Unit 1: Laboratory Safety Rules and Measurements of Physical Quantities

1.1 What is science?

The word **science** is derived from Latin word "***scientia"*** which means knowledge attained through study and practice.

Thus, ***science refers to a systematic study that uses observation and experimentation to describe and explain natural phenomena.***

The purpose of science is to produce useful models of reality which are used to advance the development of technology, leading to better quality of life for man and the environment around him.

Classification of sciences

Science is classified into three branches such as ***social sciences, natural sciences and formal sciences.***

Social sciences deal with the study of human behavior and society. Examples of these are psychology and sociology.

Natural sciences deal with the natural phenomena, for examples motion, earthquakes.

Formal sciences deal with mathematical concept and logic. An example of this is mathematics.

1.2 Physics as science and its characteristics

The ***physics*** comes from the Greek which means ***knowledge of nature***. Thus, ***physics refers to the study of matter and energy and their interaction***.

The general aim of physics is to analyze and understand the natural phenomena of the universe.

Objectives of Physics to a learner

Physics as a science subject aims at helping learners to

- deepen their knowledge of basic principles and concepts of physics.
- equip learners with scientific method and techniques of solving daily life's problems in our physical environment.
- develop initiatives and inventions
- translate learners' knowledge of physics into technological skills.

Branches of Physics

Physics is studied under several overlapping branches. The major branches of physics are:

1. ***Electromagnetism****:* is the study of electric and magnetic fields. This has lead to the development of useful electronic devices such as louderspeaskers, electric bells, generators among other devices
2. ***Mechanics:*** is the study of the action of forces on an objects and motion. The knowledge of mechanics has lead to development of many motion related objects

including vehicles, planes, ships, trains etc that have made our movement from one place to another faster and easier.

3. ***Thermodynamics:*** is the study of the relationship between heat, other forms of energy and work. The knowledge of thermodynamics is applied in making thermos flaks, refrigerators, car engine radiators and air conditioners among other devices.
4. ***Optics:*** is the study of behavior and physical properties of light**.** This has lead to development of various optical devices like the lenses, microscope, fibre optics among other devices.
5. ***Acoustics:*** is the study of sound and sound waves. This study has been an instrumental tool in the development of various musical instruments like guitars, drums and pianos among other devices
6. ***Electronics*** is a branch of physics that deals with the emission and effects of electrons and with the use of electronic devices.
7. ***Geophysics*** is the geology that uses physical principles to study properties of the Earth.
8. ***Atomics physics or Nuclear physics*** is the branch of physics that studies the internal structure of atomic nuclei.
9. ***Astronomy*** is a branch of physics that studies celestial bodies and the universe as a whole.

1.3 Physics in relation to other subjects

1.3.1 Physics in relation to chemistry

The study of structure of atoms, radioactivity, X-ray, diffraction, etc., in physics has enabled chemists to rearrange elements in the periodic table and to have a better understanding of chemical bonding and complex chemical structures.

1.3.2 Physics in relation to Biological science

The optical microscopes developed in physics are extensively used in the study of biological samples. Electron microscope X-rays and radio isotopes are used widely in medical sciences.

1.3.3 Physics in relation to geography

In **geography,** weather forecast, a geographer uses a barometer, wind gauge, etc. which are instrument developed by a physicist.

1.3.4 Physics in relation to Agriculture,

In **Agriculture,** the water sprinkler, insecticide sprayer, etc. make use of the principles developed by physicists.

1.3.5 Physics in relation to social sciences

In **History,** the determination of age fossils by historians and archaeologists use the principle developed by physics.

1.4. Careers opportunities in physics

Physics has many applications, these applications lead to diverse career opportunities depending on one's skill and attitude. Some of the careers one can fit in after studying Physics include:

- laboratory technology,
- mapping and surveying,
- civil engineer,
- electrical engineer,
- mechanical engineer,
- instrumentation technology,
- meteorology,
- electronics and telecommunication engineers,
- aeronautical engineering,
- school teacher,
- university lecturer,
- Doctor in medicine etc.

1.5. Physics, society and technology

Physicists search for reliable information and then organize it into fundamental laws and principles. On the basis of these laws and principles, the engineers and technologists design and develop devices and appliances that make our living more comfortable.

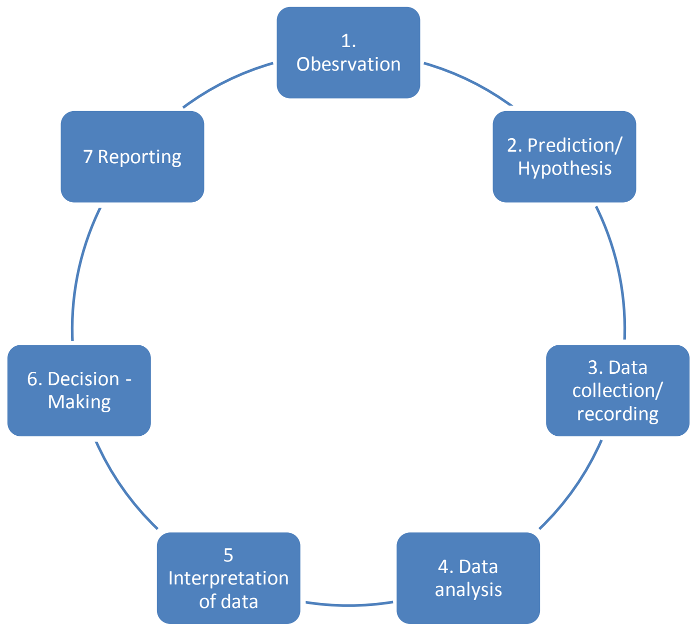
1. The development of telephone, telegraph and telex enables us to transmit messages instantly.
2. The development of radio and television, satellites has revolutionized the means of communication.
3. Advances in electronics (computers, calculators and lasers) have greatly enriched the society.
4. Rapid means of transport are important for the society.
5. Generation of power from nuclear reactors is based on the phenomenon of controlled nuclear chain reaction.
6. Digital electronics is widely used in modern technological development.

1.6. Science Processes Skills Used In Learning Physics

Scientific investigation is a systematic process of testing ideas or finding out answers to the question and observations. All scientific investigations are carried out using common process.

Stages of a scientific investigation

1. Observation
2. Prediction/ Hypothesis
3. Data collection/ recording
4. Data analysis
5. Interpretation of data
6. Decision –Making
7. Reporting



i. Observation

Observation consists of receiving knowledge of the outside world through our senses, or recording information using scientific tools and instruments. Eg: Any data recorded during an experiment can be called an observation.

It uses questions to receive information, those questions are: what, who, where, which, when, why.

ii. A prediction/hypothesis

A prediction is a guess what might happen based on observation. Eg: A college student is studying hard for their final exam really one might predict they will get an A on it.

iii. Experimentation (Data Collection/recording)

Data collection is the process of gathering and measuring information on variables of interest, in an established systematic fashion that enables one to answer stated research questions, test, and evaluate outcomes.

iv. Data Analysis

Data Analysis is the process of systematically applying statistical and/or logical techniques to describe and illustrate, condense and recap, and evaluate data.

v. The Interpretation of Data

The interpretation of data is the action of explaining the meaning of something or is an attempt to figure out what has been observed.

vi. Decision-Making (Draw conclusion)

Decision-making is regarded as the cognitive process resulting in the selection of a belief or a course of action among several alternative possibilities. Every decision-making process produces a final choice that may or may not prompt action. Decision-making is the process of identifying and choosing alternatives based on the values and preferences of the decision- maker

vii. Reporting

Scientific report is a document that describes the process, progress, or results of technical or scientific research or the state of a technical or scientific research problem. It might also include recommendations and conclusions of the research.

Evaluating a scientific investigation

After completing a scientific investigation, the researcher should evaluate the entire process of the investigation against the objectives that were outlined before the investigation.

1.7. Laboratory Safety And Safety Rules

1.7.1. Personal safety rules

1. Read labels carefully
2. Follow instructions to the latter
3. Long hair or loose clothes must be tied back or confined
4. Clean up your work area before leaving
5. While inside the laboratory, do not run, play or throw things
6. Never chew, eat or drink in the laboratory
7. Inform the teacher at once about any accidents.

1.7.2. Emergency Response safety rules

1. It is your responsibility to read safety and fire alarm posters and follow the instructions during an emergency
2. Know the location of the fire extinguisher, eye wash, and safety shower in your lab and know how to use them.
3. Notify your instructor immediately after any injury, fire or explosion, or spill.
4. Know the building evacuation procedures.

1.7.3. Personal and General Laboratory Safety

1. Never eat, drink, or smoke while working in the laboratory.
2. Read labels carefully.
3. Do not use any equipment unless you are trained and approved as a user by your supervisor.

4. Wear safety glasses or face shields when working with hazardous materials and/or equipment.
5. Wear gloves when using any hazardous or toxic agent.
6. Clothing: When handling dangerous substances, wear gloves, laboratory coats, and safety shield or glasses. Shorts and sandals should not be worn in the lab at any time. Shoes are required when working in the machine shops.
7. If you have long hair or loose clothes, make sure it is tied back or confined.
8. Keep the work area clear of all materials except those needed for your work. Coats should be hung in the hall or placed in a locker. Extra books, purses, etc. should be kept away from equipment that requires air flow or ventilation to prevent overheating.
9. If leaving a lab unattended, turn off all ignition sources and lock the doors.
10. Clean up your work area before leaving.
11. Wash hands before leaving the lab and before eating

1.7.4. Electrical Safety

1. Obtain permission before operating any high voltage equipment.
2. Maintain an unobstructed access to all electrical panels.
3. Wiring or other electrical modifications must be referred to the Electronics Shop or the Building Coordinator.
4. Never, ever modify, attach or otherwise change any high voltage equipment.

1.7.5. Additional Safety Guidelines

1. Never do unauthorized experiments.
2. Never work alone in laboratory.
3. Keep your lab space clean and organized.
4. Do not leave an on-going experiment unattended.
5. Always inform your instructor if you break a thermometer. Do not clean mercury yourself!!
6. Never use open flames in laboratory unless instructed by teacher

1.8.**First aid**

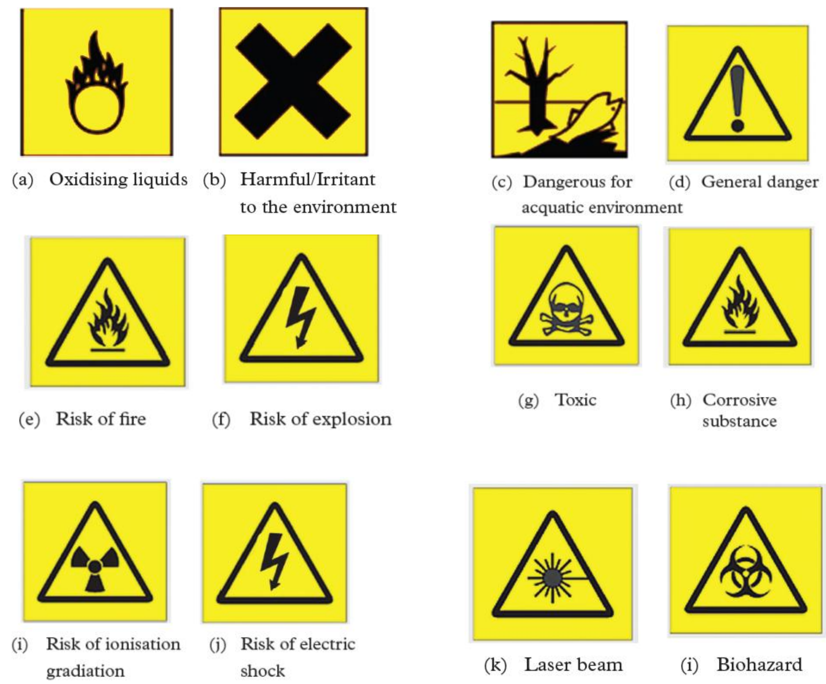
The purpose of *first aid* is to make the victim secure and comfortable. This prevents his/her condition from becoming worse until professional assistance is available.
All physics students need to have adequate knowledge of first aid. The physics laboratory should have a fire extinguisher and a first aid kit containing the following items:

- A pair of blunt-ended scissors.
- Mild antiseptic solution.
- Safety pins.
- Forceps.
- Gloves.
- An assortment of bandages.

- Adhesive plaster.
- Sterilized cotton wool and gauze.

1.9.Hazard symbols and their meanings

Signs and symbols are meant to help us quickly identify the risks we are likely to be exposed to when handling equipments, apparatus and chemicals.
The following are some of the common hazard symbols in a laboratory.



1.10. Laboratory hazards and safety precautions to be taken

a) Fire outbreak

- Move to fire assembly points using fire exit points.
- Inform the teacher or the instructor.
- If you can, use the fire extinguisher to put the fire off.
- If you can, switch off the main switch of the laboratory wiring system.
- Note: Do not scream.

b) Electrical shock

- Switch off the power at the socket first.
- Pull out the victim from the appliances
- Give the victim first Aid.
- If the victim is not breathing, tap three times on his/her left side of the chest
- If not breathing,‘give a kiss of life’ i.e. help the victim to breath
- Seek for medical assistance from medical personnel

c) Suffocation

- Take the victim out of the laboratory to open air for fresh air.
- Open all the windows and doors.

- Seek assistance from the medical personnel

d) Chemical spillage on the skin, floor, table etc

- Pour a lot of pure water to the affected part to dilute the chemical.
- In case the chemical is in contact with your eye, use the eye wash.
- If you tasted the chemicals, drink clean water.
- Seek medication immediately.

e) Breaking of equipments

- The teacher should guide the students to use equipment correctly.
- Inform the teacher immediately.
- With the help of the teacher or instructor collect the pieces of broken apparatus.

f) Breaking of general safety

- Guide and counsel the students
- Use school disciplinary committee to correct the student.

1.11. Fundamental and derived quantities of measurement

A quantity may be defined as any observable property or process in nature with which a number may be associated.

Fundamental quantities

Fundamental or base quantities are the physical quantities, which are ***self explanatory***. Like ***length, mass, time, temperature, electric current amount of substance and luminous intensity*** are known as primary fundamental quantities. The fundamental quantities are quantities that *can be measured using measuring instruments* and they are ***not expressed in terms of others***.

SI unity and symbols

In order to measure any quantity, a ***standard unity*** of reference is chosen. The standard unit chosen must be:

- unchangeable,
- always reproducible and
- not subject to either the effect of aging and deterioration or possible destruction.

Table of Fundamental quantities and SI units

Quantity	***SI basic unit***	***Symbol of unit***
Length	Metre	*M*
Mass	Kilogram	*Kg*
Time	Second	*S*
Electric current	Ampere	*A*

Thermodynamic temperature	Kelvin	*K*
Amount of substance	Mole	*Mol*
Luminous intensity	Candela	*Cd*

Derived quantities

Derived quantities are physical quantities, which are explained through fundamental quantities; they are expressed in terms of others. Examples are area, density, volume, force etc.
Their units are products and divisions of basic units

Derived quantity			
Quantity	***Symbol of quantity***	***SI basic unit***	***Symbol of unit***
Area	*A*	Metre squared	m^2
Volume	*V*	Metre cube	m^3
Speed	*v*	Metre per second	ms^{-1}
Density	ρ	Kilogram per meter cube	kgm^{-3}
Acceleration	*a*	Metre per second squared	ms^{-2}
Energy	*W*	Joule	*J*
Force	*F*	Newton	*N*
Pressure	*P*	Pascal	*Pa*
Power	*P*	Watt	*W*

Metric Prefix

A *metric prefix* is a unit prefix that precedes a basic unit of measure to indicate a multiple or fraction of the unit.
Each prefix has a unique symbol that is pretended to the unit symbol. The prefix ***kilo*** for example, may be added to gram to indicate multiplication by one thousand: one kilogram is equal to one thousand grams. The prefix ***mille*** likewise, may be added to meter to indicate division by one thousand; one millimeter is equal to one thousandth of a meter
The table below shows some common prefixes and their symbol.

Prefix	***Symbol***	***Scientific notation***
yocto	*y*	10^{-24}
zepto	*z*	10^{-21}
Atto	*a*	10^{-18}
Femto	*f*	10^{-15}
Pico	*p*	10^{-12}

Nano	n	10^{-9}
Micro	μ	10^{-6}
Milli	m	10^{-3}
Centi	c	10^{-2}
Deci	d	10^{-1}
Deca	da	10^{1}
Hecto	h	10^{2}
Kilo	k	10^{3}
Mega	M	10^{6}
Giga	G	10^{9}
Tera	T	10^{12}
Peta	P	10^{15}
Exa	E	10^{18}
Zeta	Z	10^{21}
Yotta	Y	10^{24}

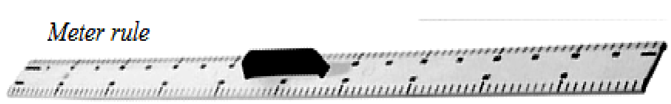
1.12. Measuring instruments

Measurements involve comparing an unknown quantity with a known fixed unity quantity (standard unity). This measurement consists of two parts, the ***unit*** and the ***number*** indicating how many units are there in quantity being measured.
Scientists had developed ***measuring devices (measuring instruments)*** to perform measurements. A measuring device has a ***scale*** marked in the standard or multiple unit of quantity to be measured. The choice of the instrument to be used depends of the quantity to be measured.

1.12.1. Measuring Length

Length means how far a distance is between two points. The SI unit of length is **metre.** Other systems use units like inch, foot, mile, light year, etc.
Some terms are referred to as length in a particular direction such as width, depth, height
Let us now discuss some of the instruments used to measure length.

1. ***Meter rules*** measure length up to 100cm and have a sensitivity of 1cm.
2. ***Rulers*** are smaller version of metre rules. They can measure length up to 30cm and their sensitivity is 1mm.



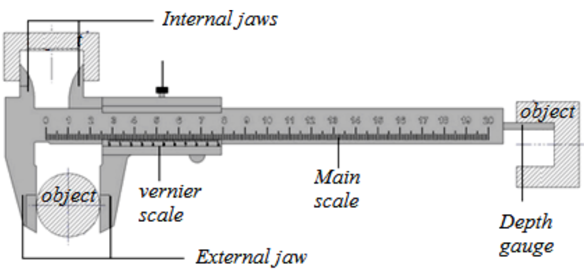
3. ***Tape*** measures are long roll, strip of plastic paper or any other fabric that is marked off in centimeters or inches.

4. ***Vernier Callipers***

Vernier calliper is an instrument for making very accurate linear measurements was introduced in 1631 by Pierre Vernier of France. Vernier callipers are widely used in scientific laboratories and in manufacturing for quality control measurement.

Description of Vernier calliper

a) ***Main Scale:*** The main scale is similar to that on a ruler, graduated in mm and cm on one side; inches on the other side.
b) ***Vernier Scale****:* The Vernier scale is a sliding scale .It slides parallel to the main scale and enables readings to be made to a fraction of a division on the main scale.
c) ***Screw:*** The Vernier scale can be fixed at any position on the main scale with the help of a screw.
d) ***Jaws****: It* has two jaws. The lower jaws are called outside jaws and they are used to measure the length of a rod, diameter of a sphere or the external diameter of a cylinder. The upper jaws are called the inside jaws which are used to measure the internal diameter of a hollow cylinder or pipe.
e) ***Strip:*** The thin strip is used to measure the depth of the objects like beakers.



How to use and read a Vernier caliper?

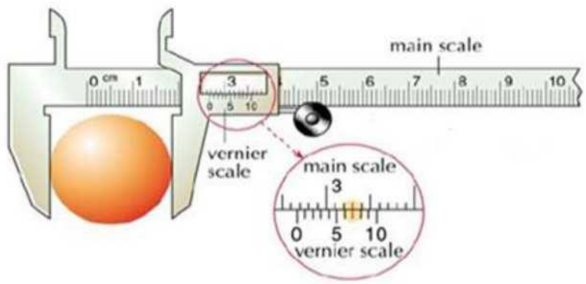
a) The jaws are first gently closed on the object to be measured.
b) Note the main scale reading (M.S.R)
c) Note the division on Vernier scale which coincides with any division of the main scale. Multiply this number of Vernier division with the least-count. This is the Vernier scale reading (V.S.R) Hence $V.S.R = Vernier\ scale\ coincidence \times Least\ Count\ (L.C.)$
d) $\boldsymbol{L.C.} = \frac{\boldsymbol{Value\ of\ one\ main\ scale\ division}}{\boldsymbol{Total\ number\ of\ divisions\ on\ Vernier}}$

e) Add the main scale reading to the Vernier scale reading. This gives the observed length. Hence,

$$\boldsymbol{Observed\ Reading = Main\ scale\ reading + Vernier\ scale\ reading}$$
$$\boldsymbol{Observed\ reading = M.S.R + V.S.R}$$
$$\boldsymbol{Observed\ reading = M.S.R + (Vernier\ scale\ coincidence \times L.C.)}$$

Example

State the value of the reading shown by the figure below



Answer

Least count $(L.C) = 0.01cm$

$M.S.R. = 2.6cm$

Vernier scale coincidence $= 7$

$V.S.R =$ Vernier scale coincidence $\times L.C.$

$V.S.R = 7 \times 0.01cm = 0.07cm$

Observed reading $= M.S.R + V.S.R = 2.6cm + 0.07cm = 2.67cm$

Other method of reading a vernier caliper

$$Reading\ = Main\ scale\ coincidence - (Vernier\ scale\ coincidence \times 0.09)$$

Observed reading $= M.S.C.R - (V.S.C.R \times 0.09)$

On our example, the $M.S.C.R = 3.3$

The $V.S.C.R = 7$

Therefore, the observed reading $= 3.3cm - (7 \times 0.09)cm = 2.67cm$

Uses of Vernier calipers

Vernier calipers are used to measure:

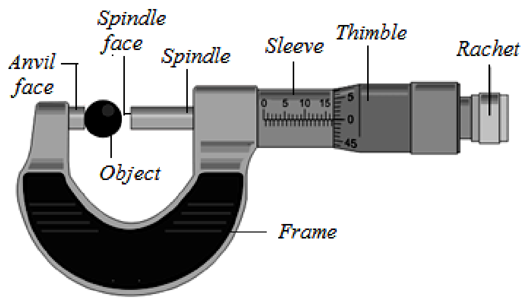
a. The length of a rod or any object.
b. The diameter of a sphere.

c. The internal and external diameter of a hollow cylinder.
d. The depth of a small beaker

5. Screw Gauge

Screw Gauge is a device which can measure very small lengths (or thickness) up to one hundredth part of a millimeter. It can be used to measure diameter of a wire, thickness of a thin metal sheet, etc.

***Description*:** A Screw Gauge is shown here and its main parts are described below.



1. ***Frame:*** It consists of U shaped metallic frame. To one side of this U frame there is a long hollow cylindrical tube with a nut inside it, the inner side of cylindrical nut contains a uniform thread cut in it. On the other side of U frame a fixed stud with a plane face is attached.
2. ***Main scale:*** The extended portion of the nut, graduated in millimeters or half-millimeters is called the main scale. It has a base line along the axis of the nut.
3. ***Thimble:*** The hollow cylinder at the end of the screw is called thimble.
4. ***Circular scale:*** The graduated head of the thimble is called circular scale (C.S.).The CS is generally divided into 50 or 100 equal divisions.
5. ***Ratchet:*** The ratchet avoids undue tightening of the screw and helps in holding the object between the stud and the end of the screw.

Principle of the screw gauge

The screw gauge works on the principle of screw. When a screw is rotated in a nut, it exhibits both linear and rotational motions.
When a screw is moved in a fixed nut, the linear distance travelled by the screw on the main scale when the circular is given one complete rotation is called Pitch of the screw.

Least count of the screw gauge

a) $\boldsymbol{L.C.} = \frac{\boldsymbol{Pitch\ of\ the\ screw}}{\boldsymbol{Total\ number\ of\ divisions\ on\ the\ circular\ scale}}$

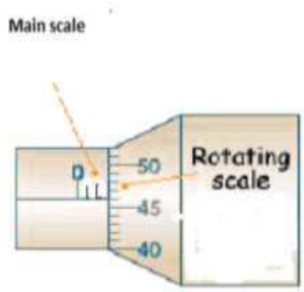
Generally, the pitch of the screw gauge is $1mm$ and it has $100 divisions$ on its circular scale. Hence, $L.C = \frac{1mm}{100} = 0.01mm \text{ or } 0.001cm$.

Determination of the diameter d of a wire

a) Place the wire between the stud and spindle end as indicated in the diagram.
b) Rotate the thimble until the wire is firmly held between the stud and the spindle.
c) The racket is provided to avoid excessive pressure on the wire. It prevents the spindle from further movement - squashing the wire!
d) To take a reading first look at the main scale and note the main scale reading $(M.S.R)$.
Note the division of the circular scale which coincides with the base line of the main scale
e) This circular scale division $(C.S.D)$ when multiplied by the least count $(L.C)$ gives the circular scale reading $(C.S.R)$.
f) Add the Main scale reading (M.S.R) and the circular scale reading $(C.S.R)$. This gives the $Observed\ reading = M.S.R + C.S.R$ or $Observed\ reading = M.S.R + (C.S.D \times L.C.)$

Example

State the value of the reading shown by the figure below



Answer

$L.C = 0.01mm$

Main scale reading $(M.S.R) = 2mm$

Division on the circular scale which coincides with the base line $(C.S.D) = 46$

Thus, observed reading $= M.S.R + (C.S.D \times L.C)$

Observed reading $= 2mm + (46 \times 0.01mm) = 2mm + 0.46mm = 2.46mm = 0.246cm$.

1.12.2. Measuring Mass

1. **Beam balance**

A beam balance basically consists of a pivoted beam on which pans are attached.

To obtain the mass of an object from the beam balance, the object is placed on one pan and is compared with a known mass placed on the other end.

Single pan triple beam balance

2. **Electronic Balance**

An electronic balance is a weighing device that displays weight of a substance in figures on a digital screen.

Electronic balance

3. **Lever arm balance**

A lever arm balance uses a pan that suspends the weight arm across a dual or a single scale

Lever arm balance

1.12.3. Measuring Time

1. **Stopwatches**

A stopwatch is a watch that can be started and stopped very quickly and that is used for measuring the amount of time elapsed.

2. **Hourglass**

An hourglass (sandglass, sand timer, sand watch, sand clock, egg timer) measures the passage of fixed and equal intervals of time. It has two connected vertical glass bulbs allowing a regulated trickle of material from the top to the bottom. Once the top bulb is empty, it can be inverted to begin timing again.

1.14.Measurement of derived quantity

1.14.1. Measurement of area

The area is a measure of the extent of the surface. The SI unit of area is m^2 derived from the multiplication of two side lengths

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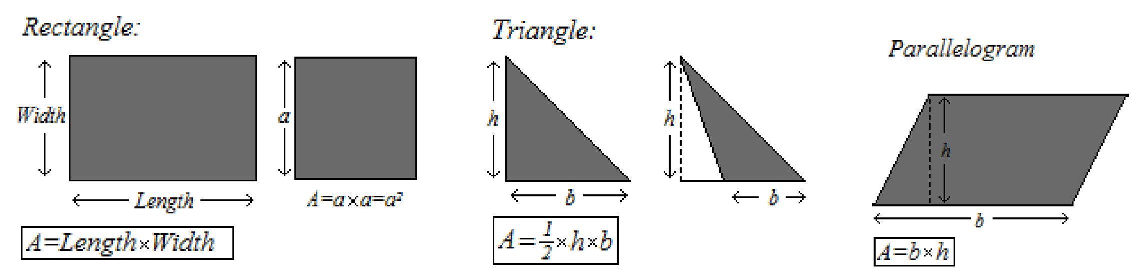
Area of regularly shaped objects

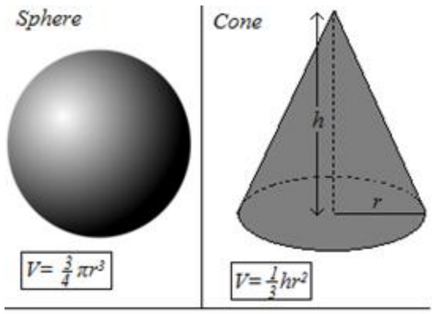
The area of a regularly shaped object may be obtained by measuring the relevant dimension(s) and then applying the appropriate formula.

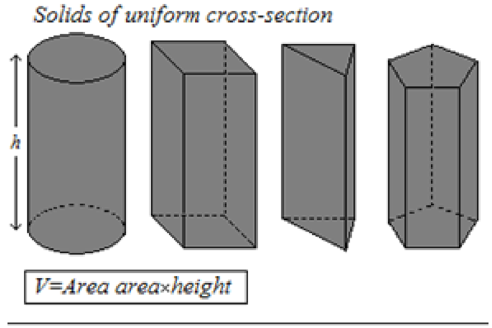


1.14.2. Measurement of volume

Volume of regularly shaped objects

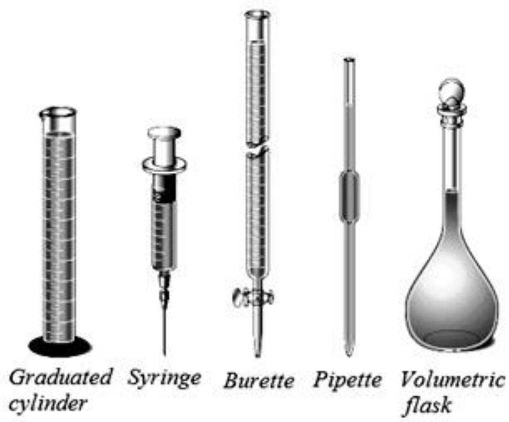
The volume of a regularly shaped solid may be determined by measuring the required dimensions and then applying the appropriate formula. The figures below show some of the solids and the formulae to find their volumes.





Volume of liquids

Liquids are measured using transparent and graduated glassware such as measuring cylinders, syringes, burettes, pipettes, flasks, beakers, etc. When making a reading on a these instruments, an instrument should be upright and the eye level with the bottom of the curved liquid surface.



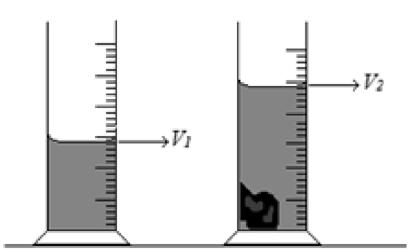
To determine the volume of an irregular solid using measuring cylinder: by displacement method.

Apparatus:

- Measuring cylinder
- An irregular solid such as a stone
- Water

Procedure:

1. Pour water into a measuring cylinder
2. Read and record the volume V_1



3. Carefully put the irregular solid into the water and record the new volume V_2

4. Find the volume of the irregular solid $V = V_2 - V_1$ and convert the answer into m^3 or cm^3

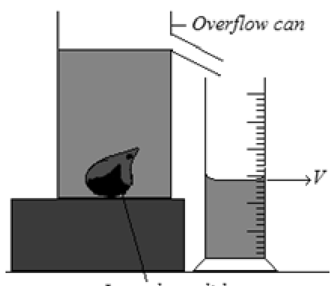
To determine the volume of an irregular solid by using Eureka can: over flow method

Apparatus:

- Overflow can
- Measuring cylinder
- An irregular solid
- Water

Procedure

1. Pour water into an overflow can until it reaches the tube and wait until water cease to flow
2. Place a measuring cylinder below the tube of the overflow can and put the irregular solid inside



3. Find the volume of the irregular solid $V = Volume of\ water\ in\ the\ cylinder$ and convert the answer into m^3 or cm^3

1.14.3. Density

Density is defined as the mass per unit volume. From the definition of density, the formula for calculating density is as follow:

$Density = \frac{mass of substance}{volume of substance}$, the SI unit: kgm^{-3} i.e. $[kg/m^3]$

To determine the density of the liquid

Apparatus:

- Liquid (Water or oil)
- Measuring cylinder

Procedure:

1. Measure the mass m_1 of an empty dry cylinder
2. Pour a liquid in the cylinder at volume V
3. Measure the mass m_2 of the cylinder containing the liquid.

4. Calculate density of the liquid $\rho = \frac{m_2 - m_1}{V}$

Relative density

The relative density is a number telling us how many times the material is denser than a standard substance. It is the ratio of its mass to that of an equal volume of a standard substance.

$$\rho = \frac{m_2 - m_1}{V}$$

$Relative\ density = \frac{densit\ y\ of\ a\ substance}{density\ \ of\ the\ standard\ \ substance}$. The relative density has no unit.

Water ($1000kgm^{-3}$) is the standard substance for liquids and solids. The standard substance for gases is hydrogen ($0.1kgm^{-3}$). Water and hydrogen were chosen because they found very often in nature. If the substance is less dense than water, the substance number is less than 1. Thus the substance floats over water. The instrument used to measure density is called ***densimeter*** or ***hydrometer***.