half of the power supplied to the bulb. So they are drained of power at a slower rate than rate than in figure 10(a).
9. To oxidize hydrogen to water hence reduces polarization/internal resistance.
10. - Alkaline cell last longer than lead acid cell.
    - Alkaline is more rugged than lead acid cell.
    - Alkaline cell is lighter than lead acid cell.

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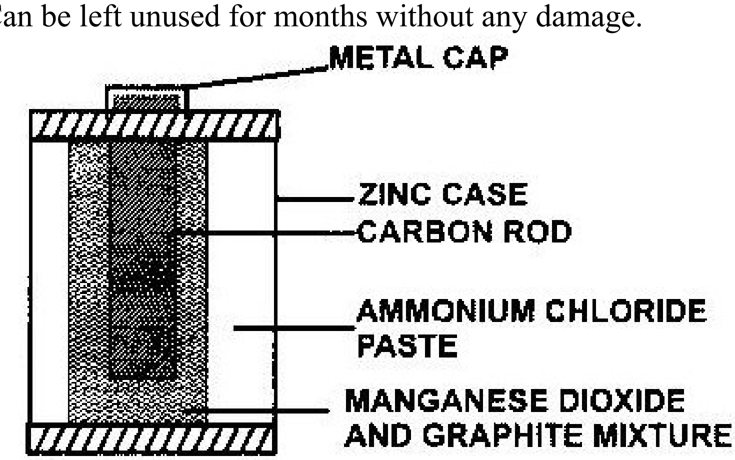
11. i)T he level of the acid in the accumulator should be inspected regularly. Add distilled water.
    ii)T he terminals should be kept clean and smeared with grease.
    iii) While charging the current used should be that specified by the manufacturer.
    iv) The level of acid should be maintained 1cm above the plates.
12. -They have a much longer life than the lead-acid ones.
    -They supply larger amounts of current and for a longer period.
    -Can be left unused for months without any damage.
13.



14. Electrical energy is produced by chemical reaction between the plates of the cell (Zinc and copper) and the dilute sulphuric acid. Electrons are produced which flow on the external circuit and detected by the ammeter.

MORE QUESTIONS

1. The circuit below shows lamps in parallel.

iv) Indicate on the diagram with an S where you would put a switch to control both lamps together.

v) Indicate on the diagram with a K_1 and K_2 position of these two switches that each would control each lamp separately.

2. What is the role a variable resistor in a circuit?
3. Draw a circuit diagram to show how two 4V lamps can be lit with normal brightness from two 2V cell.
4. A form one student made an electric circuit the one shown below.

Cells

Lamps

Ammeter

(i) Are the lamps in series or parallel?

(ii) State the mistake made by the pupil in the circuit.

5. What is polarization? State how it affects simple cells and how it can be prevented. State another defect of a simple cell and it is prevented.
6. State the purpose of manganese dioxide in a dry cell.
7. State the materials that act as positive and negative plates of a dry cell?
8. State the difference between primary and secondary cells. Give an example of each.
9. State three cares given to lead acid batteries.
10. Why must lead acid cells not be left flat for a length of time.
11. How would you check the state of charge of a lead acid?
12. State one advantage and one disadvantage of a lead –acid?
13. Define the capacity of a cell or battery and state its SI unit.
14. What is local action of a cell and how it is prevented?

15. Distinguish between primary and secondary cell.
16. In the circuit below the bulbs are identical

S_1

S_2

S_3

State and explain the change in brightness of the bulbs in the circuit as the switches S_1 and S3 are gradually switched on in turn.

17. State the relationship between current and charge.
18. If a lightning strike has an average current of 100,000A and carries a charge of 20C to the earth, how long does the strike last?
19. The charge on an electron is 1.60 x10 $^{-19}$C. A copper wire carries a current of 1A for 2 seconds. Calculate the number of electrons that passed in the 2 seconds.
20. State one advantage of a lead acid accumulator over a nickel iron (NiFe) accumulator.
21. Explain how polarization reduces current in a simple cell.
22. Name the instrument used for measuring potential difference.
23. Define electric current.
24. Currents of 3A, 4A and 2A flow into a junction in a parallel circuit. What is the current flowing out of this junction?
25. The diagram below shows identical lamps connected to identical cells.

P Q

State and explain the circuit that lights the lamp the longest.

26. State the purpose of the manganese dioxide in a dry cell.
27. The diagram below shows three identical lamps P, Q, R connected in series to a 12V dc power supply.

X

P **Q** **R**

Y

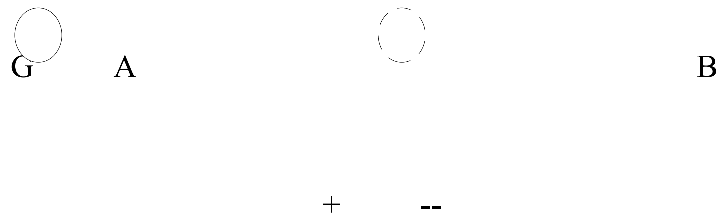
\+ - -

(i) Calculate the voltage across each lamp.
(ii) A wire is connected across X and Y. What is the new voltage across each lamp?

(i) P ____________ (ii) Q ___________________ (iii) R ______________

(iii) Is the brightness of each lamp less than, the same as , or greater than before the connection X Y made? Explain your answer. 2mks)

28. State the name of the electrolyte in a Leclanche cell.
29. What material makes the positive rod of a dry cell?
30. In a simple cell with sulphuric acid as the electrolyte, explain briefly how current is able to pass through the liquid.
31. A car battery requires topping up with distilled water occasionally. Explain why topping is necessary and why distilled water.
32. Define coulomb.
33. Draw in the electrical circuit symbols for .(i) Cell (ii) rheostat
34. Describe a complete circuit.
35. Name the instrument used for measuring current in a circuit and state how its connected to measure the current.
36. Name the instrument used for measuring potential difference and state how its connected to measure the potential difference.
37. State what happens to the chemical materials in a cell as it produces current .What is the effect of this?
38. Name the liquid used in a simple cell.
39. From which plate to which plate do electrons flew in a simple cell to constitute an electric current.
40. Describe an open circuit.
41. Describe the two ways in which hydrogen gas bubbles weaken the current during polarization in a simple cell.
42. Why the electric current produced by a simple cell quickly does falls to zero.
43. How is polarization in a simple cell overcome?
44. State what causes the zinc plate in simple cell to be wasted.
45. How is the effect stated in (Q) 14 overcome?
46. State one advantage of dry cells.
47. State the main disadvantage of primary cells.
48. Describe secondary cells.
49. State what happens to the sulphuric acid as the secondary cell gives current.
50. State the instrument which is used to check on the condition of an accumulator.
51. How is an accumulator connected when being charged?
52. State three precautions to be taken in maintaining accumulators in good condition.
53. The capacity of an accumulator 120n Ah. What does this mean?
54. State the energy changes in cell as they provide current.
55. (a) When the apparatus shown below is set up, the small conducting sphere swings repeatedly between the two plates and a current of 7.0×10^{-6} A is recorded by galvanometer.



(i) What particles are responsible for transferring charge round the circuit ?

(ii)Explain in terms of charges why the sphere moves from plate A to plate B repeatedly.

(iii) The sphere makes thirty five complete swings per second. Calculate the average charge transferred by each complete swing.

(b) The diagram below shows a series circuit.

mA

+ --

A current of 2mA flows around the circuit.

(i) State the charge carries present in the liquid.

(ii) How much charge passes through the liquid in?
- (i) 10s
- (ii) 3min.

56. A form three student suggested that a battery which has gone flat can be revived by placing it in a warm environment. Describe an experiment which would help you investigate the above suggestion. In your answer include;
    - a) Suitable means of warming the battery.
    - b) How you would carry out the experiment safely.
    - c) A table showing the readings you would record.
    - d) A statement of the treatment of results.