S.1 PHYSICS NOTES

WHAT IS PHYSICS?

Physics is a branch of science which deals with matter in relation to energy.

Physics involves the study of the physical universe called physical science. Physical science is mainly about non- living matter. There two types of physical science:

- Physics
- Chemistry

and how they affect each other. Physics tries to explain how things work and why things happen. People who do physics are called **physicists**. They do practical investigations or experiments on many problems or aspects of life. They gather all known facts about a problem and come out with a possible solution called a **hypothesis**. Hypothesis is a scientific statement that has not been proven to be true. When hypothesis has been a test of time, it becomes a theory, if a theory is proved beyond any reasonable doubt it becomes a law or principle e.g. Newton's law of gravitation (gravity). The hypothesis enables scientists to proceed with further measurements until they become generally accepted theories. In physics, these generally accepted conclusions become the laws or principles and theories. The laws of physics tell us how things happened. The theories of physics are used to explain why they behave like they do.

BRANCHES OF PHYSICS

Mechanics
Thermal physics/ heat
Waves/ optics
Electricity
Magnetism
Modern physics/ nuclear physics
Magnetism

The study of Physics goes through a series of daily experiences, classroom experiences and experiments in the laboratory. However, while in laboratory, a code of conduct is observed. This code of conduct is composed of a set of rules and regulations.

Laboratory rules and regulations

1. Never enter the laboratory unless accompanied by a teacher or a laboratory attendant, technician or laboratory staff.
2. Conduct yourself in a responsible manner at all times in the laboratory.
3. Never touch any equipment or chemicals or other material until you are instructed to do so.
4. Do not eat or drink or chew anything while in the laboratory.
5. Report any breakages or injuries however minor they may appear.
6. Be alert and proceed by caution at all times in the laboratory.
7. Labels and equipment instructions must be read carefully.
8. Keep hands away from the face, eyes, mouth and body while using chemicals.
9. Know the locations and operating procedures of all safety equipment like fire extinguishers, first aid kits, fire alarm and the exit.
10. Never enter the equipment storage room without an instructor.
11. At the end of the laboratory session, ensure that the main gas outlet valves are closed/shut off; the water is turned off, desk tops, floor area and sink are clean and that all the equipment used are clean.
12. If you don't understand how to use equipment, ask the instructor for assistance.

Measurements

In order to progress accurate measurements are necessary. Physics is called the science of measurements.
Scientific method requires careful measurements and analysis. Measurements are used o determine how much, how long, how big the physical quantity of matter is. Importance of measurement is to ascertain quantity and quality

QUANTITIES MEASURED

1. **Fundamental (basic) quantities**
   These are physical quantities that cannot be expressed or defined in terms of any other quantities. They all have clearly defined symbols and international system units (SI UNITS). There are three basic quantities of physics
   - **Length**
   - **Mass**
   - **Time**

Other physical quantities are called derived quantities. The units of derived quantities are based on the units of basic quantities. They include the following; area, volume, density, speed, force, energy, pressure, e.t.c.

Quantity	SI UNITS	SYMBOLS
Area	Square metre	m^2
Volume	Cubic metre	m^3
Density	Kilogram per metre cubed	Kg/m^3
Speed	Metres per second	m/s
Force	Newton	N
Energy	Joules	J
Pressure	Newton per metre squared	N/m^2

Units

The conference on weight and measurement selected the seven quantities and their units as the basic quantities. These are the basics of the new system known as the international system of units (SI units).in this system length is measured in meters (m), mass is measured in kilograms (kgs), and time is measured in seconds (s).

Basic Quantity	S.1 Units	Symbol
Length	Metre	M
Mass	Kilograms	Kg
Time	Second	S
Temperature	Degrees Celsius	^{0}c or k
thermodynamic	or Kelvin	
Electric current	Amperes(Amps)	A
Amount of substance	Mole	M
Luminous intensity	Candela	Cd
Force	Newton	N

All SI Units satisfy the following conditions:
- They are well defined
- They don't change with time
- They have fixed value
- They can easily and accurately be reproduced when ever needed

Standard:
In order to measure any physical quantity we need to know the quantity to measure and the units for measuring it. Measurement involves comparing the given quantity with a given standard.

MEASUREMENT OF LENGTH
Length is the distance between two points. The SI unit of length is metres (m)

The international system is used at present with the basic S.1 unit of length being the metre. The metre is divided into smaller units like millimetres (mm), centimetres (cm) and decimetres(dm). Other smaller units of length are micrometres (μm) nanometre (nm). Length can also be measured using other bigger units of the metric system for example Decametres (dm), Hectometres (hm) and kilometre (km). Length can be measured using nautical miles.

Conversions
1m = 1000mm, 1m = 100cm, 1m = 10dm, 1km=1000m, 1km = 10000dm, 1km = 100,000cm, 1km = 1,000,000mm
1mile = 1.61km, 1mile =1610m.

A metre rule is used to measure length of a straight line. The tape measures are also used to measure the length. The choice of the actual instrument to be used for measuring depends very much on what is to be measured. For example, if the length of a foot ball field is to be measured, a tape measure calibrated in metres and centimetres or millimetres may be used. If the width of a desk is to be measured the metre rule calibrated in cm and mm may be used. For smaller measurements of length a vernier calliper and a micrometre screw gauge is used.

Metre rule

When measuring an object using a metre rule the following should be noted:

1. The zero mark of a metre rule should be aligned with one edge of the object your measuring to reduce errors.
2. The eye is placed directly above the other end of the object your measuring to avoid errors in guessing the position of the end of the object (to avoid errors due to parallax).
3. There should never be a gap between the metre rule and the top of the object your measuring to avoid errors of guessing the position of the ends.

We can also measure the best accuracy and sensitivity of a reading obtained from any measuring instrument depends on the smallest scale division. For the metre rule the small scale division is one millimetre (1mm). If we estimate to a fraction of a mm, the sensitivity becomes 0.5mm hence the accuracy in reading value obtained using any measuring instrument depends on the sensitivity of an object and the size of the quantity being measured.

Example 1

Length of the teacher's rectangular table = 364.5cm

1m = 100cm

Length of the teacher's rectangular table

$$\frac{364.5}{100} = 3.645m$$

Width of the teacher's rectangular table = 89.9cm

$$= \frac{89.9}{100} = 0.899\text{m}$$

Area of the teacher's rectangular table = length × width

$$= 3.645\text{m} \times 0.899\text{m}$$
$$= 3.276855\text{m}^2$$

Example 2

Length of the rectangular chalk board = 493cm

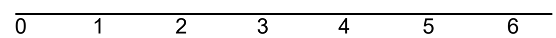
$$= \frac{493}{100} = 4.93m$$

Width of the rectangular chalk board = 120cm.

$$\frac{120}{100} = 1.20\text{m}$$

Area of the chalk board = length × width

$$= 4.93\text{m} \times 1.20\text{m}$$
$$= 5.9160\text{m}^2$$



Length of the wooden block is 5.25cm

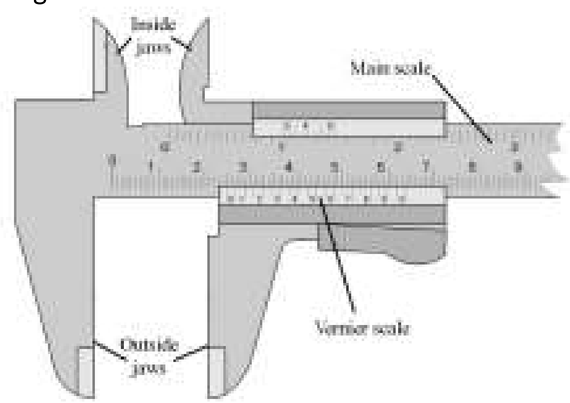
The reading obtained in measuring the length of the wooden block above is 5.25cm. The last digit was obtained by guessing the actual length of the block lies between 5.2cm and 5.3cm.

VERNIER CALLIPERS

In the vernier callipers the vernier scale is designed to eliminate this guessing of the last digit. The instrument has two scales the main scale and the vernier scale. The main scale is divided into centimetres and millimetre. The vernier scale which slides over the main scale has a length of 9mm divided into ten equal divisions of $\frac{9}{10} = 0.9\text{mm}$ each.

The difference between the main scale division and the vernier scale division is $0.1mm$ and this is the best accuracy or sensitivity of vernier callipers measurements.

Diagram



To measure any length using the vernier calliper the object is placed either between the outside jaws or the inside jaws grip the sides or edges of the vernier scale slid over the main scale until the jaws grip the object.

How to use a vernier calliper

1. Close the jaws of the calliper and check if the zero of the main scale and the vernier scale coincide. If they differ, the amount by which they differ is known as a zero error
2. Open the jaws to touch appropriately the positions whose distance apart is to be measured. The inside or outside jaws should be used depending on what the measurement is, internal or external
3. You record the readings on the main scale immediately preceding a zero mark on the vernier scale
4. Record the number of graduations on the vernier scale. Which comes directly in line with the graduation on the main scale, this gives the second decimal place in centimetres
5. The final reading is the sum of the two readings in centimetres

Exercise.

Find the readings given by the following vernier callipers:

3 4 5 6

Main scale reading = 3.20cm
Vernier scale reading = 0.07cm

Reading of vernier calliper
= Main scale reading + vernier scale reading
= 3.20 cm + 0.07 cm
= 3.27 cm

4 5 6

Main scale reading = 4.00cm
Vernier scale reading = 0.06cm

Reading of vernier calliper
= Main scale reading + vernier scale reading
= 4.00 cm + 0.06 cm
= 4.06 cm

1 2

Main scale reading = 1.20cm
Vernier scale reading = 0.04cm

Reading of vernier calliper
= Main scale reading + vernier scale reading
= 1.20 cm + 0.04 cm
= 1.24 cm

3 4 5

Main scale reading = 3.20cm
Vernier scale reading = 0.00cm

Reading of vernier calliper
= Main scale reading + vernier scale reading
= 3.20 cm + 0.00 cm
= 3.20 cm

Uses of vernier callipers

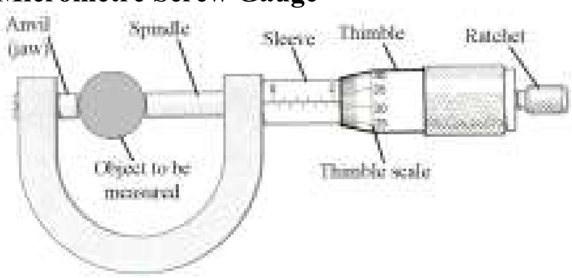
1. Callipers are tools or equipments, industries and laboratories use to measure small lengths accurately
2. They are used for precise accurate measurement of lengths

Reasons for using vernier callipers

1. Wide range of measurements can be made
2. Imperial British and metric scales are usually found on the same scale instrument.

3. They can make both inside and outside measurements e.g. measuring the internal diameter of a tubes

Micrometre Screw Gauge



The micrometer screw gauge is used to accurately measure very small lengths e.g. diameter of a wire, thickness of a ruler, paper.
The scale of the micrometer screw gauge is shown in two parts.

Part1: Main scale (Sleeve scale)
The main scale is marked along the sleeve scale. The upper divisions are marked in mm. The lower marks divide the upper scale into half a mm each.

Part 2: The thimble
The scale along the edges of the thimble is called the thimble scale. The scale marked on the edges of the thimble is divided into 50 or 100 each division according to its marking. For the micrometer screw gauge with 50 each division in one complete revolution. The thimble moves 0.5mm along the sleeve. Therefore for a thimble marked in 50 each division each is $\frac{0.5}{50} = \frac{5}{500}$ mm = 0.01mm For a micrometer screw gauge whose thimble is marked in 100 each division each complete revolution moves 1mm on the sleeve scale. Hence each division is $\frac{1}{100} mm = 0.01\text{mm}$.
The object whose thickness is to be measured is placed between the jaws of the micrometer screw gauge. The ratchet is turned so that the jaws grip on the object. The ratchet starts to slip when the object is gripped tightly enough. To avoid errors, the anvil and spindle jaws should be wiped clean to remove any dirt and the (0) error of the micrometer screw gauge should be noted.

How to measure using a micrometer screw gauge
As in the vernier calliper, the reading in the micrometer screw gauge is taken in two parts.
Part1
The reading of the sleeve scale is read off at the edge of the thimble inmmand $\frac{1}{2}$mm .

Part 2
The reading on the thimble scale is the reading off opposite the centre line of the sleeve scale in hundredths of mm.

1m =1000mm

$(1\text{m})^2 = (1000\text{mm})^2$

$= (1000\text{mm} \times 1000\text{mm})$

$1\text{m}^2 = 1000000\text{mm}^2$

$1\text{mm}^2 = \frac{1}{1000000}\text{mm}^2$

Note: Length can be measured in nautical miles.
1mile =1.6kilometres
1km = 1000m
1mile= (1.6×1000)m =1600metres
1m= 100cm
$(1\text{m})^2 = (100\text{cm})^2 = (100\times100)\text{cm}^2$
$1\text{m}^2 = 1000\text{cm}^2$
$1\text{cm}^2 = \frac{1}{10000}\text{m}^2$
1km =1000m
$(1\text{km})^2 = (1000\text{m}^2) = 1000\text{m}\times1000\text{m}$
$1\text{km}^2 = 1{,}000{,}000\text{m}^2$
$1\text{m}^2 = \frac{1}{1{,}000{,}000} km^2$
1m = 1000mm
$(1\text{m})^2 = (1000\text{mm})^2$
$= (1000\text{mm} \times 1000\text{mm})$
$1\text{m}^2 = 1000000\text{mm}^2$
$1\text{mm}^2 = \frac{1}{1000000}\text{m}^2$
1mile = 1.6km
$(1\text{mile})^2 = (1.6\text{km})^2 = (1.6\times1.6)\text{km}^2$
1square mile = 2.56km^2

$1\text{km}^2 = 1000000\text{m}^2$
1square mile = 2.56km^2

$(2.56 \times 1000000)\ m^2 = 2560000 m^2$

Example

Find the readings on the following micrometer screw gauges

Sleeve reading = 3.50mm
Thimble reading = 0.20 mm
Reading of the micrometer screw gauge
= Sleeve reading + Thimble reading
= 3.50mm + 0.20mm
= 3.70 mm

Sleeve reading = 5.00mm
Thimble reading = 0.92 mm
Reading of the micrometer screw gauge
= Sleeve reading + Thimble reading
= 5.00mm + 0.92 mm
= 5.92 mm

Sleeve reading = 11.50mm
Thimble reading = 0.61 mm
Reading of the micrometer screw gauge
= Sleeve reading + Thimble reading
= 11.50mm + 0.61 mm
= 12.11 mm

Sleeve reading = 17.00mm
Thimble reading = 0.32 mm
Reading of the micrometer screw gauge
= Sleeve reading + Thimble reading
= 17.00mm + 0.32 mm
= 17.32 mm

Summary of the measuring instruments and their accuracy

Instrument	Smallest measurement	Accuracy	Examples of the length of measured
Micrometer screw gauge	0.01 mm	2 decimal places in mm	- Diameter of a wire - Thickness of a cardboard
Vernier calliper	0.1 mm or 0.01 cm	1 decimal place in mm or 2 decimal places in cm	- Thickness of a book - Diameter of a tennis ball - Internal diameter of a test-tube
Metre rule	1 mm or 0.1 cm	0 decimal place in mm or 1 decimal place in cm or 3 decimal places in metres	- Length of a bench - Length of a book

The accuracy of the measurement depends on both the sensitivity of the instrument and the size of the quantity measured e.g. the sensitivity of the vernier callipers and the micrometre screw gauge is 0.1m and 0.01mm. Accuracy refers to the closeness of a measurement of the correct value of the quantity being measured. It is expressed as an error.

Measurement of time

The SI unit of time is a second (s). A nature standard for measurement of time was originally the motion of the earth whose one rotation makes one day. The day is divided into 24hours (hrs), 1hr = 60 minutes (min) and 1min = 60 seconds (s). However not all day are of equal length in all parts of the world. The only days which are equal are the one during which the sun is overhead on the equator and these are called the **mean average days.** Today the standard time is based on the vibrations of **caesium clock.**

How to measure time

1day = 24 hours
1hour = 60 minutes
1minute = 60 seconds
1hour = 60 × 60 = 3600 seconds
1day = (24 × 3600) seconds

Other smaller units of measuring time are based on second, millisecond, microsecond, nanosecond.

1millisecond (ms) = $\frac{1}{100}$
= 0.001s.

1microsecond (μ) = $\left[\frac{1}{1,000,000}\right]s$
= 0.000001s

1nanosecond (ns) = $\left[\frac{1}{1,000,000,000}\right]s$
= 0.000000001s

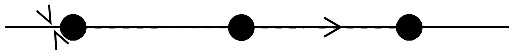
There various devices for measuring time intervals. The device chosen depends on convenience and accuracy needed and same extent the duration of the time interval.

Methods of measuring time intervals and where they are commonly used

1. Oscillation of alternating current mains electricity as used in ticker tape timers
2. Oscillation of quartz crystals as used in modern electronic watches and clocks
3. Oscillation of simple pendulum as used in pendulum clocks
4. Oscillation of balanced wheels as used in clocks and watches.
5. Time taken by small grains of sand to fall through a small hole as used in sand clocks
6. Determination of the half-life of the radioactive material e.g. age of a fossil using carbon-dating.

Simple pendulum

It is a massive bob tied at one end of a light string and the other end of the string is tied to a rigid support e.g. a damp stand. The bob is free to swing to and fro when displaced slightly at one side. Then time for one complete oscillation or swing is called the period or period time of the pendulum.



The length l on the pendulum is the distance from the point of support to the approximate centre (0) of the bob. The angular amplitude of a swing is the angle between the extreme position of a pendulum and the rest position of a thread.
When an object accelerates, it does so because a force is acting on it but some objects have more resistance to acceleration.

Area

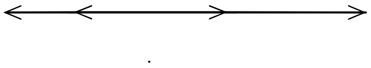
The area of a regular surface is easy formed by measuring length and width and then applying a known formula e.g. the area of a circular surface is equal to πr^2 where r is the radius of the circular surface and π is a constant which is $\frac{22}{7}$

Area of a square equals (length × width)
$= l \times l = l^2$
Area of a rectangle equals length × width
Area is measured in square metres or (m^2). Area can also be measured in square centimetres or cm^2
Area of a triangle

Area = $\frac{1}{2}$(base length × perpendicular height)

$Area = \frac{1}{2}bh$

Area of a trapezium

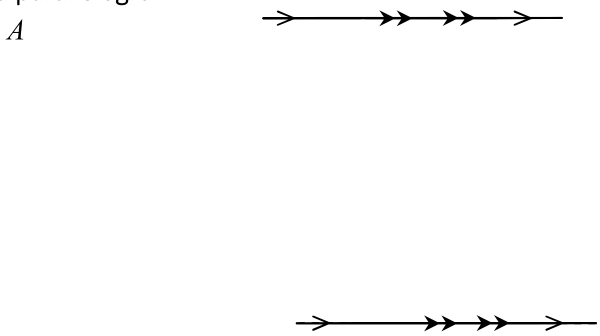


Area $= \frac{1}{2} \times$ (sum of parallel sides) $\times$ perpendicular height

$$= \frac{1}{2} \times (a+b)h$$

$$= \frac{1}{2}(a+b)h$$

Area of a parallelogram



AB = DC = l
CB = DA = w
CF = EA = x
BF = ED = h

Area of a rectangle *EBFD*= *length* $\times$ *width*

$= (x + l) \times h = (xh + lh)$

Area of a triangle *EAD* (I)

$$= \frac{1}{2} \times b \times h = \frac{1}{2} x \times h = \frac{xh}{2}$$

Area of a triangle *BCF* (II)

$$= \frac{1}{2} \times b \times h = \frac{1}{2} \times x \times h = \frac{xh}{2}$$

Total area of triangle *I* and *II* $= \frac{xh}{2} + \frac{xh}{2} = xh$

Area of parallelogram *ABCD* = Area of a rectangle *EBFD*-Total of triangles *I* and *II*
$=(xh + lh) - xh = lh$

Area of parallelogram = $l \times h$

Area of a rhombus

Area of a kite

Area $=\frac{1}{2}h\times b+\frac{1}{2}h\times b$

The surface area of a cuboid

Total surface area
$= 2(l \times w) + 2(w \times h) + 2(h \times l)$
$=2lw + 2wh + 2hl$

The Cube
It is a special form of a cuboid with equal sides

$=2lw + 2lh + 2wh$
$w = h = l$
$= 2(l \times L) + 2(l \times L) + 2(l \times L)$
$= 2l^2 + 2l^2 + 2l^2 = 6l^2$

Total surface area of a sphere

$T.S.A = 4\pi r^2$

Total surface area of a cylinder
A cylinder consists of two circular surfaces and a curved surface
Area of circular surface = πr^2
$= 2 \times \pi r^2$
$= 2\pi r^2$

Area of the curved surface = $2\pi rh$
Total surface area of a cylinder $2\pi r^2 + 2\pi rh$

Area of irregular objects is determined by dividing it into many small equal regular surfaces. The area of one of these small surfaces is determined from its measurements. The total area of the irregular shape is the product of this small area and the total number of small surfaces or total area of a regular is got by summing up all the areas of the small regular shapes.

Example;
Take π as $\frac{22}{7}$ find the total surface area in square cm of a cylindrical shape of radius 14m and height 10cm.
Total surface area $= 2\pi r^2 + 2\pi rh$

$$= 2\times\frac{22}{\cancel{7}}\times\cancel{14}\times 14 + 2\times\frac{22}{\cancel{7}}\times\cancel{14}\times 10$$
$$= 44\times 28 + (22\times 20)$$
$$= 1232 + 880$$
$$= 2112cm^2$$

Volume (capacity)
Volume is space occupied by an object. The volume of regular objects can be determined from measurement of their lengths and then application of a known formula. Volume is measured in cubic metres (m^3). Although the SI unit of volume is m^3, other smaller units like;
Cubic centimetres (cc)
Cubic decimetres ($dm^{3)}$
Cubic metres ($mm^{3)}$
For volumes of liquids or capacity litres (l), millilitres (ml) etc

Conversions
1m = 100cm
$(1m)^3 = (100cm)^3$
$1m^3 = (100cm \times 100cm \times 100cm)$
$1m^3 = 1000000cm^3$
$1cm^3 = \frac{1}{1000000}m^3$

$1\text{m} = 1000\text{mm}$

$1\text{m}^3 = (1000\text{mm})^3 = 1000 \times 1000 \times 1000\,\text{mm}^3$

$1\text{m}^3 = 1000000000\text{mm}^3$

$1\text{km} = 1000\text{m}$

$1\text{m} = \frac{1}{1000}\text{km}$

$1\text{m}^3 = \left[\frac{1}{1000}\text{km}\right]^3 = \left[\frac{1}{1000} \times \frac{1}{1000} \times \frac{1}{1000}\right]\text{km}^3$

$1\text{m}^3 = \frac{1}{1000,000,000}\text{km}^3$

For pure water at standard temperature and pressure
1litre of water weighs1kg
1litre = 1000ml
1litre = 1000cm^3
1ml = 1cm^3
Hence 1m = 1000000cm^3 = 1000000ml

$1\text{m}^3 = \frac{1000000}{1000}\text{l}$

$1\text{m}^3 = 1000\text{l}$

Volume of regular objects

Volume of a cube/ cuboid __________________

Volume = length × width × height
= $l \times w \times h$
= lwh cubic units

Volume of a cube = $l \times w \times h$
= $l \times l \times l$
= l^3 cubic units

Find the volume of a cube of 5cm and give your answer in m^3

Volume

$= l \times l \times l$

$= 5\text{cm} \times 5\text{cm} \times 5\text{cm}$

$= 125\ \text{cm}^3$

But 1 m = 100 cm

$1\ \text{m}^3 = (100\ \text{cm})^3$

$1\text{m}^3 = 1000000\text{cm}^3$

$1\text{cm}^3 = \frac{1}{1000000}\text{m}^3$

$152\text{cm}^3 = 125\text{cm}^3 \times \frac{1}{1000000}$

$= \frac{125}{1000000}$

$= 0.000125\text{m}^3$

Volume of a cylinder

Volume = base area × perpendicular height

Volume = $\pi r^2 \times h$

Volume $= \pi r^2 h$ cubic units

Volume of a sphere

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

Volume of a cone

Volume

$= \frac{1}{3} \times$ base area × perpendicular height

$= \frac{1}{3} \times$ length × width × height

$= \frac{1}{3} \times l \times w \times h$ cubic units

Volume of a pyramid

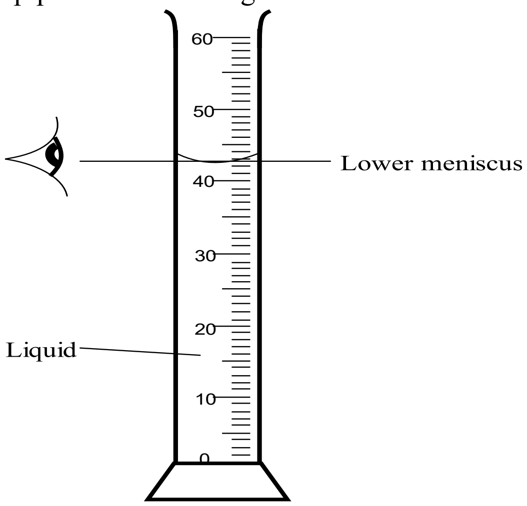
Volume of a pyramid $= \frac{1}{3} \times$ base area × perpendicular height

$= \frac{1}{3} \times (l \times w) \times \text{h}$ cubic units

Volume of irregular objects

1. Capacity of fluids(liquids and gases)

The volume of a liquid is determined by pouring the liquid or fluid into a graduated measuring cylinder and reading off the volume. In reading off the volume, your eye level is placed with the bottom of the meniscus. For more accurate measurements of volume a burette or pipette or measuring flasks are used.



Irregular solids

For irregular solids the volume is determined by measuring the volume of a liquid which the solid displaces when fully immersed in the liquid. A measuring cylinder or eureka may be used.

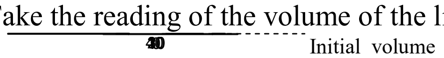
Experiment to determine the volume of an irregular solid body

Apparatus:

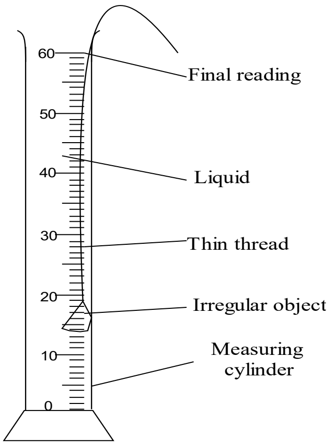
- measuring cylinder
- over flow can/eureka can
- liquid (water)
- thin thread (string)
- collecting beaker

Procedure:

Take the reading of the volume of the liquid in the measuring cylinder



Tie a thin thread around the irregular solid and immerse it in the liquid making sure its fully immersed.



Read the final volume of the liquid and determine the volume of the irregular solid in the measuring cylinder from the expression below.

Volume of the displaced

Liquid = final – initial

$= (V_2 - V_1)ml$

$V_1 = 33ml$

$V_2 = 55ml$

Volume of displaced $= V_2 - V_1$

$= (55 - 33)$ ml

$= 22$ml

Since the irregular solid object displaces its own volume then the volume of the displaced liquid must be equal to the volume of the irregular solid object. Hence the volume of the irregular solid object is

$V_2 - V_1$

Using the over flow can

Pour a liquid in the over flow can until the liquid starts dripping out through the spout.

Allow it stand and stabilise i.e. the liquid level is on the spout level.

Immerse your irregular solid in the liquid using the thin thread and collect all the displaced liquid through the spout in the measuring cylinder.

Conclusion:

Since the solid body displaces its own volume then the volume of the displaced liquid in the measuring cylinder is equal to the volume of the irregular object.

Mass

Measurement of Mass

Mass is defined as the quantity of matter a body contains.

Mass of a substance can also be defined as a measure of the amount a material contains. It does not vary or change with pressure, temperature or any other physical change. It will have the same value on earth, moon or in free space. The *SI* unit for mass is a kilogram (*kg*). At present the standard mass is the mass designed at one kilogram. All other instruments for measuring mass are standardised, derived from a standard mass of k*g*. The mass of an object is measured by comparing it with a known mass from a balance. Most balances work on the principle of a beam balance. When a known mass is equal to the unknown mass the beam balances.

Measurement of mass using Beam balance

Mass m_1=mass m_2

There many types of balance e.g. the chemical balance, laboratory beam balance, lever arm balance, triple beam balance, shop beam balance, weighing scale, electronic beam. The choice of a beam balance to use depends on the accuracy required. For very accurate measurements of masses, we use an electronic balance. Although the *SI* unit of mass is 1kg, other metric units may be used e.g. gm.

$$1kg = 1000g$$

$$1g = 1000mg$$

$$1kg = (1000 \times 1000)mg$$

$$1kg = 1000000mg$$

Larger masses are measured in tones

1tone = 1000kg

Home work

With well labelled diagrams draw the following apparatus for measuring mass.

Triple beam balance, lever arm balance, electric top pan balance, laboratory beam balance.

Density

The heaviness or lightness is referred to as density.

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

Measurement of density

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

If mass is measured in *kgs* and volume in m^3then density is measured (kg/m^3) or (kgm^{-3}) kilogram per metre cubed. Although density is measured in kg/m^3, it may also be measured is g/cm^3or (gcm^{-3}) gram per centimetre cubed. The symbol for density is ρ (rho).

$$\text{density}(\rho) = \frac{\text{mass}}{\text{volume}}$$

The higher the density of a substance the more the massive a unit volume of that material is. Since different materials have different materials density can be used to identify a material and to determine its purity. Densities are important to engineers, architects, in the designing of structures e.g. air craft's, and overhead cables for the transmission of electricity are made of alloys of aluminium because it has a lower density.

$$1kg = 1000g$$

$$1m^3 = 1000000cm^3$$

$$1kg/m^3 = \frac{1kg}{1m^3}$$

$$= \frac{1000g}{1000000cm^3}$$

$$1kg/m^3 = \frac{1}{1000}g/cm^3$$

By cross multiplying;

$$1g/cm^3 = (1 \times 1000)kg/m^3$$

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

Example 1

Given that the density of mercury is 13.6g/cm^3, convert it into kg/m^3

Density of mercury=13.6g/cm^3

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

Density of mercury = 13.6g/cm^3

= (13.6×1000) kg/m^3

= 13600 kg/m^3.

Example 2

Given the density of oil as 800 kg/m^3, convert it into g/cm^3.

Density of oil = 800kg/m^3

$$1kg/m^3 = \frac{1}{1000} g/cm^3$$

Density of oil = 800kg/m^3

$$= \left[800 \times \frac{1}{1000}\right] g/cm^3$$

= 0.8g/cm^3

Example 3

Find the density of an object whose mass is 40kg and of the volume 100cm^3. Give your answer in g/cm^3

$$\text{Density } (\rho) = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{40kg}{100m^3}$$

= 0.4kg/m^3

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

$$\text{Density} = \frac{0.4}{1000} g/\text{cm}^3$$

= 0.0004g/cm^3

Example 4

A cube has length of 2cm and weighs 40g. Find the density of the cube in kg/m^3.

Volume of the cube

=length × width × height

= (2 × 2× 2)cm

= 8cm^3

$$\therefore \text{Density } (\rho) = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{\cancel{40}g}{\cancel{8}cm^3} = 5\text{g/cm}^3$$

Density of the cube =5g/cm^3

$$1\text{kg/m}^3 = \frac{1}{1000} g/cm^3$$

x kg/m^3 = 5g/cm^3

By cross-multiplying;

$$\frac{x}{\cancel{1000}} \times \cancel{1000} = 5 \times 1000$$

$x = 5000\text{kg/m}^3$

Example 5

Given that the density of mercury is 13g/cm^3, what is the mass of 12.2cm^3 of mercury in kg.

$$\text{Density } (\rho) = \frac{\text{mass}}{\text{volume}}$$

$$1.36\text{g/cm}^3 = \frac{\text{mass}}{12.2\text{cm}^3}$$

Let mass be *m*

$$12.2\cancel{cm^3} \times 13.6g / \cancel{cm^3} = \frac{m}{\cancel{12.2}cm^3} \times \cancel{12.2}cm^3$$

$M = 165.92\text{g}$

$\therefore$mass $=165.92\text{g}$

$1\text{kg} = 1000\text{g}$

x kg = 156.92g

$$\frac{165.92g}{10000} = \frac{\cancel{1000}x}{\cancel{10000}}$$

$x = 0.16592\text{kg}$

$\therefore$ Mass of mercury in kg is 0.16592kg.

Example 6

The volume of a block of wood is 2.5×10^{-4} cm^3. If the density of wood is 0.8g/cc, find the mass of wood in kg.

Volume = $2.5\times10^{-4}\ \text{m}^3$

Density = 0.8g/cc

Mass = ?kg

Mass = density × volume

$1\text{g/cc} = 1000\text{kg/m}^3$

Density of wood = 0.8×1000

$= 800\text{kg/m}^3$

$=8.0\times10^2\text{kg/m}^3$

Mass = $2.5 \times 10^{-4}\ \text{m}^3 \times 8.0 \times 10^2\ \text{kg/m}^3$

$= 2.5 \times 8.0\times10^{-4}\times10^2$

$= 20.0 \times 10^{-2}$

$= 2.0 \times 10^1 \times 10^{-2}$

$= 2.0 \times 10^{(1-2)}$

$= 2.0 \times10^{-1}\text{kg}$

More examples on conversion:

Convert the volumes to m^3.

a) 2.5 litres

$1\,litre = 1000\text{cm}^3$

$$2.5\ litres = \frac{25}{1\cancel{0}} \times 100\cancel{0}\ \text{cm}^3$$

$= 2500\text{cm}^3$

$1\text{m}^3 = 1000000\text{cm}^3$

$1000000\text{cm}^3 = 1\text{m}^3$

$1cm^3 = \frac{1}{1000000} m^3$

$2500cm^3 = \frac{2500}{1000000} m^3$

$= 0.0025m^3$

b) $20000cm^3$

$1000000cm^3 = 1m^3$

$1cm^3 = \frac{1}{1000000} m^3$

$20000cm^3 = \frac{2\cancel{0000}}{100\cancel{0000}}$

$= 0.02m^3$

c) 5000 litres

$1l = \frac{1}{1000} m^3$

$5000l = \frac{1}{1\cancel{000}} \times 5\cancel{000}\ m^3$

$= 5m^3$

Convert the following densities to kgm^{-3}

a) $0.85gcm^{-3}$

$100cm = 1m$

$1000000cm^3 = 1m^3$

$1cm^3 = \frac{1}{1000000} m^3$

$0.85 = \frac{0.85}{1000} \div \frac{1}{1000000}$

$= \frac{85}{100\cancel{000}} \times \frac{1000\cancel{000}}{1}$

$= 850kg/m^3$

b) $1.8gcm^{-3}$

$1000g = 1kg$

$1.8g = 1.8 \div \frac{1000}{1}$

$= \frac{18}{10} \times \frac{1}{1000}$

$= \frac{18}{10000}$

$100cm = 1m$

$1000000cm^3 = 1m^3$

$1cm^3 = \frac{1}{1000000} m^3$

$= \frac{18}{10000} \div \frac{1}{1000000}$

$= \frac{18}{1\cancel{0000}} \times \frac{100\cancel{0000}}{1}$

$=1800kgm^3$

Exercise
A box measures 2cm×3cm×4cm and its density is 400gcm^{-3}.
Calculate its:
a) Volume in cm^{-3}
b) Its mass in g
c) Express the mass in kg
d) Convert its density to kgm^{-3}

A package has a mass of 500 gm and its dimensions are 2.5cm×3.0cm×5.0cm.
Calculate:-
a) Volume
b) Mass
c) Density

Density of a Regular Object
1. The mass of the object is determined using a beam balance.
2. The dimensions, length, width, height or radius of the object are measured and the volume of the object is then calculated.
3. The density of the object is then calculated from :-

$$\text{Density}=\frac{\text{mass (m)}}{\text{volume(v)}}$$

Example
The mass of a wooden cube is 40g and its length is 4.5cm. Calculate its density.

Solution:
Mass m = 40g
Volume $v = l \times l \times l$

$$=4.5\times4.5\times4.5$$
$$=\frac{25}{10}\times\left(\frac{45}{10}\times\frac{45}{10}\times\frac{45}{10}\right)$$
$$=\frac{91125}{1000}$$
$$=91.125\text{cm}^3$$
$$\text{Density}=\frac{40}{91.125}$$
$$=\frac{40}{1}\div\frac{91125}{1000}$$
$$=\frac{40}{1}\times\frac{1000}{91125}$$
$$=\frac{8000}{18225}$$
$$=\frac{320}{729}$$
$$= 0.43895\ \text{g/cm}^3$$

Density of an irregular object that sinks in water
The mass of irregular objects is determined using a beam balance.
Water is filled in a displacement can upright. The level of the beaker is placed below the spout.
Using a string, the irregular object is slowly lowered into the displacement can and water over flows in the beaker is measured using a measuring cylinder.

The density of the irregular object is then calculated from: density $\frac{\text{mass}(m)}{\text{volume}(v)}$

Example:-
The mass of a certain irregular object is 9.4 kg. The initial volume of water in a measuring cylinder was 130cm^3. The final volume of water after placing the object was 136cm^3. Calculate the density of the irregular object.
Solution:

$$D = \frac{m}{v}$$

Measurement of density
$M = 9.4\text{g}$; $V_1 = 130\text{cm}^3$; $V_2 = 136\text{cm}^3$
$V_2 - V_1 = 136 - 130$
$= 6\text{cm}^3$

$$D = \frac{m}{v}$$
$$= \frac{9.4}{6}\ \text{gcm}^{-3}$$
$$= \frac{94}{10} \div \frac{6}{1}$$
$$= \frac{94}{10} \times \frac{1}{6}$$
$$= \frac{47}{30}$$
$$= 1\frac{17}{30}\ \text{gcm}^{-3}$$

Experiments to measure the density of an irregular object that floats on water
Procedure:
The mass m of the specimen object is determined by using a beam balance. Water is poured in a measuring cylinder and the initial volume is noted.
A strong sinker is lowered into the water in the measuring cylinder and the volume V_2 is noted.
The irregular object is then attached to the sinker and using a string the two are lowered into the measuring cylinder.
The final volume V_3 of the sinker and irregular object is noted from the results.
Volume of irregular object = $V_3 - V_2$.
Density of an irregular object $= \frac{D_1}{V_3 - V_2}$

Practical
Weigh the mass of the object provided to you and record its mass, mass = 4.5g
Put water in the measuring cylinder and record the volume of water, $V_1 = 150\text{cm}^3$
Lower a sinker into a measuring cylinder and record the volume V_2
$V_2 = 161\text{cm}^3$
Attach the sinker to the irregular floating object in water in the cylinder and record the volume V_3.
$V_3 = 171\text{cm}^3$.
Calculate the volume of the irregular object.
$V_3 - V_2$
$= 171 - 161$

$= 10cm^3$

Calculate the density of the object.

$$\text{Density} = \frac{m}{V_3 - V_2}$$

$$= \frac{4.5g}{171-161}$$

$$= \frac{45}{10} \div 10$$

$$= \frac{45}{10} \times \frac{1}{10}$$

$$= \frac{45g}{100cm^3}$$

$= 0.45gcm^{-3}$

Importances of density

- Helps when designing building structures by Engineers and Architects e.g. sky-scrappers
- It is used in chemistry to test purity of some substances
- It is used in the manufacture of aircrafts and overhead cables for transmission.
- Through density calculations, strengths of substances can be compared and relationships can be established.
- Density has led to discovery of a new gas, Argon, important industrially.

Relative density

Relative density of a substance is the ratio of the mass of a substance to the mass of an equal volume of water. It can also be defined as the ratio of the density of a substance to the density of water **OR** relative density is the ratio of the weight of a substance to the weight of an equal volume of water. An easy way of measuring density of (liquids and gases) fluid is to measure its density relative to the density of water.

Relative density has no units.

1litre of water weighs 1kg

$1000cm^3$ of water weigh 1kg

$1000cm^3$ of water weigh 1000g

$$\text{Density of water (pure)} = \frac{\text{mass of water}}{\text{volume of water}}$$

$$= \frac{1000g}{1000cm^3} = 1kg / cm^3$$

Relative density is determined from the following formula.

Relative density of a substance

$$= \frac{\text{density of a substance}}{\text{density of water}}$$

$$\text{Since density} = \frac{\text{mass}}{\text{volume}}$$

∴relative density of a substance

$$= \frac{\text{mass of asubstance}}{\text{mass of an equal volume of water}}$$

Relative density of a substance

$$= \frac{\text{weight of a substance}}{\text{weight of an equal volume of water}}$$

Determination of Relative density of liquids

For liquids, relative density is determined using a relative density bottle or specific gravity bottle. Since the relative density bottle has a fixed point volume it is not necessary to measure its volume. This method removes errors that would arise if volume was to be measured.

Since relative density is the ratio of density of a substance to the density of an equal volume of water knowing the relative density of a substance you can determine its density by multiplying its relative density with the density of water.

Density of a sub stance = relative density of a substance × density of water.

Determination of relative density of a substance (methylated spirit)

Using the relative density bottle

Procedure:

Find the mass of the clean dry relative density bottle with its glass stopper on using a mass measuring instrument e.g. triple beam balance.

Remove the glass stopper and fill the density of relative bottle with water. Replace the glass stopper and let the excess water escape through the hole in the glass stopper.

Wipe the outside of the density bottle clean and find the mass of the water and the density bottle with the glass stopper on using a beam balance.

Remove the glass stopper and pour water out of the density bottle and dry the density bottle.

Refill the density bottle with a liquid substance e.g. methylated spirits.

Replace the glass stopper and let the excess liquid escape through the hole of the stopper.

Wipe the outside of the density bottle clean and measure the mass of the density bottle filled with methylated spirits and glass stopper on using a beam balance.

Results:
Mass of empty density bottle with glass stopper on = M_1kg.
Mass of density bottle full of water in the glass stopper on = M_2kg.
Mass of density bottle of methylated spirit with glass stopper on = M_3kg.
∴ Mass of water only = $(M_2 - M_1)$ kg
Mass of substance only = $(M_3 - M_1)$ kg

Conclusion:

Relative density of substance (methylated spirit)

$$= \frac{\text{mass of substance (menthylated spirit)}}{\text{mass of an equal volume of water}}$$

Relative density of a substance = $\dfrac{(M_3 - M_1)}{(M_2 - M_1)}$

Note: If the density of water is known (1000kg/m^3) then the density of a substance (methylated spirit) can be calculated.

Density of a substance
= Relative density × Density of water

$$= \frac{(M_2 - M_1)}{(M_3 - M_1)} \times \text{Density of water}$$

Example I
The density of oil is 800kgm^{-3} while the density of water is 1000kgm$^{-3.}$ Calculate the relative density of oil.

$$\text{R.d} = \frac{\text{density of a substance}}{\text{density of water}}$$

$$= \frac{800\text{kgm}^{-3}}{1000\text{kgm}^{-3}}$$

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

$$= 0.8$$

Example II
A metal has a density of 5000kg/m^3 where as the density of water is 1000kg/m^3. Calculate the relative density of the metal.

$$\text{R.d} = \frac{\text{density of metal}}{\text{density of water}}$$

$$= \frac{5000\text{kgm}^{-3}}{1000\text{kgm}^{-3}}$$

$$= \frac{5}{1} = 5$$

Example III

The density of a piece of metal is 2.5g/cm^3 where as the density of water is 1g/cm^3. Calculate the relative density of the metal.

$$\text{R.d} = \frac{\text{density of piece of metal}}{\text{density of water}}$$

$$= \frac{2.5\text{gcm}^{-3}}{1\text{gcm}^{-3}}$$

$$= \frac{25}{10} \div \frac{1}{1}$$

$$= \frac{25}{10} \times \frac{1}{1}$$

$=2.5$

Example IV

The density of wood is 0.7gcm^3 whereas the density of water is 1000kg/m^3. Calculate the relative density of wood.

Solution

Density of wood = 0.7gcm^{-3}

1gm^{-3} = 1000kgm^{-3}

$$0.7\text{gcm}^{-3} = \frac{7}{1\cancel{0}} \times 100\cancel{0}$$

$= 700\text{kgm}^{-3}$

$$\text{R.D} = \frac{\text{density of wood}}{\text{density of water}}$$

$$= \frac{700kgm^{-3}}{1000kgm^{-3}} = 0.7$$

Experiment to measure the relative density of a liquid using a density bottle

The mass m_1 of the empty density bottle is determined using a beam balance.

The mass m_2 of the density bottle filled with water is also determined using a beam balance

The density bottle dried and then filled with the liquid whose relative density is required.

The mass m_3 of the density bottle filled with the specimen liquid is determined using a beam balance.

Summary

Mass of empty bottle = m_1

Mass of density bottle filled with water =m_2

Mass of density bottle filled with liquid = m_3

Mass of liquid = m_3-m_1

Mass of water = m_2-m_1

$$\text{Relative density} = \frac{m_3 - m_1}{m_2 - m_1}$$

The above formula gives the relative density of the specimen liquid

Examples

In an experiment to determine the relative density of mercury, the following results were obtained.

Mass of empty bottle = 20g

Mass of bottle filled with water= 45g

Mass of bottle filled with mercury=360g

Calculate the relative density of mercury.

Mass of mercury = $M_3 - M_1$

$= 360 - 20$

$= 340g$

Mass of water = $M_2 - M_1$

$= 45 - 20$

$= 25g$

$$R.d = \frac{m_c}{m_w}$$

$$= \frac{340}{25}$$

$$= 13.6$$

Experiment to measure the relative density of air

Procedure:

- The screw clip is opened and air sucked out of the flask by using a vacuum pump.
- When all the air is sucked out the levels of mercury in the barometer are equal
- The screw clip is closed and the mass m_1 on the empty flask determined using a beam balance.
- The flask is now connected to a calcium chloride drying tube.
- The screw clip is opened and air is allowed to enter the flask until it is full.
- The clip is closed and the mass M_2 of the flask determined using a beam balance.
- The flask is disconnected, filled with water. The volume V of the flask is equal to the volume of water and this is measured using a measuring cylinder.
- The room temperature is measured using a thermometer and the atmospheric pressure read from a barometer

From the results obtained,

Mass of air in the flask = $M_2 - M_1$

Volume of air in the flask = V_1

Density of air = $\frac{M_2 - M_1}{V_1}$

Note:

- The purpose of the connecting calcium chloride apparatus is to dry the air entering the flask.
- There is need to record the temperature because density changes with temperature and pressure.
- The micrometre is for showing that the flask is empty.
- The vacuum pump is for sucking out air from the flask.

Precaution when using a relative density bottle

When measuring using a relative density bottle the outside of the density bottle must be wiped dry before weighing the mass of the density bottle and its content.
The relative density bottle should not be hold in warm hands or high temperature.

Advantages of using a relative density bottle
- ✓ Accurate measurement of density of liquids.
- ✓ No measurement of volume is needed
- ✓ Only measurement of mass (weighing) is needed

Disadvantages of using a relative density bottle
- ✓ Errors in measurement of mass
- ✓ It cannot measure density of solids

Example1:
Relative density of some type of wood is 0.96. Find the density of wood in kg/m^3. Given that the density of water is $1g/cm^3$.

Solution
Density of water = $1g/cm^3 = (1\times1000)\ kg/m^3$
$=1000kg/m^3$

Relative density = $\frac{\text{density of substance}}{\text{density of water}}$

Density of substance
= relative density × density of water
$= 0.96 \times 1000kg/m^3$
$= 960kg/m^3$

Example 2
Given the following measurements find the density of a liquid substance if the density of water is $1g/cm^3$
Mass of empty relative density bottle = 250g
Mass of relative density bottle full of water = 1250g
Mass of relative density bottle full of liquid substance = 950g

Solution
Relative density of a substance

$$= \frac{\text{mass of a substance}}{\text{mass of an equal volume of water}}$$

Mass of water only = 1250g – 250g = 1000g
Mass of substance only= 950g – 250g = 700g

Relative density = $\frac{7\cancel{00}g}{10\cancel{00}g} = \frac{7}{10} = 0.7$

Relative density of liquid = 0.7

Example 3
A density bottle has a mass of 70g when empty 90g when full of water 94g when full of a liquid. If the density of water is $1000kg/m^3$, calculate:

a. Relative density of a liquid
b. Density of the liquid

Solution
Relative density of a substance

$$= \frac{\text{mass of a substance}}{\text{mass of an equal volume of water}}$$

Mass of water only = 90g – 70g =20g
Mass of substance only = 94g – 70g = 24g

Relative density $= \frac{24g}{20g} = 1.2$

Density of water $= \frac{1000kg/m^3}{1000} = 1g/cm^3$

Relative density $= \frac{\text{density of a substance}}{\text{density of water}}$

$\therefore$ Density of a substance

= relative density × density of water = 1.2 × 1

= $1.2g/cm^3$

Relative density of insoluble solid powder

This method is used in determining relative density of a substance in powder or granular form such as sand and lead shots. For accuracy ensure that the small air bubbles are not trapped in the powder. Air bubbles can be removed by gently shaking the density bottle. Violent shaking is avoided because the powder (sand) can be lodged in the glass stopper hole.

Measuring relative density of sand (powder) using a density bottle.

Procedure

Measure the mass of an empty relative density bottle with glass stopper on and let the mass be M_1kg.

Pour sand in the density bottle and measure the mass with sand and glass stopper on let mass be M_2.

Pour water in the density bottle until it completely fills the bottle and measure the mass of water and sand in the density bottle with glass stopper on, let the mass be M_3.

Pour everything out of the density bottle fill it with water and measure the density bottle full of water with glass stopper on.

Mass of density bottle full of water with stopper on = M_4

Relative density of sand (powder)

$$= \frac{\text{mass of any volume of sand}}{\text{mass of an equal volume of water}}$$

Results:

Mass of any volume of sand = $(M_2 - M_1)$ kg

Mass of water only = $(M_4 - M_1)$ kg

Mass of water added to the sand

= $(M_3 - M_2)$ kg

Mass of an equal volume of water
$= (M_4 - M_1) - (M_3 - M_2)$

Conclusion:

Relative density

$$= \frac{\text{mass of any volume of sand}}{\text{mass of an equal volume of water}}$$

$$= \frac{(m_2 - m_1)}{(m_4 - m_1) - (m_3 - m_2)}$$

Example

In an experiment measure the relative density of sand a student obtained the following.
Mass of empty density bottle = 38g
Mass of density bottle, filled with sand = 74g.
Mass of density bottle, filled with sand and topped with water = 98g.
Mass of density bottle full of water only= 80g. Calculate the relative density of sand.

Solution

Relative density

$$= \frac{\text{mass of any volume of sand}}{\text{mass of an equal volume of water}}$$

Mass of any volume of sand = 74g – 38g
=36g
Mass of water only = 80g – 38g = 42g
Mass of water added to sand = (98 – 74) g
= 24g
Mass of an equal volume of water
= 42g – 24g
= 18g

Relative density of sand = $\frac{36g}{18g} = 2$

Measuring the relative density of a stone using displacement method

***Apparatus*:**

Measuring instrument e.g. beam balance, measuring cylinder, string, over flow can.

Procedure:

Measure the mass of a stone using a beam balance or a string balance.
Fill the over flow can with water until it starts dripping out of the spout.

Measure the mass of an empty dry beaker using a beam balance.
Place the beaker under the spout when the water has stopped dripping.
Tie the stone with a thin thread and immerse it completely in the water in the eureka can.

Remove the beaker with the displaced water when the water has stopped dripping from the spout.
Measure the mass of the beaker with the displaced water using a beam balance.
Results:
Mass of the stone = M_s
Mass of empty dry beaker = M_b
Mass of a beaker with displaced water = M_d
Mass of an equal volume of water = ($M_d - M_b$)
Conclusion:

$$\text{Relative density} = \frac{\text{mass of the stone}}{\text{mass of an equal volume of water}}$$

$$= \frac{m_s}{m_d - m_b}$$

Significant figures

Length of the block is 3.15cm

When taking measurements e.g. the length of the block above using a metre rule, the last digit in the figure or reading was obtained by guessing between two points either 3.1 or 3.2. The reading is said to be correct to three significant figures. The 1st two figures 3and 1 are known to be correct but the 3rd digit 5 is an estimation.
Measurements are always given correct to a certain number of significant figures. To determine the number of significant figures the following rules are applied.

1. All non zero (0) digits are significant e.g. 3.15 has 3 significant figures. 4879 has 4 significant figures.
2. All zeros between non – zero digits are significant e.g. 4000.7 has 5 significant figures. 102.09 has 5 significant figures. 103.008 has 6 significant figures.
3. Zeros to the right of a non-zero digit but to the left of a decimal point which is not indicated (an understood decimal point) may or may not be significant e.g. 76.4000 may be correct to 3, 4, 5, or 6 significant figures. 100 may be correct to 1, or 2 or 3 significant figures.
4. All zeros to the right of a decimal point following a non-zero digit are significant e.g. 92.00 is correct to 4significant figures. 7.980 is correct to 4 significant figures. 1.0 has 2 significant figures.
5. All zeros not mentioned in the above rule are not significant that is to say all zeros to the right of a decimal point and before a non- zero digit are non- significant e.g. 0.02 has only one significant figure which is 2. 0.00002 is correct to 1 significant figure. 0.00782 has 3 significant figures.

Examples:
Correct the following readings to have 2 significant figures.

a) $6687 \approx 6700$
b) $0.000392 \approx 0.00039$
c) $200.05 \approx 200$

d) 12.016648 $\approx$ 12

e) 105.06 $\approx$ 1100

Standard form

Some numbers e.g. 0.000,000,000,000,456cm; 1,000,000,000,000kg; 0.00,000,000,000,001 km; 600,000,000,000,000,000,000,000 kg, 0.00401s, 120145m are inconvenient to write especially during calculation, using powers or indices or exponents of 10 these numbers can be simplified. A positive power or positive indices is the number of times the number must be multiplied by 10 while a negative power or indices is the number of times the number must be divided by 10. These numbers can be written by in the form ($a \times 10^n$) where a is a number which has only one non-zero digit to the left of a decimal point (it lies between 1.0 to 9.9) and n is a positive integer or negative integers. This method of representing numbers is called the standard form (exponential notation or scientific notation).

Positive integers

$1 = 1\times 1=1 \times 10^0$

$10 = 1 \times 10 = 1 \times 10^1$

$100 = 1 \times 100 = 1 \times 10^2$

$1000 = 1 \times 1000 = 1 \times 10^3 = 1.0 \times 10^3$

$10000 = 1 \times 10000 = 1 \times 10^4 = 1.0\times 10^4$

$100000 =1 \times10\times10\times10\times10\times10 = 1\times10^5$

$1000000 = 1\times10\times10\times10\times10\times10\times10= 1\times10^6$ 1.0×10^6

Negative integers

$0.1= \frac{1}{10} =1.0\times10^{-1}$

$0.01=\frac{1}{100}=\frac{1}{10^2}=1.0\times10^{-2}$

$0.001=\frac{1}{1000}=\frac{1}{10^3}=1.0\times10^{-3}$

$0.0001=\frac{1}{10000}=\frac{1}{10^4}=1.0\times10^{-4}$

$0.00001=\frac{1}{100000}=\frac{1}{10^5}=1.0\times10^{-5}$

$0.000001=\frac{1}{1000000}=\frac{1}{10^6}=1.0\times10^{-6}$

Examples:

a. 6000000000000000000000000kg
$= 6.0\times10^{24}$kg

b. $70000001 = 7.0000001 \times 10^7$

c. $1000000 = 1.0\times 10^6$

d. $384 = 3.84\times10^2$

e. $12 = 1.2\times10^1$

f. $7 = 7.0\times10^0$

g. $5260000= 5.26\times10^6$

h. $106000 = 1.06\times10^5$

i. $1000 = 1.0\times10^3$

j. $156.2 = 1.562\times10^2$

k. $1000.37 = 1.00037\times10^3$

l. $\frac{8}{1000}=\frac{8}{10\times10\times10}=\frac{8}{10^3}=8\times10^{-3}$

Note: $a^m\times a^n = a^{(m+n)}$

$\frac{a^m}{a^n} = a^m \div a^n = a^{(m - n)}$

$(a^m)^n = a^{(m \times n)} = (a)^{mn}$

$a^0 = 1$

$a^{-1} = \frac{1}{a^1}$

$a^{-n} = \frac{1}{a^n}$

$a^{\frac{1}{n}} = a^{-n}$