UNIT ONE....1
MEASUREMENTS....1
Introduction....1
SI Units....2
Basic / Fundamental Units of Measurements....2
Important points to Note....3
Derived Units....3
Length....4
Measurement of Length....5
Area....7
Volume....9
Volume of Regular Solid....9
Volume of liquid....9
Measurement of Mass....10
Measurement of Time....10
Measurement of Temperature....10
Measurement of Electric Current....10
Measurement of Luminous intensity....10
Summary of Measuring Instrument....10
Some Instruments and their Uses....11
Venier Calipers....11
Pair of Calipers....11
Micrometer Screw Gauge....12
Spherometer....12
Opisometer....12
Odometer....12
Speedometer....12
Anemometer....12
Aneroid Barometer....12
Hydrometer....12
MASS AND WEIGHT....13
Mass....13
Weight....13
Difference between mass and weight....14
Speed....14

Velocity 15
Volume 15
Density 16
Experimental Determination of Density of Regular And Irregular Objects 17
Worked Examples on Relative Density 20
Temperature 22
Conversion of Temperature between the Two Scales 22
Worked Examples 23
UNIT 2 24
WORK, ENERGY AND POWER 24
ENERGY 24
Forms of Energy 24
Law of Conservation of Energy 25
Energy Transformation (Interconversion Of Energy) 26
Efficiency of Energy Change 28
Worked Examples 28
Kinds of Energy 29
Examples of Body Possessing PE 30
Mechanical Energy 30
Worked Examples 33
Work 33
Types of Work done 34
Power 35
Worked Examples 35
UNIT 3 37
LIGHT ENERGY 37
Properties of light 37
a) Natural sources: 37
b) Artificial sources 37
Description of Bodies in Relation to Light 38
Rectilinear Propagation of Light 39
Effect of Obstacles in Light Path 39
Experiment to Show that Light Travels in a Straight Line 39
Propagation of Light Ray 40
A ray of light 40
The Pinhole Camera 40

Nature of a Pinhole Camera....41
Principle of Action....41
How the Image is Produced....41
Characteristics of the Image Produced in a Pinhole Camera....41
Effect of Increasing Size of a Pinhole Camera....42
Advantages of a Pinhole Camera....42
Disadvantages of a Pinhole Camera....43
Magnification (M) 43
Worked Examples....43
Reflection Of Light....45
Reflection by Plane Mirror....46
Types Of Reflection....47
Laws of Reflection....48
Differences between Real and Virtual Image....50
Image Formation on Plane Mirror....50
Characteristics of the Image Formed by a Plane Mirror....51
Uses of plane mirrors....51
Application of Reflection in Plane Mirrors....52
REFRACTION....52
Conditions for Light to be Refracted....52
Formation of images in plane mirrors....50
Absolute Refraction Index....55
Effects of Refraction....55
Critical Angle (C) 58
Total Internal Reflection....59
Question....60
Conditions for Total Internal Reflection to Occur....60
Application of Total Internal Reflection....60
Question....60
Reflection at curved surfaces....61
Construction of ray diagrams....61
Rules for constructing images formed by spherical mirror....63
Images....63
Uses of Converging Mirror....65
Images formed by a convex (diverging) mirror....66

UNIT I

MEASUREMENTS

Introduction

Science is studied all over the world, and it is important that scientific measurements obtained in one country can be compared with results from another country. Measurement is taking dimension of an object. For scientific measurement to be meaningful and credible, it has to be taken and expressed in a set of standard units which are internationally accepted. Measurement is determining the magnitude of some attribute of an object, such as its length, weight, or depth relative to some standard (unit of measurement), such as a meter or a kilogram. The term is also used to indicate the number that results from that process.

The act of measuring usually involves using a measuring instrument, such as a ruler, weighing scale, thermometer, speedometer, or voltmeter, which is calibrated to compare the measured attribute to a measurement unit. Any kind of attributes can be measured, including physical quantities such as distance, velocity, energy, temperature, or time.

Measurement is fundamental in science; it is one of the things that distinguish science from pseudoscience. It is easy to come up with a theory about nature, hard to come up with a scientific theory that determines measurements with great accuracy. Measurement is also essential in industry, commerce, engineering, construction, manufacturing, pharmaceutical production, and electronics.

SI Units

The International System of Unit (abbreviated as SI unit from the French word Systême International d'Unitès) is the modern, revised form of the metric system. It is the world's most widely used system of units, both in everyday commerce and in science. The SI was developed in 1960 from the metre-kilogram-second (MKS) system, rather than the centimetre-gram-second (CGS) system, which, in turn, had many variants. At its development the SI unit also introduced several newly named units that were previously not a part of the metric system. SI units are universally accepted units of measurement, regardless of country or language.

SI units are of two types:

1) .Fundamental SI unit   2).Derived SI units.

Basic / Fundamental Units of Measurements

All physical quantities can be expressed in terms of seven base units. These are:

Base Quantity	Name	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Thermodynamic

Important points to Note

a. when using the symbol, the letter 's' is never used to show a plural form e.g. **5kg** not 5kgs, **2m** not 2ms

b. When writing units named after famous scientists in full, never begin with a capital letter e.g. **newton** not Newton, **kelvin** not Kelvin

Derived Units

Derived units are **the combination of two or more of the fundamental units**, e.g. **density** as seen earlier is "mass per unit volume".

$$\text{density} = \frac{\text{mass (in kg)}}{\text{volume (in m3)}}$$

To find the derived unit of density, we have

$$\text{density} = \frac{\text{kg}}{\text{m3}}$$

✍ kg/m^3 or kgm^{-3}

Again, **speed/ velocity** is the rate of change of distance,

$$\text{speed} = \frac{\text{distance (in m)}}{\text{time (in s)}}$$

$$\textit{unit of}\,\text{speed} = \frac{\text{m}}{\text{s}}$$

✍ unit of speed is $= m/s$ or ms^{-1}

Also **acceleration** is the rate of change of velocity.

$$\text{Acceleration} = \frac{\text{Velocity (in } ms^{-1})}{\text{Time (in s)}}$$

Finally, **force** = mass x acceleration

Unit of force = mass (kg) x acceleration (m/s^2)

$= kg \times m/s^2$

$= kgm/s^2$ ✍ newton (N)

Force is measured in newton, symbolized as N

Derived quantities, are defined in terms of the seven base quantities via a system of quantity equations. The SI derived units for these derived quantities are obtained from these equations and the seven SI base units. Find in the table below the summary of derived quantities and their respective derived units

Derived Quantity	**Name**	**Expression in terms of SI**
Area	square metre	m^2
Volume	Cubic metre	m^3
speed, velocity	metre per second	m/s or ms^{-1}
Acceleration	metre per second squared	m/s^2 or ms^{-2}
Density	kilogram per cubic metre	kg/m^3 or kgm^{-3}
Force	newton (N)	kgm/s^2 or $kgms^{-2}$
Pressure	pascal	kg/ms^2 or $kgm^{-1}s^{-2}$
Energy, Work	joule (J) N-m	kgm^2/s^2 or kgm^2s^{-2}
Electric Potential	volt (V)	kgm^2/As^3 or $kgm^2s^{-3}A^{-1}$

Length

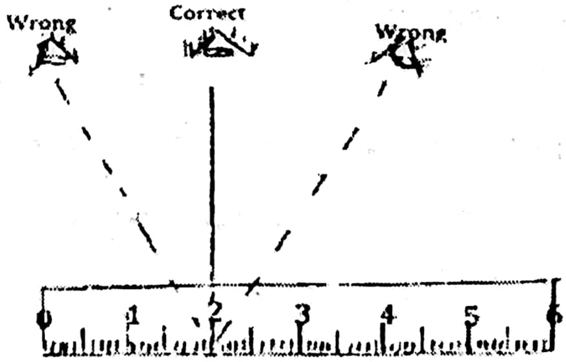
Length could be defined as the distance between two points. However, a straight line is the shortest distance between two points in space. Straight edges and distances are measured with a rule or surveyors tape. The ruler is the instrument used to **rule** straight lines and the calibrated instrument used for determining length is called a measure. However common usage calls both instruments rulers and the special name straight-edge is used for an unmarked rule. The use of the word measure, in the sense of a measuring instrument, only survives in the phrase tape measure, an instrument that can be used to measure but cannot be used to draw straight lines.

In using the metre rule to measure, the rule is placed against the object to be measured and the zero mark of the rule made to coincide with the one end of the object. The length of the object being measured is the mark on the metre rule that coincide with the other end of the object.

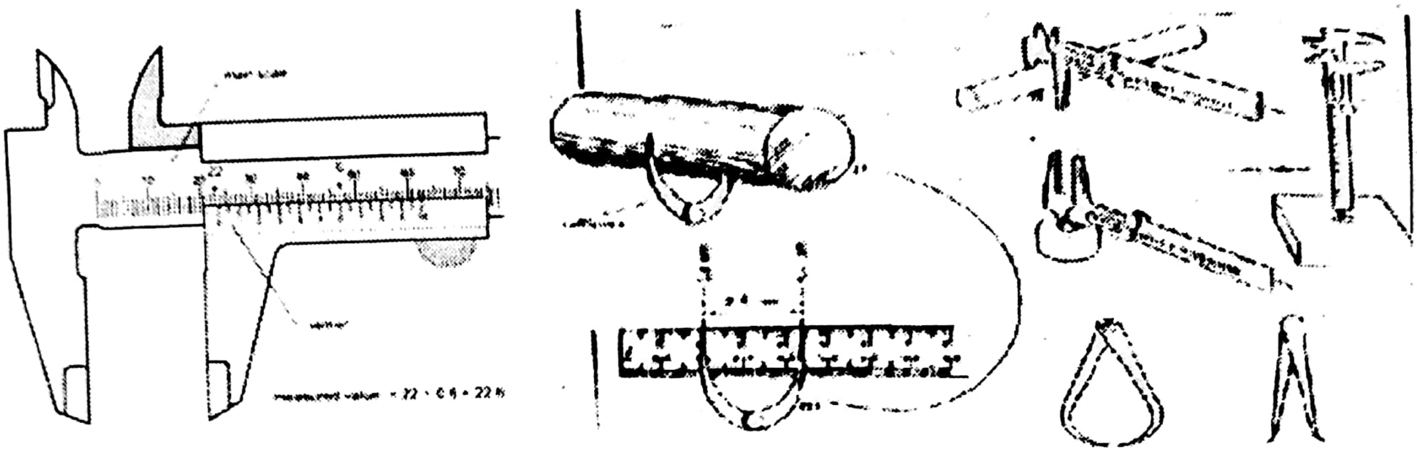
The units used for measurement of length are meters (m), Centimeters (cm) and millimeters (mm). Other instruments that can be used to measure length are the veneer caliper for measuring both internal and external diameters of objects and the micrometer screw gauge used to measure small lengths such as the diameter of a wire.

Measurement of Length

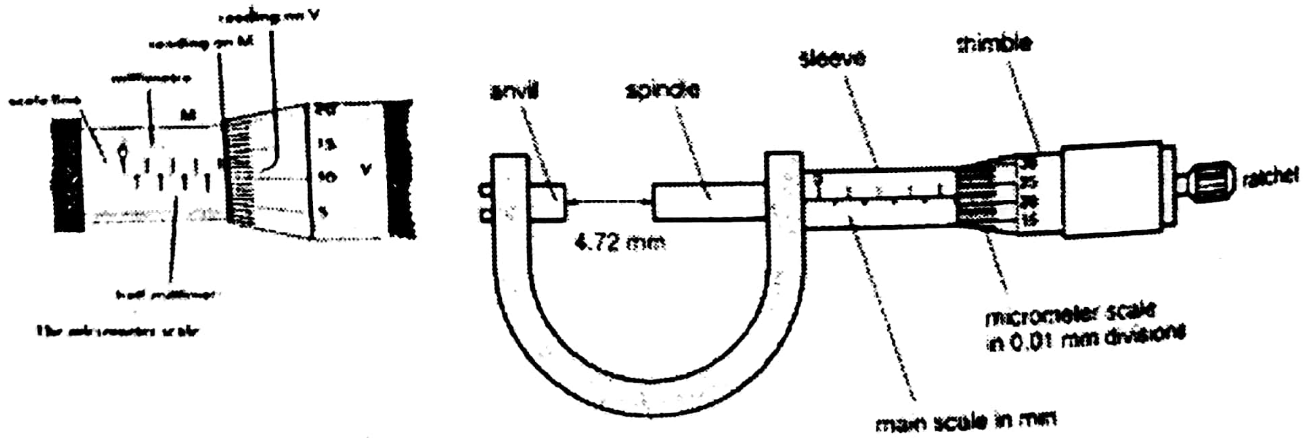
Distances could be measured with a **metre rule**, a **surveyor's tape, tape measure** or ruler. Points on metre rule are marked in centimetres and millimetres and the measurement is accurate to the nearest 0.5mm. That is the least a rule or a tape can measure correctly is 0.5mm, so it has a precision of 0.5mm. In all measurement of length, the errors should be avoided by reading at right angles to the point of reading as shown below.



Short straight line distances between two points can be measured with **vernier callipers**. The vernier callipers measures to precision of 0.1mm or $^1/_{10}$mm. This instrument is used for measuring the diameter of cylindrical objects.



Extremely short distances are measured with the **micrometer screw gauge**. The micrometer screw gauge has precision of 0.01mm or $^1/_{100}$mm. This instrument can be used to measure the thickness of a metal foil or sheet of paper or cloth. The diameter of a wire can be taken with micrometer screw gauge.



Curved lines are measured with **opisometer** and the radius of spherical surface such as a curved mirror or egg shell is measured with a **spherometer** .

The metric system can be used to covert length of objects from one unit to the other. The Table below can help you convert.

10 millimetres (mm)	1 centimetre
10 centimetres (cm)	1 decimetre
10 decimetres (dm)	1 metre
10 metres (m)	1 decametre
10 decametres (da)	1 hectometre
10 hectometres (hm)	1 kilometre

Area (A) in m^2 is;

$A = 1m \times 1m$

$A = 1m^2$

Area (A) in cm^2 is;

$A = 100cm \times 100cm$

$A = 10000cm^2$

Therefore, from the calculations above,

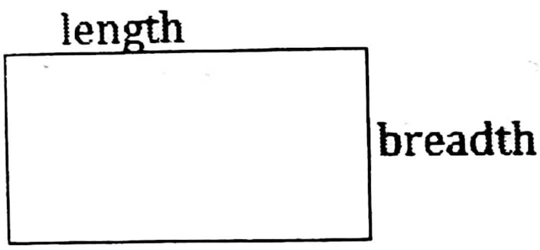
$$1m^2 = 10,000cm^2$$

and

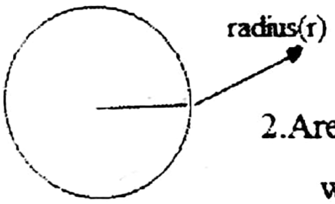
$$1m^2 = 1,000,000mm^2$$

NOTE $100cm^2$? $1m^2$

Area of Rectangular surfaces



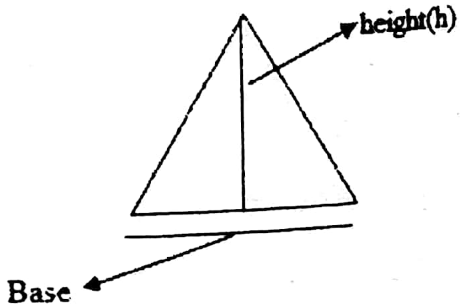
1 Area of Rectangle = length x breadth



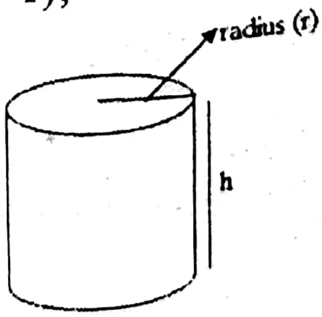
2.Area of circle = πr^2

where r = radius

3. Area of triangle = ½ base x height



4. Surface area of a cylinder = $2\pi r(h + r)$,



where h = length or height of cylinder, r= radius

Volume

Volume is the three-dimensional space occupied by matter. The SI unit for volume is cubic metre (m^3) but the litre is commonly used for liquid in everyday life (1litre – $^{1}/_{1000}m^3$)

Note; 1 litre = $1000cm^3$

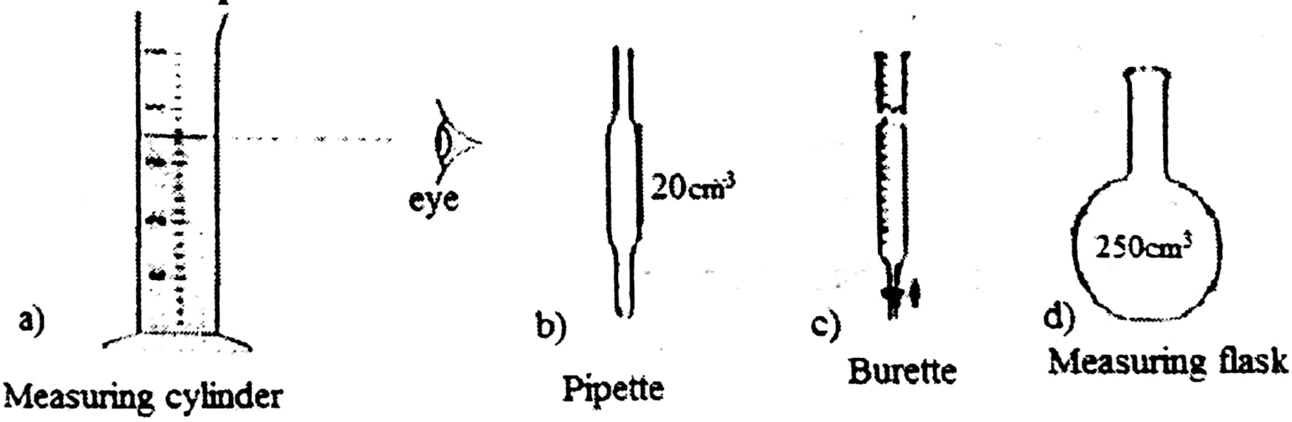
Volume of Regular Solid

1. Volume of a cuboid = l x b x h,

   where l = length, breadth = b and h=height

2. Volume of sphere = $^{4}/_{3}\pi r^3$, where r = radius
3. Volume of a cylinder = $\pi r^2 l$, where r = radius, l= length or height
4. Volume of cube = l^3, where l = length of one side

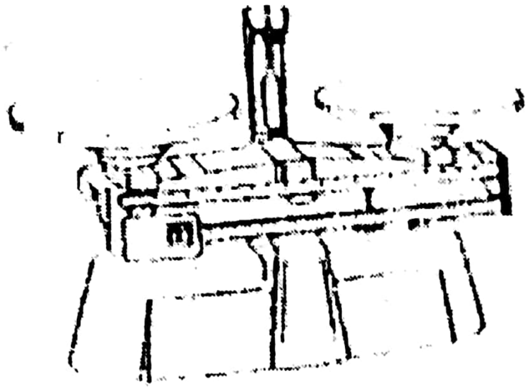
Volume of liquid



The volume of an irregular solid can be found by completely immersing the solid in a liquid and finding the volume of the liquid displaced. The difference in volume before and after immersion can be easily calculated. For larger objects a displacement can is used. The principle used here is that the solid will displace its own volume of liquid when completely immersed.

Measurement of Mass

Mass is the amount of substance in a body. In other words it is the quantity of matter a body contains. Mass is usually measured using a beam balance or chemical balance.



A beam balance

Measurement of Time

The SI unit is the second (s) and in the laboratory time is measured with a stop-watch or stop-clock.

Measurement of Temperature

Temperature is the degree of hotness or coldness of a body. Thermometers are used to measure temperature. Among them are absolute thermometer, Celsius thermometer and clinical thermometer.

Measurement of Electric Current

The instrument used for measuring electric current is ammeter. It is measured in ampere (A) but there are other sub units like milliamperes (mA).

Measurement of Luminous intensity

Photometer can be used to measure this quantity.

Summary of Measuring Instrument

The table below illustrates the summary of the quantities with the instruments used to measure them.

Quantity	Measuring Instrument
Mass	Beam balance, chemical balance or electronic balance,
Length	Metre rule, venier calipers / pair of calipers, surveyors tape, measuring tape.
Volume	Graduated beaker, volumetric flask, measuring cylinder burette, pipette NB: They are for measuring specific volumes of liquids.
Time	Stop watch, stop clock, electronic watch, and electronic clock
Temperature	Thermometers e.g. absolute thermometer, clinical thermometer,
Atmospheric pressure	Barometers e.g. fortins barometer, aneroid barometer
Electric potential	Voltmeter
Electric current	Ammeter
Luminous intensity	Photometer

Some Instruments and their Uses

Venier Calipers

- Measuring short straight lines
- Measuring distance between two points
- Measuring diameter of a drinking cup
- Measuring small narrow hole/ cavity in objects

Pair of Calipers

- Measuring internal and external diameter of a solid hollow object e.g. bucket cup.

Micrometer Screw Gauge

Measuring extremely short distances

- Measuring diameter of a wire, rings.
- Measuring thickness of paper, cloth, metal sheet etc.

Spherometer

- Measuring radius of a spherical surface
- Measuring curved surface e.g. curved mirror, surface of an egg or surface of football.

Opisometer

- Measuring curved lines

Odometer

- Measuring mileage (miles per hour) of moving object, e.g. vehicles

Speedometer

- Measuring speed (meters per second) of moving object, e.g. vehicles

Anemometer

- Measuring speed of wind

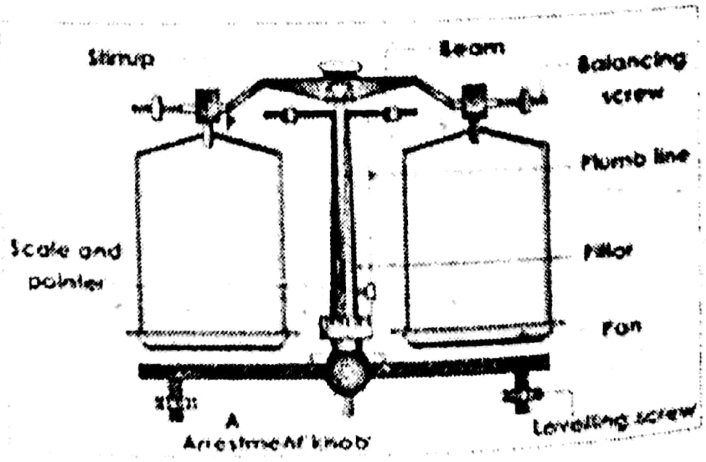
Aneroid Barometer

- Measuring atmospheric pressure

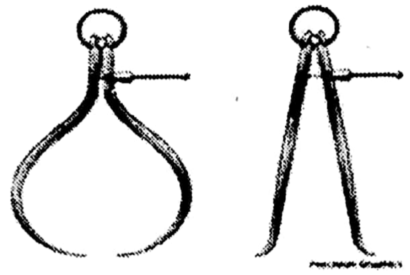
Hydrometer

Measuring the density of liquids, such as milk

Diagram of some Measuring Instruments

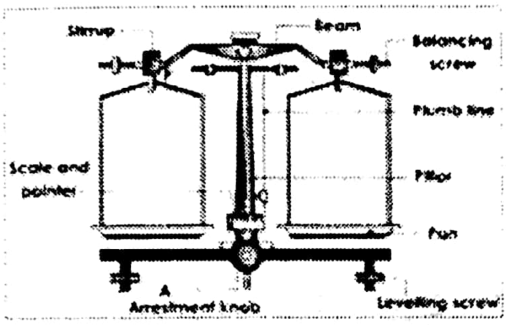


Beam balance

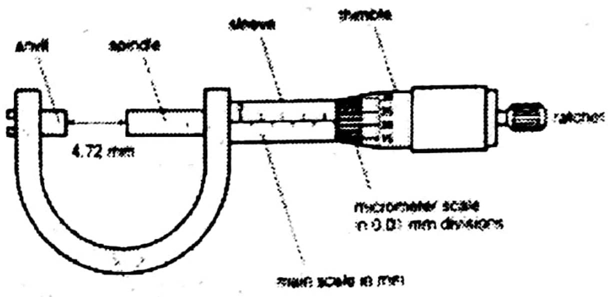


Engineer's outside and inside callipers

spring balance



beam balance



micrometer screw gauge

MASS AND WEIGHT

Mass of an object is the amount of matter it contains.

Mass

Mass is the amount of substance a body contains. It is also defined as the atomic content of the body.

Mass is measured in **kilogram (kg)**, this is the SI unit.

Mass is measured with an instrument called beam balance.

Mass is a **scalar quantity** and does not vary. It is constant everywhere.

Weight

Weight is a force exerted on a body by gravity. Weight, on the other hand, refers to the downward force produced when a mass is in a gravitational field. Simply,

Weight is measured with an instrument called **spring balance or newtonmeter**. Weight always points downwards, hence a vector quantity.

Weight has the SI unit of newton (N). Weight is not constant. It varies from place to place. The value of gravity on equator is $9.8ms^{-2}$ and $1.7ms^{-2}$ on the moon.
The mass of a body and its weight is related by this equation;
$W = mg$
Where W = weight, m = mass and g = acceleration due to gravity.

Difference between mass and weight

Mass	Weight
1. **It is the amount of substance a body contains**	It is the force exerted on a body by gravity
2. **It is measured by beam balance**	It is measured by spring balance or newtonmeter
3. **It is measured in kilogram**	It is measured in newton
4. **It is constant**	It varies from place to place
5. **It has only magnitude and therefore a scalar quantity**	It has both magnitude and direction, s o it is a vector quantity.

Speed

Speed is distance moved per unit time. Thus total distance covered within certain time taken.

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

The SI unit of speed is metre per second. (m/s or ms^{-1})
Speed has no particular direction. It is a scalar quantity since it has no direction. Physical quantities that have both magnitude and directions are called **vector quantities**. Those with only magnitude are called **scalar quantities**.

Velocity

The velocity of a body measures its speed and direction in which it travels. Velocity is change in displacement per unit time.

NB; Displacement is distance in a specified direction.

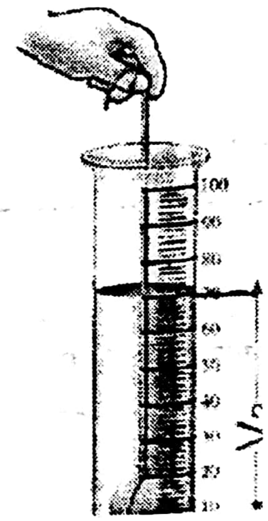
$$Velocity = \frac{displacement}{time\ taken}$$

The SI unit of velocity is metre per second ~~square~~. (m/s^{1} or ms^{-1})

Velocity is a vector quantity because it has both magnitude and direction.

Volume

The volume of a body or an object is the amount of space occupied by the body or the object. Volume is measured in cubic metre (m^3). the volume may be measured directly (from the geometry of the object) or by the displacement of a fluid.



A very common instrument for the direct measurement of density of a liquid is the **hydrometer** which measures the volume displaced by an object of known mass.

In physics, the measuring cylinder is the most commonly used for volume measurements of liquids. When reading the volume it is important to look at the bottom of the curved liquid surface [meniscusl.

To find volume there are two displacement methods, you can gently lower the object directly into a graduated cylinder partially filled with water and see what the displacement or change in volume in the figure above, or use of an overflow can (Fig 1.2) to measure the volume of displaced liquid.

The volume of some objects can be found from the formulae below:

a) Volume of a cube = $(side)^3$ or l^3
b) Volume of a rectangular solid = length x width x height
c) Volume of a right pyramid = 1/2 x Area of base x height
d) Volume of a cylinder = $\pi r^2 \times h$
e) Volume of a sphere $4/3 \pi r^3$

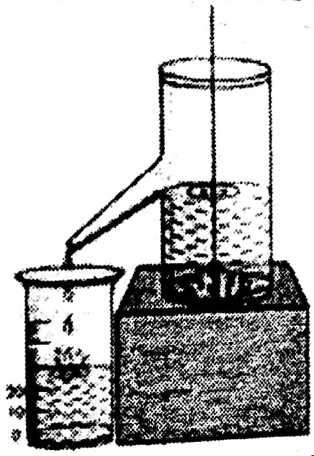


Figure1.2: Using the Overflow can

Density

The **density** of a material is defined as its mass per unit volume, i.e (kgm^{-3}). The densities and relative densities for some common substances are listed in the table below.

Substance	Density (kgm^{-3})	Relative Density
Air	1.3	0.0013
Ethanol	940	0.94
Methanol	790	0.79
Ice	930	0.93
Fresh water	1000	1.00
Sea water	1030	1.03
Aluminum	2650	2.65
Lead	11300	11.30
Gold	19300	19.30
Wood	750	0.75
Iron	7870	7.87
Brass	8900	8.90
Mercury	13600	13.60
Glass	3700	3.70
Petrol	700	0.70
	[illegible]	0.95

Scanned with CamScanner

NB:

I g/cm^3 or 1gcm^{-3} is equivalent to 1000kg/m^3 or 1000kgn1^3.

One cubic metre (m^3) = 1000 cubic centimeters,(1000cm^3) = one litre (1litre).

1000cm^3 = 1 m^3 = I litre

If the same body is immersed in different liquids, the body will sink more in the liquid with lower density. From the table above, since sea water has relative density of 1.03, whereas fresh water has 1.00, a boat or ship will sink deeper in fresh water than in sea water. Also, since water is having higher density than that of ethanol, person carrying fresh water with the same volume as that of ethanol will fill fresh water being heavier than that of ethanol.

Experimental Determination of Density of Regular And Irregular Objects

Regular Solid: The mass of the solid is found by placing it on a beam balance or chemical balance as discussed. The volume of the solid is obtained by length measurements using a ruler, venier calipers or a micrometer screw gauge, depending on the accuracy required. This method is applicable to cuboids, spheres, cylinders and cones amongst other regular shapes. The formulae discussed under the volume section can be used to calculate for such shapes.

The density of the regular shape is then calculated from the formula:

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

An Irregular Solid: The mass *(M_I)* of the irregular solid is found the same way as the regular one. In order to find the volume, it is necessary to partly fill a measuring cylinder with water (Fig 2.1). The initial reading (V_i) on the cylinder is taken and the solid lowered gently into the cylinder with water on the length of a thread, until it is completely immersed. The new reading *(V_2)* is taken. The difference between the two readings (V_2-V_1) gives the volume of the irregular solid. The density of the irregular solid is given by;

$$Density = \frac{mass}{V2 - V1}$$

A Liquid: A mass of measuring cylinder is first found empty; say M_I using, for example, a beam balance. Some of the liquid to be tested is poured into the cylinder and the mass determined together with the liquid, say *M2*. The difference between the two readings *($M_2 - M_I$)* gives the mass of the liquid. The volume of the liquid is obtained by direct reading of the measuring cylinder, say *V1*. The density of the liquid is calculated from:

$$Density = \frac{M2 - M1}{V2 - V1}$$

Worked Examples

Question 1: A piece of silicon metal has a mass of 144g and a volume of 24cm^3. Find the density of the silicon metal.

Solution

volume mass = 144g and volume = 24cm3

$$Density = \frac{144}{24} = 6g/cm3$$

Question 2: If $25cm^3$ of a quantity of wood ash has a mass of 45g, calculate the density of the wood ash in kgm^{-3}

Solution

Mass of wood ash = 45g = 45 x 10^{-3}**kg**

Volume of wood ash = $25cm^3 = 25 \times 10^{-6}m^3$. Therefore, the density of wood ash is given as,

$$Density = \frac{45000}{25000000} = 1800kg/m3$$ (1.8 x 10^3 kgm⁻

Question 3: A gold metal which is to be used to make a necklace has mass 90g on a beam balance. When it was immersed in a measuring cylinder containing water, the water level rose from $55cm^3$ mark to $95cm^3$ mark. What is the density of the piece of gold?

Solution

Mass of gold metal, $M_1 = 90g$

Initial volume of water, $V_1 = 55cm3$

Final volume of water, V2 = 95cm3

Volume of gold metal, $V = V2 - V_1 = (95 - 55)\ cm^3 = 40cm3$

$$Density = \frac{90}{40} = 2.25g/cm$$

Experiment to Determine the Relative Density of a Liquid (e.g. ethanol)

1. Find the mass (M_1) of an empty relative density bottle.
2. Fill the bottle with the liquid (ethanol), cork it and place it on the beam balance again to find the mass of the liquid and the bottle, say M2.

3. Empty and dry the relative density bottle.

Fill the bottle with water and cork it and place it on the beam balance again to find the mass of the water and the bottle, say M3. Wipe any excess liquid on the bottle.

4. The relative density of the liquid (ethanol) can he calculated as follows;

Mass of empty bottle = M1

Mass of bottle filled with liquid (ethanol) = M2

Mass of bottle filled with water = M3

Mass of liquid (ethanol) alone = $(M_2 - M_1)$ kg

Mass of water alone = $(M_3 - M1)$

$$Relative\ Density = \frac{Mass\ of\ liquid}{Mass\ of\ equal\ volume\ of\ water}$$

Worked Examples on Relative Density

Question 1. An empty relative density bottle has mass 25kg. It has mas 65kg when filled with ethanol and 75kg when it is filled with water. Find the relative density of the ethanol and hence its density.

Solution

Let M_1 be the mass of empty relative density bottle = 25kg

M2 be the mass of ethanol and the relative density bottle = 65kg

M3 be the mass of water and the relative density bottle = 75kg

$$Relative\ Density = \frac{M2 - M1}{M3 - M1} = \frac{65 - 25}{75 - 25} = \frac{40}{50} = 0.8$$

Therefore,

Density of ethanol = Relative Density of ethanol X Density water = 0.8 x 1000kg/m3

= 800kg/m3

Note: Density of water is $1g/cm^3$ or $1000kg/m^3$

Question 2. The relative density of an alloy is 6.5

a) Find the mass of a solid alloy cube of side 20cm

b) What volume of the alloy has a mass of 13kg? (Density of water = 1g/cm3)

Solution

Density of alloy = relative density of alloy x density of water

= 6.5 x 1g/cm3

=6.5g/cm3

Volume of alloy = LxBxH = 20x20x20 = 8000cm3

Mass = Density x volume = 6.5 x 8000 = 52,000g

Volume = mass / density = 13000 / 6.5 = 2000cm³

(b) Density of alloy = 6.5 g/cm3

Mass of alloy = 13kg = 2000cm³ volume

Exercise

a. Calculate the mass of air in a room of floor dimensions 10m x 12m and a height of 4m if the density of air is $1260g/cm^3$. Give your answer in kgm^{-3} 604.8kgm⁻¹

b. f $35cm^3$ of a quantity of marbles has a mass of 60g, calculate its density in kg/m3. 0.171 kg/m³

c. find the density of the material of a sphere of radius 0.4m if its mass is 28kg. Find the volume if the mass is changed from 28kg to 30kg whilst the density remains unchanged?

Temperature

Temperature and heat are related but they are not the same and should not be confused. Temperature is the degree of hotness or coldness of a body or substance. It has the SI unit of kelvin but can be measured in degree celsius (°C) or kelvin (K) which corresponds to the celsius and the absolute scale respectively.

There are two fixed points on the celsius scale. These are;

The lower fixed point which is the temperature of pure melting ice.

The upper fixed point which is the temperature of pure boiling water at normal atmospheric pressure.

The absolute scale of temperature is based on the kinetic theory of matter. This theory assumes that there exist temperatures at which the particles of a substance stop moving completely. This temperature is called the absolute zero and it corresponds to 273K or 0°C.

Conversion of Temperature between the Two Scales

The temperature between the temperature in kelvin and degree celsius

$$K = (T°C + 273)$$

$$T°C = (K - 273$$

where T is the temperature in degree celsius and K is the temperature in kelvin.

Worked Examples

1. Convert 57°C to a temperature in kelvin scale.

Solution

$K = 273 + T°C \quad T = 273 + 57 = 330K$

2. What is the equivalent of— 112°C on the kelvin scale?

Solution

$K = 273 + T°C = 273 + (-112) = 273 - 112 = 161K$

3. Find the equivalent of 90K on the celsius scale.

Solution

$T°C = K - 273 = 90 - 273 = -183°C$

Fahrenheit

$$T°F = \left(T°C \times \frac{9}{5}\right) + 32$$

$$T°C = \left(T°F - 32\right) \times \frac{5}{9}$$

$\text{Pressure} = \frac{\text{Force}}{\text{Area}} \quad N/m^2 \quad \frac{Kgms^{-2}}{m^2} \quad Kgm^{-1}s^{-2}$

UNIT II
WORK, ENERGY AND POWER

ENERGY

You have heard of the word "energy" all your life. You need to eat vegetables to grow strong and have "energy". You need to go to bed early so you will have "energy" in the morning to go to school. Energy is **the ability to do work.** Energy is everywhere in nature; sunlight, wind, water, plants, and animals. We use energy everyday. The S.I unit for energy is the joule (J).

Forms of Energy

Energy is found in different forms, such as light, heat, sound and motion. Different forms of energy are:

a. Light
b. Chemical
c. Mechanical
d. Heat
e. Sound
f. Nuclear
g. Electric

a. **Electrical Energy** is the movement of electrical charges. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Applying a force can make some of the electrons move. Electrical charges moving through a wire is called electricity. Lightning is another example of electrical energy.

b. Chemical Energy is energy stored in the bonds of atoms and molecules. Is the energy that holds these particles together. Biomass, petroleum, natural gas, and propane are examples of stored chemical energy.

c. Mechanical Energy is energy stored in objects by the application of a force. Compressed springs and stretched rubber hands are examples of stored mechanical energy. Mechanical energy is the sum of both Potential and Kinetic energy.

Mechanical Energy (ME) = Potential Energy (PE) + Kinetic Energy (KE)

A good example of kinetic and potential energy is a frog leaping. A frog sitting on a lily pad is an example of potential energy. The frog leaping is an example of kinetic energy.

d. Thermal Energy, or heat, is the internal energy in substances—the vibration and movement of the atoms and molecules within substances. Geothermal energy is an example of thermal energy.

e. Nuclear Energy is energy stored in the nucleus of an atom—the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called fission. The sun combines the nuclei of hydrogen atoms in a process called fusion. Scientists are working on creating fusion energy on earth, so that someday there might be fusion power plants.

f. Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate—the energy is transferred through the substance in a wave.

g. Gravitational Energy is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy. Hydro power, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

h. Radiant Energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Light is one type of radiant energy. Solar energy is an example of radiant energy.

Law of Conservation of Energy

Energy can neither be created nor destroyed. Energy is always changing from one kind to another. The total energy of an object never changes.

Potential energy + Kinetic energy = Total energy,

Total energy - Kinetic energy = Potential energy and

Total energy - Potential energy = Kinetic energy

Energy Transformation (Interconversion Of Energy).

Energy can be transformed from one form to another and is detected when it is always stored or hidden devices are used to carry out energy transformation. Examples of such transformation are;

Candle changes chemical energy into heat and light energy. The energy chain will be; Chemical energy ------ heat energy--------
____ light energy.

a. _A spring compressed by the fingers and then released

Chemical energy----. kinetic energy ----- potential energy------
____kinetic energy

b. _When a stone is falling from a height

Potential energy------kinetic energy-------sound energy----
____________________+heat energy

c. _When a pendulum is swing

Potential energy----------- kinetic energy-------- potential energy

d. _Rubbing the palms together to feel warm

Chemical energy--------- _kinetic energy-------- heat energy

e. _Using a dry cell to light a lamp

Chemical energy--------_electrical energy----- light energy +heat energy

f. _Carpenter hitting a nail with a hammer

Chemical energy---- potential energy----- kinetic energy-----sound + heat energy

g. _Using electric fan

Electrical energy------ _kinetic energy + heat energy

h. _Telephone receiver

Electrical energy-------- __sound energy

i. _Electric iron/heaters

Electrical energy----- heat energy

j. _Television set

Electrical energy ----- light energy + sound energy + heat energy

Efficiency of Energy Change

The conversion of one form of energy to another is not 100 percent efficient because some of the energy is lost in the process. The efficiency *(E)* of energy transformed is given as

$$\text{The efficiency } (E) = \frac{useful\ energy\ obtained}{\text{total energy transformed}} x100$$

$$\text{The efficiency } (E) = \frac{Energy\ output}{\text{energy input}} x100$$

$$\text{The efficiency } (E) = \frac{work\ output}{\text{work input}} x100$$

Worked Examples

1. A 120J of useful work is done by a machine when 150J of energy is supplied to it. What is the efficiency of the machine?

Solution

$E_o = 120J, E_i = 150J$

$$\text{Bur efficiency } (E) = \frac{work\ output}{\text{work input}} x100$$

$$\text{The efficiency } (E) = \frac{120}{150} x100 = 80\%$$

2. A machine has 75% as its efficiency when a 40000J of energy is supplied to it. What useful work does it produce?

Solution

$E = 75\%, E_i = 40000J$

$$\text{The efficiency } (E) = \frac{\text{work output}}{\text{work input}} x100$$

$$\text{work output} = \frac{\text{efficiency x work input}}{100} = \frac{75 \, x \, 40000}{100} = 30000J$$

3. In the conversion of 1000J electrical energy into heat, 250J of energy got lost. What is the output energy and hence its efficiency?

Solution

$E_i = 1000J$

Energy Output, Eo = Input Energy — Wasted Energy = 1000J — 250J = 750J

$$\text{The efficiency } (E) = \frac{750}{1000} x100 = 75\%$$

4. A crane at Bans Timbers uses a fuel which when burnt produces energy of $7.5X10^3J$. If the efficiency of the crane is 80%, calculate the work done by the crane in lifting logs.

Solution

$$\text{The efficiency } (E) = \frac{\text{work output}}{\text{work input}} x100$$

$$\text{work output} = \frac{\text{efficiency x work input}}{100} = \frac{80 \, x \, 75000}{100} = 60000J$$

Kinds of Energy

Two kinds of energy are kinetic and potential. Kinetic energy, (KE) is the energy of motion. Kinetic Energy is the energy a body possesses by virtue of its motion.

$$KE = \frac{1}{2}mv^2$$

where m is the mass of the body and v the average speed.

Potential energy, (PE) is stored energy. It is also the energy a body possesses by virtue of its position or state. Weight = mg.

$$PE = mgh,$$

where m - mass of the body (object) g is acceleration due to gravity and h is height of object from reference level.

Examples of Body Possessing PE

1. A large stone at the top of a hill is capable of doing work. Hence it possesses PE. As it rolls down the hill it can dislodge other stones and roll them down the hill. As it rolls down it also release other forms of energy such as heat and sound.

2. When a spring is compressed, stretched or wound up, it possesses energy. Work is done against the elastic forces in the spring. The energy possessed by the spring due to its state is called the elastic PE.

3. Stretched rubber (elastic) bund.
4. Wound clock – spring.
5. Hanging or raised body.
6. Water behind dam.

Mechanical Energy

Mechanical energy is the sum of both Potential and Kinetic energy.

Mechanical Energy = Potential Energy + Kinetic Energy

A good example of kinetic and potential energy is a frog leaping. A frog sitting on a lily pad is an example of potential energy. The frog leaping is an example of kinetic energy.

Worked Examples

1. A body of mass 50kg is placed at a point 9.5m above the ground. Calculate its potential energy ($g = 10ms^{-2}$).

Solution

PE = nigh = 50 x 9.5 x 10 = 4750J

2. A student of mass 30kg climbs a step of 30 with 15cm high in each step. Calculate the PE of the student at the maximum height (g = 10ms-2)

Solution

Since each step has a height of I.5cm

Total height covered = 15 x 30 = 450cm = 4.5m

PE = mgh = 30x10x4.5 = 130J.

3 .A car of mass 20kg is moving with a velocity of 3m/s. Calculate the Kinetic Energy of the car.

Solution

$$KE = \frac{1}{2}mv^2 = \frac{20\ x\ 3x3}{2} = 90J$$

4. Calculate thc KE of mass $1.0x10^3$kg moving with a velocity of 120.5kmh^{-1}

$$\text{velocity v} = \frac{120.5\ x\ 1000}{60\ x 60} = 33.472 m/s$$

$$KE = \frac{1}{2}mv^2 = \frac{1000\ x\ 33.472\ x\ 33.472}{2} = 56018.74J$$

4. The potential Energy of a stretched string of a bow and arrow is 80J. What will be the velocity of the arrow when the stretched string is released, given that the mass of the arrow is 0.05k2?

Solution

When the string is released the potential energy is converted to KE i.e.

PE= KE =80J

But

$$KE = \frac{1}{2}mv^2$$

$$v^2 = \frac{2\ x\ KE}{m} = \frac{2\ x\ 80}{0.05} = 3200$$

$v^2 = 3200$

Solution

a. W = Fd = mgd = 2.5 x 9.8 x 3.0 = 73.5 J

b. Magnitude of the weight = - mg W = Fd = mgd = -2.5 x 9. 8 x 3.0

(Negative force) = -73. 5J

c. While the boy hold the body stationary no work is done

W = mgd, d=0

= 2.5 x 9.8 x 0 = OJ

7. A body of mass 10kg is acted upon by a force, which caused the velocity of the body to change from 20m/s to 30m/s in 2 seconds. Calculate the change in KE of the body.

Solution

$KE = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$ where u and v are initial and final velocities

$$KE = \frac{1}{2}m(v \quad - u)^2 = \frac{1}{2}x10(30 - 20)^2 = 2500J$$

Work

Work is defined as the dissipating or expenditure of energy. Work is said to be done, when the point of application of a force moves a body in the direction of the force. The point of application of the force, F moves through a distance, d.

Work (W) = Force x Distance = F x d = Fd

The S.I unit of work is the joule (J).

Worked Example

1. What Work is done when a body of weight 10N is lifted through a vertical height of 2m? Solution

W=Fxd= 10 x 2=20J.

1. A body is moved horizontally by a force of 20N (applied horizontally) through a distance of 10m. Calculate the work done.

Solution

W=Fxd= 20 x 10 = 200J

Types of Work done

- **Positive Work:** If the component of the force is in the same direction as the displacement. the work done is positive. Examples are;

a. A boy running up a flight of steps.

b. Work done when a force is applied to a body to left it upwards in the same direction.

c. Work done when a force is applied to a spring to stretch it in the direction of the applied force.

- **Negative Work:** If the component of the force is in opposite direction to the displacement, the work done is negative. Some examples are;

a. Work done by friction on a moving body

b. Work done gravitational force on a body being lifted

- **Zero Work:** If the component of the force is perpendicular to the displacement, the work done is zero. Also if the point of application of the force makes no displacement. no work is done e.g.

a. A man pushing a load which refuses to move does no work.

b. Work done by the normal reaction on a body by the surface on which the body is placed.

Power

It is the rate of doing work or the rate of expenditure of energy. It is a scalar quantity. The unit of power is the **watt (W).**

Watt = 1joule/second (one joule per one second).

$$\text{Power (P)} = \frac{\text{workdone}}{\text{time taken}}$$

1 kilowatt (**1** kW) = 1000Watts = 1000J/s

The kilowatt - hour (kWh) is another unit which is used for work.

It is the work done in one hour at the rate of I kW.

I kW = 1000J/s x 1 hour

= 1000J/s x 60 x 60 =1000J/s x 3600 = 3.6×10^6 J = 3.6 MJ.

Worked Examples

1. A pump raises water at a height of 20m. If it delivers 400kg of water in 19.6s, what is the power of the pump? (Take g = $9.8 m/s^2$)

Solution

Work done = F x d = 400 x 9. 8 x 20 =78400Nm

$$\text{Power (P)} = \frac{78400}{19.6} = 4000W$$

2. A loaded cab of an elevator has a mass of 3.0 x 10^3kg and moves 210m up the shaft in 23s at a constant speed. At what average rate does the cable do work on the cab? (g = 9. 8m/s2).

Solution

$$\text{Power (P)} = \frac{3000x\ 9.8 \times 210}{23}$$

$$= 268.4\ kW$$

$$= \frac{3000 \times 9.8 \times 210}{23}$$

$$= 268434.8$$

Optics

UNIT III

LIGHT ENERGY

Optics is the study of visible light, which forms a small part of the electromagnetic radiation. Light is a form of energy, which forms part of the electromagnetic spectrum having a short wave length to which the eye is sensitive. Light is believed to have dual nature, which are:

a. Particles nature

b. Wave nature

Properties of light

Light travels in a straight line
The speed of light in air is 3.0×10^{8} m/s
It can travel in a vacuum
Light waves are transverse waves
Light rays undergo reflection, refraction, diffraction, and interference
Light affect photographic plates or films.

- Light comprises of seven colors which can be seen when light is dispersed. The colors are red, orange, yellow, green, blue, indigo, and violet.

Sources of Light

There are two main sources of light. These are

a) Natural sources:

- The sun,
- Stars and
- Some fishes,
- Fire flies,
- lighting

b) Artificial sources

- Combustion of fuel. (burning firewood)

- Heating metals until they glow
- Glowing electric light bulb
- Lit kerosene lamp, (lantern)
- Car heads lamp
- The moon

Description of Bodies in Relation to Light

a. **Luminous Body**: Luminous body is a body that gives light on it own. Examples are sun, star, burning firewood, electric bulb, fireflies, glow-worm and some kind of fishes, burning magnesium.

b. **Incandescent Body**: It is a body that gives light when it is heated. Examples are; charcoal. firewood. and tungsten wire in electric bulb. palm kernel shells.

c. **Non Luminous Body**: a body that does not produce its own light. Examples are moon, mirror, water, and glass.

d. **Transparent Body**: Transparent body is *a* body, which allows light to pass through it easily. Some examples are glass, clean water, and air.

e. **Translucent Body**: It is a body that transmits light but scatters or diffuses the light. An object behind this body cannot be seen. Examples are frosted glass, waxed paper, oiled filter paper and tracing paper.

f. **Opaque Body**: It is a body that does not transmit light to pass-through. This body absorbs all the light. Examples are human body, stone, black wall, cement block and wooden door.

g. **Fluorescent Body**: Is a body that gives out light in a relatively cold state. This body changes some chemical energy in to light at low temperature e.g. fireflies, deep sea fish, and some plant.

h. **Phosphorescent Body:** Phosphorescent Body is a body, which takes (absorb) energy, stores energy and emitting the energy as a visible light after the cause has ceased. Examples are paint used on roads and advertisement paintings.

Rectilinear Propagation of Light

Rectilinear propagation of light means that li^g^ht travels in a straight line. This is also the principle of rectilinear propagation of light. It means that light cannot bend round corners of obstacles so if an opaque body is placed in the path of li^g^ht, it will cut off the light to produce a shadow.

Effect of Obstacles in Light Path

An object placed in the path of light may have one or more of the following effect.

a) Reflection

b) Refraction

c) Absorption

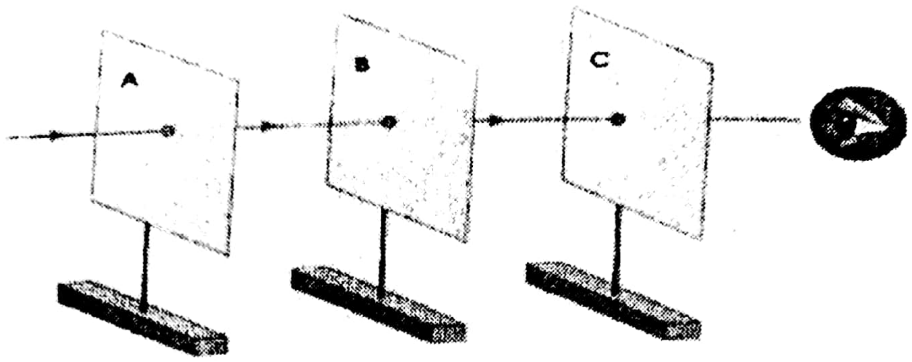
d) Dispersion (diffraction)

e) Transmission the Light.

Experiment to Show that Light Travels in a Straight Line

1. Take 3 card board (screens) of the same size
2. Make small holes in their center at exactly the same height.
3. Place them up so that the holes are in a straight line by treading a string through the holes and pulling it taut.
4. Place a source of light. (Lighted candle, electric bulb at one end, of the arrange screens.
5. The light can be seen through the three holes by an eye or observer viewing at the other end of the li^g^ht source.
6. Move one of the screens so that the holes are no more in a straight line. It could be observed that light could no longer pass through.

Light Travels in a Straight Line



Propagation of Light Ray

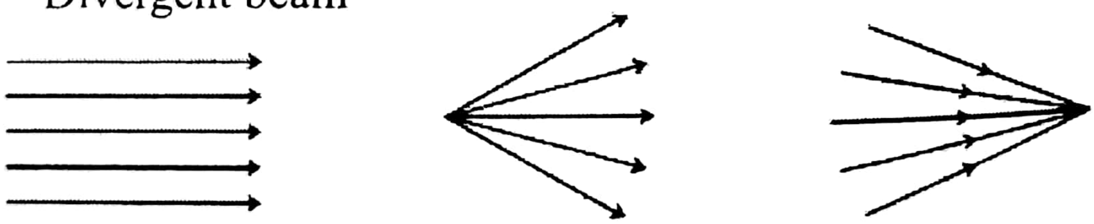
A ray is the simple line, which indicates the direction or path along which light travels.

A ray of light

Beam: A beam is a collection of two or more rays moving together.

There are three types of beams of light. These are:

- Parallel beam
- Convergent beam
- Divergent beam



(a) Parallel beam *(b) Divergent Beam* *(c) Convergent Beam*

Beam of light

The Pinhole Camera

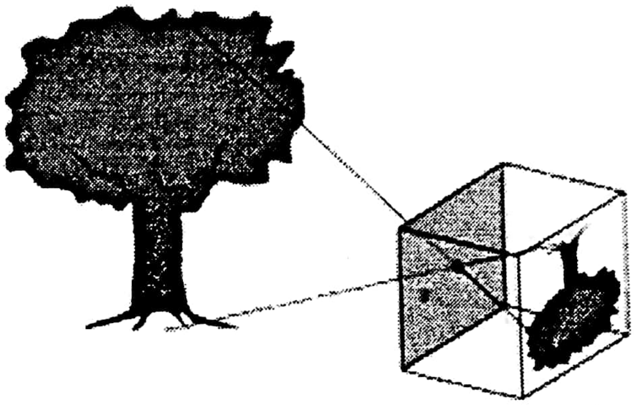
The pinhole camera which is the invention of Arabic civilization was used to view solar eclipse. This camera operates on the principle of rectilinear propagation of light. It is currently used in the field of architecture to take photographs of buildings and architectural design to scale.

Nature of a Pinhole Camera

It consists of adjustable lightproof wooden box, one of it which is covered with translucent glass and the other end is provided with a circular hole. The circular hole is covered with tinfoil and in the tin-foil is pinhole. The film is placed on the translucent glass. The inside of the box is painted black to avoid reflection of light inside the box.

Principle of Action

The pin-hole camera depends for its action on the fact that light travels *in* straight line.



How the Image is Produced

A given point on the screen (film) is illuminated (made clear) by light from a given point on the object coming through the pin-hole. Light from a point A on the object illuminates a point A 1 on the screen. And also light from B illuminate a point B1 on the screen. Hence the object AB forms an image A 1 Bl.

Characteristics of the Image Produced in a Pinhole Camera

a. The image produced is real (can be formed on a screen laterally)

b. The image is inverted (turned outside down)

c. The image is smaller than the object (image is diminished)

d. The image formed is sharply focused if the hole is small and a large hole produces a blurred image to be formed is long. This is because a small amount of light enters the pin-hole

Effect of Increasing Size of a Pinhole Camera

A small pinhole gives a sharp dim and well defined (focused) or image. This is so because a large hole can be considered as being equivalent to a number of small holes close to together each of which produces its own image. The image overlaps each other because they are produced on different position on screen. In practice these images will appear as a single large image, which is bright but blurred. The image is bright because the large hole allows lighter to enter the box to illuminate the screen.

Note:

1. Increasing the object distance from pin-hole makes the image smaller.
2. When the distance of screen is increased, by making the box longer the image becomes bigger but less bright, The image is less bright because the light entering the box covers a larger surface of the screen. Decreasing the length of box makes the image smaller but brig,hter.

Advantages of a Pinhole Camera

1. The image of a pinhole camera is always in focus. The image produced by a lens camera is not always in focus and must be focused by the camera man.
2. Image produced by a pinhole camera is not distorted.

Disadvantages of a Pinhole Camera

1. It requires a long exposure time for the image to be formed on the screen. This is because only a small amount of light enters the camera. It cannot be used to take pictures of moving object because of the long exposure time required. The object would have moved away
2. Is not as portable as lens camera because, it must always be covered with black cloth to prevent light from entering the camera through the sides and the edges.

Magnification (M)

The magnification of the image produced is the ratio of the size of the image to the object.

$$\text{Magnification} = \frac{size\ of\ image}{size\ of\ object} = \frac{height\ of\ image}{height\ of\ object}$$

$$\text{Magnification (M)} = \frac{distance\ of\ image\ (v)}{distance\ of\ object\ (u)} = \frac{height\ of\ image(hi)}{height\ of\ object(ho)}$$

Magnification is also equivalent to the ratio of the distance of the image from the pinhole (V) to the distances of the object from the pinhole (U).

Magnification has no unit and gives the number of times the image is as big as the object.

Worked Examples

1. A tree which is 8.4m tall is photographed with a pinhole camera from a distance of 2.4m from the pinhole. If the film is placed 12cm behind the pinhole, what is the least height of the frame of the film.

Solution

$V=12cm=12/100=0.12m, U=2.4m, h=8.4m$

$$\text{Magnification (M)} = \frac{distance\ of\ image\ (v)}{distance\ of\ object\ (u)} = \frac{height\ of\ image(hi)}{height\ of\ object(ho)}$$

$$\text{Magnification (M)} = \frac{(hi)}{(ho)} = \frac{(v)}{(u)}$$

$$(\text{hi}) = \frac{v\ x\ ho}{(u)} = \frac{8.4\ x\ 0.12}{2.4} = 0{,}42m$$

2. In a pinhole camera the distance between the pinhole and the screen is 10cm. If it is used to take photograph of a tree 5.0m tall and away from the pinhole, calculate the height of the image.

Solution

$h_o=5.0m, U=10m, V=10cm=0.1m$

$$\text{Magnification (M)} = \frac{distance\ of\ image\ (v)}{distance\ of\ object\ (u)} = \frac{height\ of\ image(hi)}{height\ of\ object(ho)}$$

$$\text{Magnification (M)} = \frac{(hi)}{(ho)} = \frac{(v)}{(u)}$$

$$(\text{hi}) = \frac{v\ x\ ho}{(u)} = \frac{0.1\ x\ 5}{10} = 0{,}05m$$

3. A boy1.2m tall stands 3.6m in front of a pinhole camera. If the image is formed 30cm behind the pinhole, calculate the height of the image.

[Answers=0.1 m= 10cm]

4. A body 1.7m tall stands 6m in front of a pinhole camera. If the camera is 15m deep, how large is the boy's image. (Answer: $h_i = 0.044m$)

5. The magnification of image an object is in a pinhole camera. If the length of the box is 10cm, what is the size of the object and its distance from the pinhole given that the size of image is 2.5cm? [Answer: ho = 10cm]

6. An object of height 250cm is placed at a distance of 90cm in front of a pinhole camera, if the image between the pinhole and the screen is 40cm. Find the,

a. Height of image.

b. Magnification of the object [Answer: h_i = 111.1cm, M = 0.44]7. An object of height 15cm is placed at a distance of 9cm from the pinhole of a pinhole camera, it forms an inverted image of height 7.5cm, calculate

a) The magnification b) the image distance from the pinhole

[Answer: (a) M = = 0.5, V = 4.5cm]

Reflection Of Light

Reflection is the change in direction of light ray as it meets an obstacle of the same optical medium. Reflection is the bounce back of light ray after it hits a reflective surface. When a ray of light is traveling through a medium arrives at a boundary such as silvered glass surface, the ray can be reflected (as in mirror) part may be absorbed (e.g. black surfaces) and transmitted (as in glass). The amount of light reflected depends on the nature of the surface of the obstacle being used. Good reflectors of light are smooth surfaces, shining and white and well-polished surfaces.

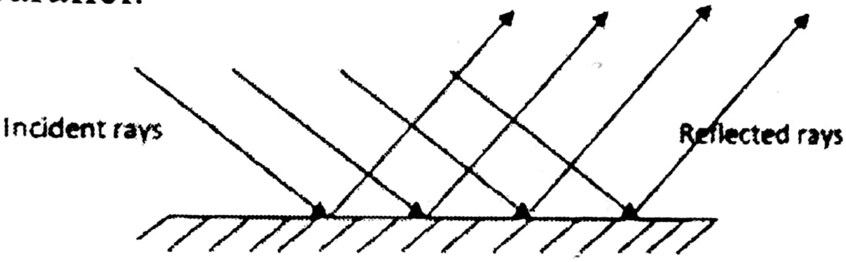
Reflection by Plane Mirror

The following are some of the observations about reflection by plane mirrors.

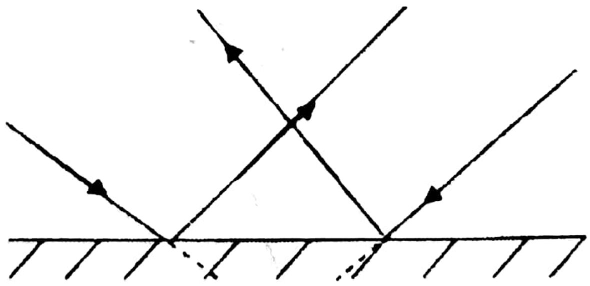
- A ray perpendicular to the mirror surface is reflected in the same direction along the same path.

A ray incident at an angle to the reflecting surfaces is reflected with the same angle.

- Parallel rays incident on a plane mirror are reflected parallel.

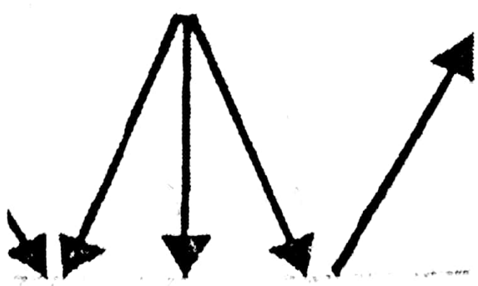


- Converging rays incident on the mirror are still converging after reflection.



- Diverging rays are still divergent after reflection.

The reflected rays appear to from a point behind the mirror.



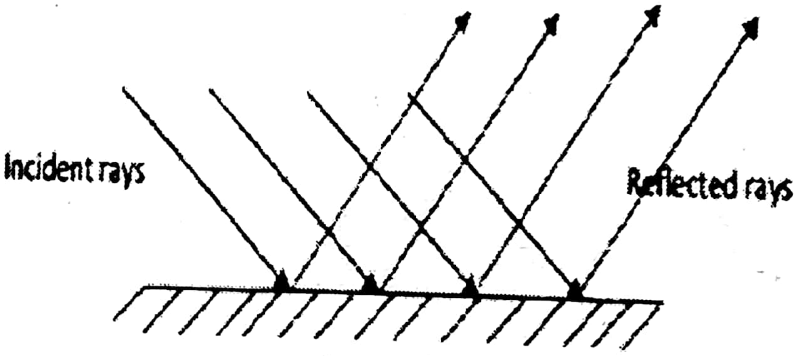
Types Of Reflection

Reflection surface reflect light in two different ways

(a) Regular (specular) reflection

(b) Diffused or Irre^g^ular, or scattered reflection

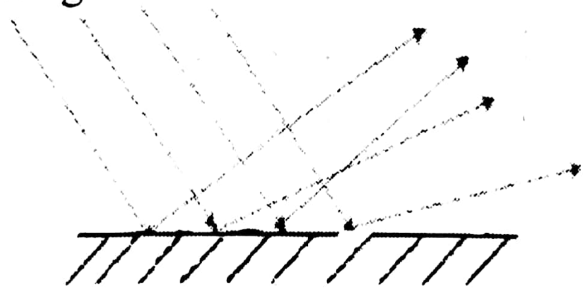
Regular (specular) Reflection: Regular Reflection is the type of reflection that occurs when the surface of reflection is smooth or highly polished. Surfaces that can produce regular reflection are mirrors; surface of water, shiny cooking utensils and polished furniture. This reflection obeys the laws of reflection and also all parallel rays indenting on a surface are reflected through the same angle with the angle produced been clear and well defined.



Regular Reflection

Irregular reflection: Irregular (Scattered) Reflection is the type of reflection caused by rough or unpolished surfaces. Examples of such surfaces are; a white paper sheet with matt surfaces pages of book a person's face, flowers etc.

When parallels rays of light are incident on rough surfaces, the reflected rays are not parallel but are scattered outwards. Since the surface is rough each incident ray is incident at different angle of incidence and portion of the surface reflects the light in a different direction so that the light is scattered.



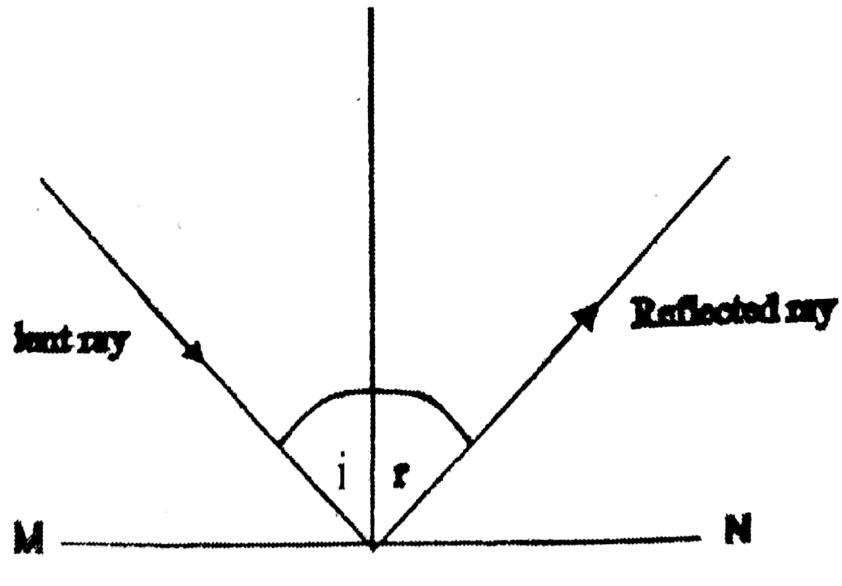
Diffused/Irregular Reflection

Differences between Regular and Irregular Reflection

Regular	Irregular
Parallel rays are reflected in the same directions.	Parallel rays are reflected in different directions.
Occurs on highly polished surfaces.	Occurs on rough, unpolished surfaces.
All rays strike at the same angle of incidence.	Individual rays strike at different angl es of incidence.
Image formed here are clear and well defined.	Images formed by this type of reflection are not clear and not defined.
Obeys the laws of reflection.	Does not obey the laws of reflection.

Laws of Reflection

Normal



Point of Widow

MN is a reflecting surface e.g. plane mirror

Incident Ray - is the ray which falls on or hits the surface

Reflected ray - the ray that travels away from the surface of incidence

Normal - the line perpendicular to the surface and passing through the point of incidence **Angle of Incidence** (i) - the angle between the incident ray and the normal

Angle of Reflection(r) - the angle between the reflected ray and the normal

Glancing Angle (g) - the angle between the incident ray and the normal

The laws of reflection are;

1. The incident ray, the reflected ray and the normal, at the point of incidence, all lie in the plane.
2. The angle of incidence (i) is equal to the angle of reflection (r). That is i = r **The Formation of Images**

An image is produce where two or more rays from a surface can be traced to the point of intersection or apparent intersection point after reflection or refraction.

Types of images

1. **Real Images:** They are images that can be produce on a screen and it is formed by actual intersection of light rays. Examples are images formed by photographic film, television screen. They are also formed in lenses and concave mirrors.

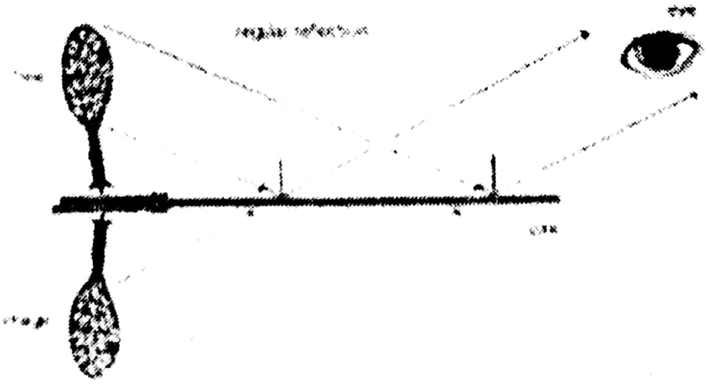
2. **Virtual Images:** They are images formed by the apparent intersection of rays when their directions have been produce backwards. That's here; light rays from the source do not reach the point. Virtual images cannot be captured on driving mirrors, convex (diverging) mirrors, and pool of water

Differences between Real and Virtual Image

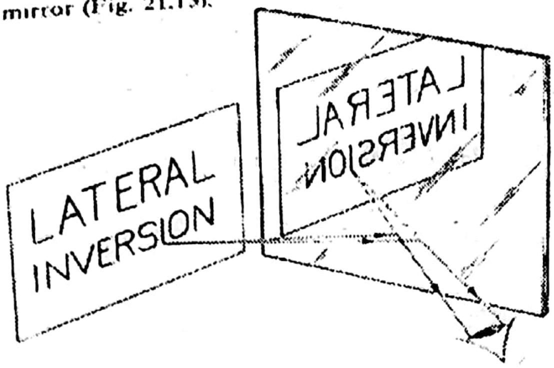
Real Image	Virtual Image
Formed by actual intersection of rays	Formed by apparent intersection of r ays
It can be formed on a screen	It cannot be formed onto a screen.

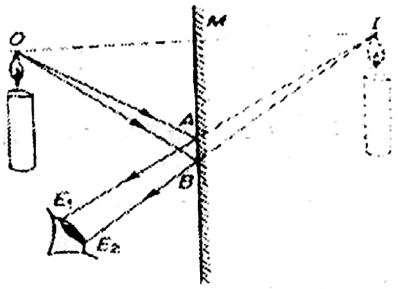
Image Formation on Plane Mirror

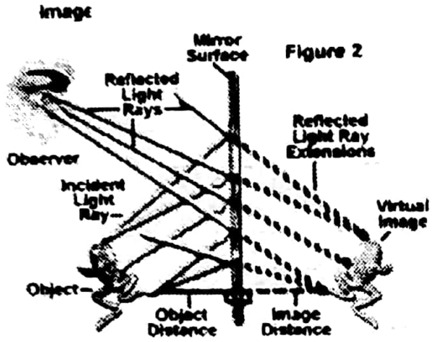
A plane mirror is a piece of glass silvered at the back. Because of its shiny and polished surface, it produces regular reflection. How Images are formed on a Plane Mirror Light rays from a point object are incident on a mirror. These rays are regularly reflected and the reflected rays are to come from a point behind the image. The mirror reflects similarly light rays from a point of objects. The reflected rays appear to come from corresponding points on the image behind the mirror.



Let us consider how the eye sees the tip of the image of a candle flame in a plane mirror (Fig. 21.13).







Refraction of Light at a Plane Interface 0

Characteristics of the Image Formed by a Plane Mirror

- The image is of the same size as the object
- The image is virtual
- The image is laterally inverted e.g. If you look at yourself in a mirror you will notice that your left ear becomes your right ear.
- The image distance behind the mirror is the same as the object distance in front of the mirror.
-

Uses of plane mirrors

It is upright.

1 Uses of a Plane Mirror

1. as dressing mirror
2. Used in periscope, cameras, microscope
3. Used in Sextant.
4. Used in mirror galvanometer
5. Used in kaleidoscope.

Application of Reflection in Plane Mirrors

1. Hairdressing salon mirrors
2. Mirrors in shops to detect shoplifting
3. In microscopes and cameras to reflect light onto the objective lens.
4. In meters to eliminate parallax errors.
5. Periscope - used by submarines, drivers of double Decker buses
6. Many planes mirrors are used to reflect the sun's beam onto metals in solar furnaces to produce very high temperature to boil substances or to assess the properties of certain materials.

Differences between Image Formed by Plane Mirror and Pinhole Camera

Plane Mirror	Pinhole Camera
Erect	Inverted
Same sizes as object	Diminished
Virtual	Real
Laterally inverted	Erect (not laterally inverted)
Image is blurred when the surface is dusty(tarnished)	Increasing the size of image makes the image
Distance between mirror and object is the same	Distance from the Image to the pinhole is always longer.

REFRACTION

Refraction is the change in direction (bending) and velocity of light when the light traveling in a transparent medium enters into another transparent medium of different density.

Conditions for Light to be Refracted

For any ray of light to be refracted

1. Two media of different optical density must be in contact

2. The light ray must pass obliquely through the medium

Rules for Refraction of Light

Ø A ray of light passing from optically dense medium to a less dense medium is refracted away from the normal.

Ø A ray of light passing from less dense refracted towards the normal.

Ø The refracted ray and incident ray lie on the opposite side of the normal. Medium into a dense medium is the normal.

ABCD - A glass block with a light incident on it

OREF - The path of the ray through which the glass block OR - incident ray

RE - Refracted ray

EF - Emergent ray

NP - The normal through the glass block at R

Definition of Terms

1. Angle of incidence (i): Is the angle between the incident ray and the normal at that point of incidence.

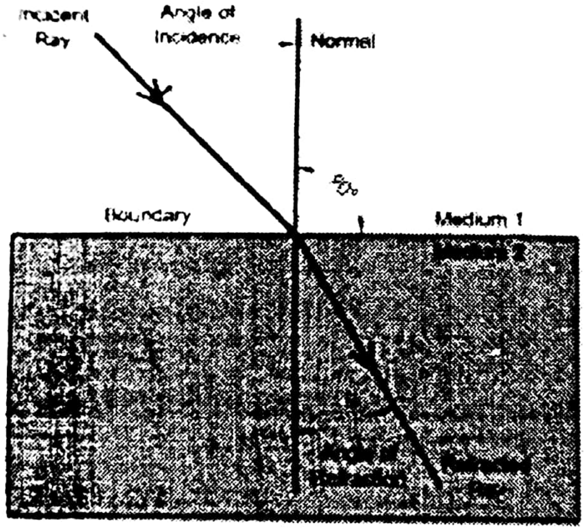
2. Angle of refraction (r): Is the angle between the refracted ray and the normal at that point?

3. The emergent Angle (e): Is the angle between the emergent ray and the normal?

4. The angle of Deviation (D): The angle between the original path of light and the final path of the light. That is the angle between OQ and RE.

5. The Lateral Displacement (d): Is a line drawn from the point 0 emerging perpendicular to the incident ray produced.

Laws of Refraction



The laws state that, when a ray of light enters a medium from another medium

1. The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane.
2. The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

This second law is also known as the Snell's law. g is a constant where the constant which is known as the refractive index g of the particular medium. Therefore

Refractive index,

$$\eta = \frac{\text{sine of the angle of incidence}}{\text{sine of the angle of refraction}}$$

☐ can also be given

$$\eta = \frac{\text{Speed of the light in the first medium } C1}{\text{Speed of the light in the second medium} C2}$$

Where,

C_1 - speed of light in the first medium

C2 - speed of light in the second medium

Therefore:

$$\eta = \frac{Sin\ i}{Sin\ r} = \frac{C1}{C2}$$

Absolute Refraction Index

The absolute refractive index of a material is given as the ratio of the speed of light in Vacuum to the speed of light in the material (medium).

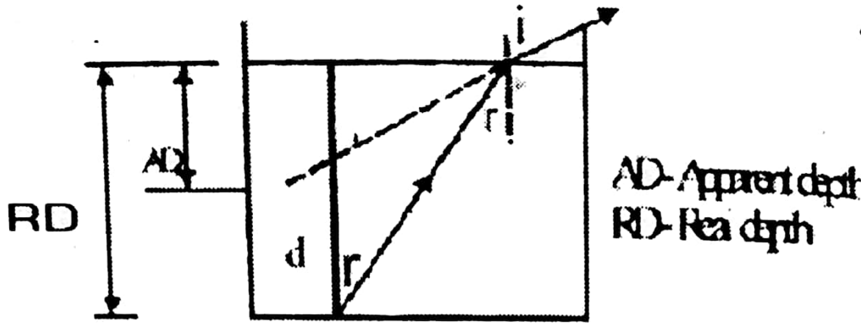
$$\text{Absolute Refractive Index } \eta = \frac{\text{Speed of light in a vacuum}}{\text{Speed of light in a medium}}$$

Effects of Refraction

When light changes direction when entering from one medium to another the following can happen due to refraction:

- The bottom of a pond or a swimming pool appears to be shallow than they actually are.
- A straight stick e.g. a ruler, appearing bent when partly immersed in water.
- Apparent rising of the bottom of glass or a print viewed or top of a table through the top of a piece of thick glass.
- Mirages (A "pool of water" on a stretch of road far ahead on a hot day (sunny day)
- A coin in a cup of water appears to be nearer to the surface than it actually is.

Real Depth and Apparent Depth



$$\text{Refractive Index } \eta = \frac{\text{Real depth (R)}}{\text{Apparent Depth (A)}}$$

$$\eta = \frac{R}{A}$$

But Displacement (lateral displacement **d) is given** as d = R - A

A = R - d

But

$$\eta = \frac{R}{R - d}$$

So

$$\eta(R - d) = R$$

$$\eta R - \eta d = R$$

$$R = \eta R - \eta d$$

$$\eta d = \eta R - R$$

$$d = \frac{\eta R - R}{\eta}$$

Therefore

$$d = R(1 - \frac{1}{\eta})$$

Solution

R = 0.03m. d = 0.0105m

A=R d = 0.03 0.0105 = 0.0195m.

4. A ray of light is incident in water at an angle of 30° on water - airplane surface. Find the angle of refraction in the air (refractive index (g) for water = 4/3).

5. What is meant **by** the statement "the refractive index of glass is 1.5"?

Solution

It means for a ray of light passing from air to glass the ratio of the speed of light in air to speed of li^ght in glass equals 1.5.

6. If sin i = 0.4 for a ray of light traveling from a vacuum into a block of glass of refractive index 1.6, the value of sin **r** is?

Critical Angle (C)

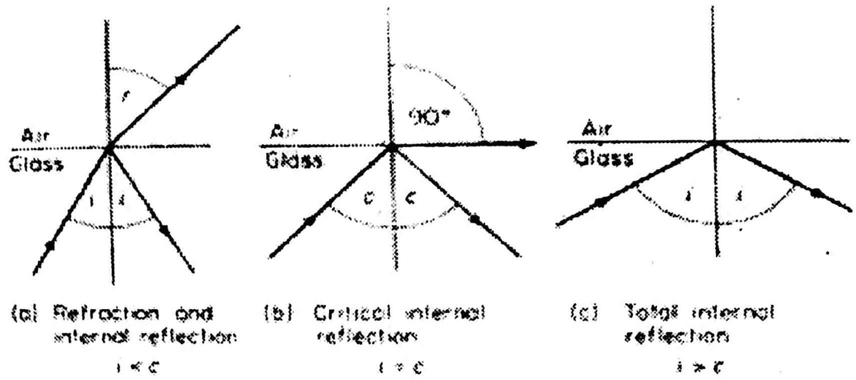
It is the angle of incidence in the denser medium for which the angle of refraction in the less dense medium is 90°. Also, **it** is the minimum angle beyond which total internal reflection occurs.

, where C is the Critical angle

If the critical angle is greater than one (1) then

a. There is no refracted ray

b. All the light is reflected back into the denser medium



What happens when light passes from glass to air

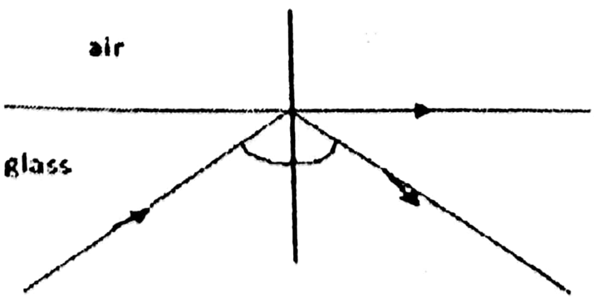
Total Internal Reflection

It is the phenomenon whereby light rays traveling from an optically denser medium to a less dense medium are completely reflected inside the denser medium.

a) It should be noted that the phenomenon of total internal reflection can occur only when light travels from a move dense medium to a less dense medium. This cannot occur when light travels from a less dense medium to a denser medium. The practical use is in binoculars. As the angle of incidence increases, the angle of refraction also increases and at the same time the intensity of the reflected ray gets stronger and that of the refracted ray weaker.

b) At a certain critical angle of incidence c, the angle of refraction becomes 90^0.

c) Since it is impossible to have angle refraction greater than 90^0, it follows that for all angles of incidence greater than the critical angle c the incident light undergoes total internal reflection.



Total Internal Reflection

Question

Calculate the critical angle of (i) and air glass surface (ii) an air water surface (iii) a water-glass surface. Draw diagrams in each case illustrating the total reflection of a ray incident on the surface (a ∩ g = 1.5, a ∩ w = 1.33)

Calculate the angle of incidence for a glass block of refractive index 1.5 such that the reflected ray is at right angle to the refracted ray, diagram is essential. $\cap g = \frac{1}{\sin C}$

Where c is the critical angle,
It should be noted that the phenomenon of total internal reflection can occur only when light travels from a move dense medium to a less dense medium. This cannot occur when light travels from a less dense medium to a denser medium. The practical use is in binoculars.

Conditions for Total Internal Reflection to Occur

a. Two different media of different optical density must be in contact.

b. Light ray must be passing from denser into a less dense medium.

c. The angle of incidence in the denser medium must be greater than the critical angle.

Application of Total Internal Reflection

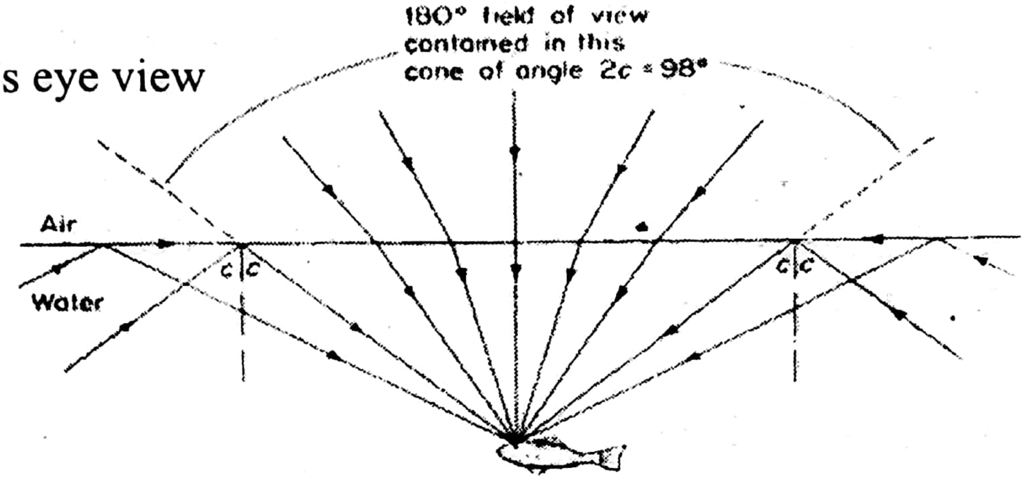
1. Prism periscope
2. Fish eye - view
3. Mirage
4. Multiple images in thick mirror e. Prism Binoculars
5. Inversion correction
6. Optical fiber (light tube)

Question

Calculate the critical angle of (i) and air glass surface (ii) an air water surface (iii) a water-glass surface. Draw diagrams in each case illustrating the total reflection of a ray incident on the surface (a ∩ g = 1.5, a ∩ w = 1.33)

Calculate the angle of incidence for a glass block of refractive index 1.5 such that the reflected ray is at right angle to the refracted ray. diagram is essential.

The fish's eye view

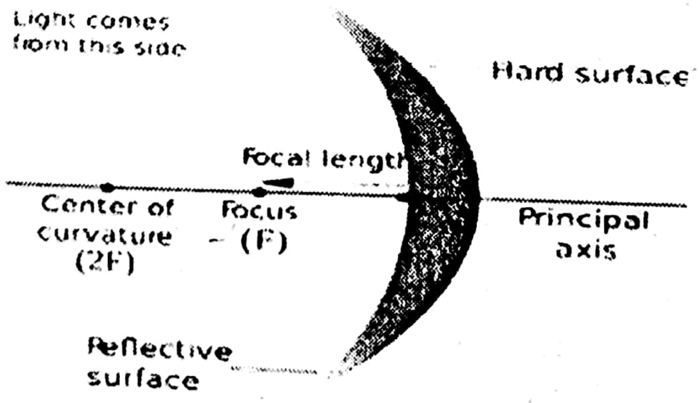


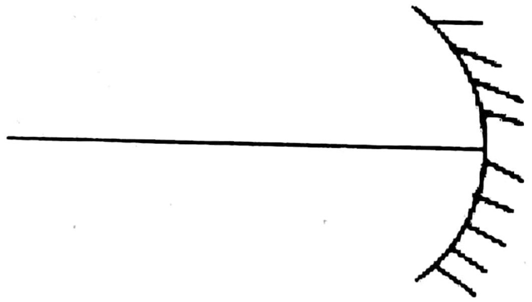
The fish eye field contain in a this cone of angle 2c = 98°

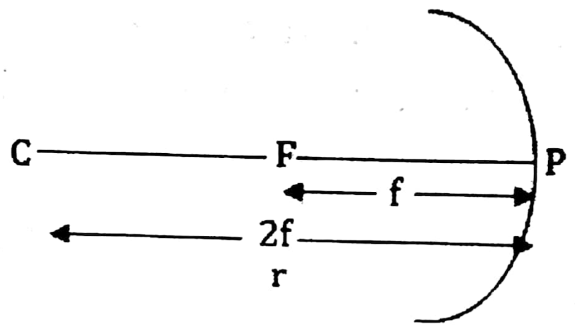
At whatever depth a fish happens to be, it has a full view of everything above the water, if the water surface is unruffled. From the diagram the fish enjoys 180^0 field of few apparently all squeezed into a cone of angle about 98^0 (ie twice the critical angle for water).
Outside this range the fish sees only objects reflected through total internal reflection from the bottom of the water.

Reflection at curved surfaces

Curved mirrors are obtained from hollow spheres. The type of curved mirror depends on the part of the sphere, which is painted. When a small sector of a hollow sphere glass is cut, a curved mirror can be made by silvering either the inside or the outside of it. Silvering the glass on the inside, gives concave mirror converging mirror.







Aperture (MN): Aperture is the distance from one edge across to the other. The greater the aperture. the more the light incident on the mirror.

- Pole (A): The middle of the portion of the shell from which the lens is made (The midpoint (center) of the mirror). It is also known as the vertex.
- Center of Curvature (C): The point in the center of sphere from which the mirror was sliced is known as the center of curvature. And it is the center of the sphere of which the mirrors forms a part. For a convex, C is behind the mirror, while for concave its in front of the mirror. Principle axis is the imaginary line through the pole and the center of curvature.
- Radius of Curvature (r): Is the distance between the center of curvature and the pole of the mirror.

o Principal Focus (F): Is a point on the principal axis to which all rays close and parallel to the principle axis converge (concave mirrors) or from which they diverge (convex mirror) from after reflection.

Focal Length (f): It is the distance between the pole and principal focus.

Thus, r = 2f.

Construction of ray diagrams

By geometry, the normal to a curved surface at any point is the radius of curvature at that point.

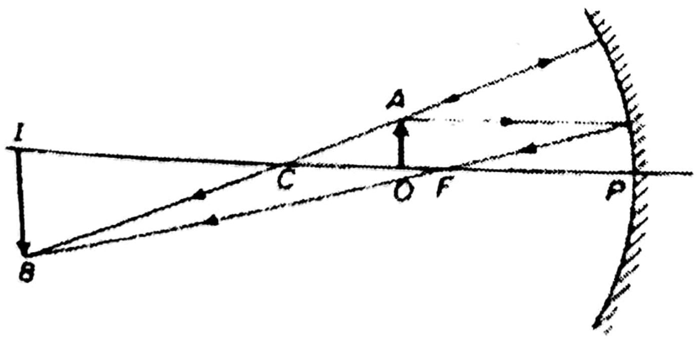
To form a point on an image, there must be a point of intersection of two reflected rays.

Rules for constructing images formed by spherical mirror

1. Rays passing through the centre of curvature are reflected back along their own paths.
2. Rays parallel to the principal axis are reflected through the principal focus
3. Rays through the principal focus are reflected parallel to the principal axis
4. Rays incident at the pole are reflected, making same angle with the principal axis.

Images

1.Object between F and C



OBJECT BETWEEN F and C

the image is,

(1) Beyond C

(2) Real

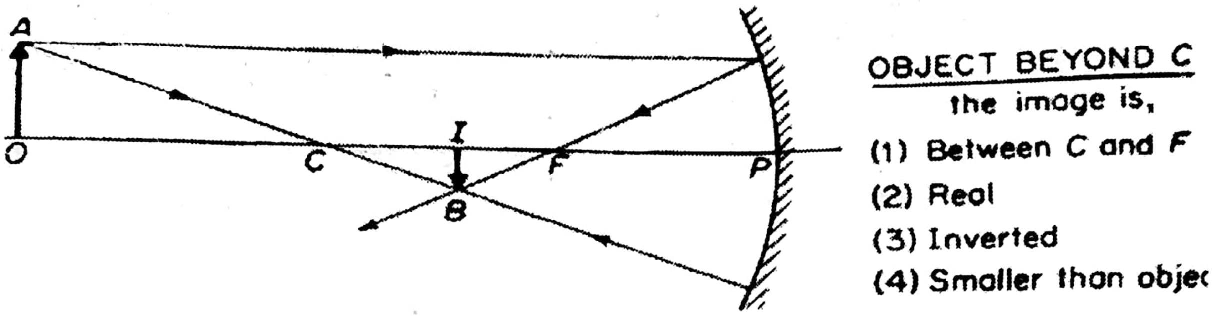
(3) Inverted

(4) Larger than object

The image is beyond C, real, inverted and magnified.

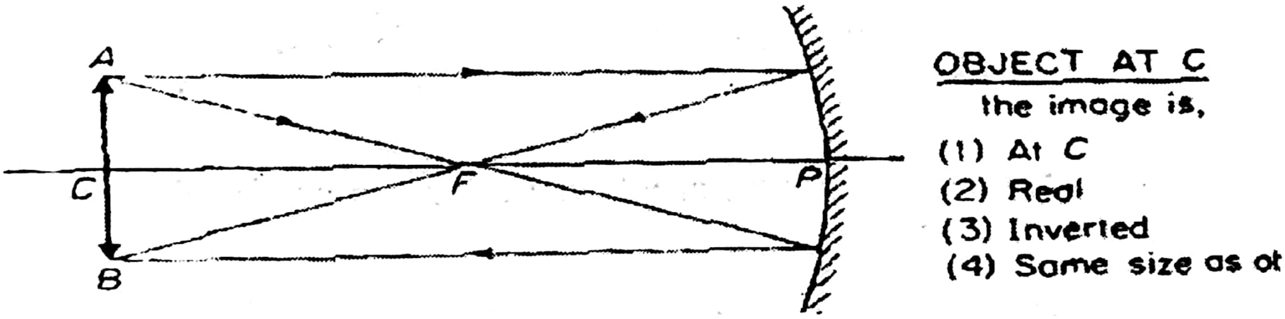
Scanned with CamScanner

2 Object beyond C



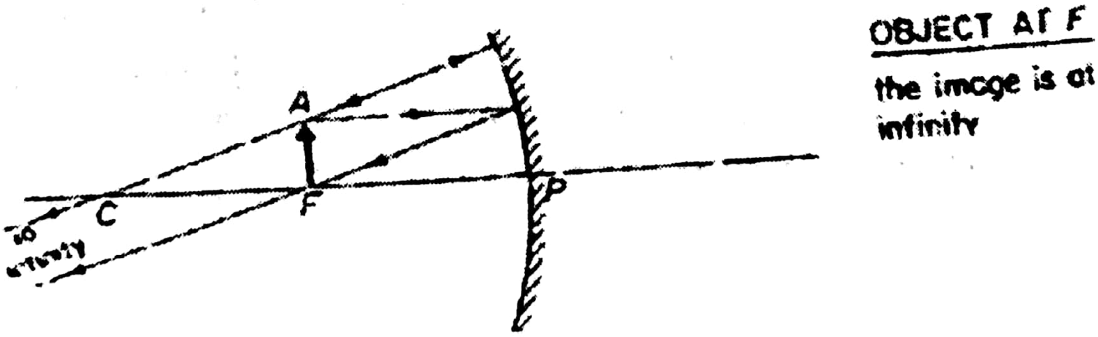
The image is between C and F, Real, Inverted and diminished.

1.Object at C



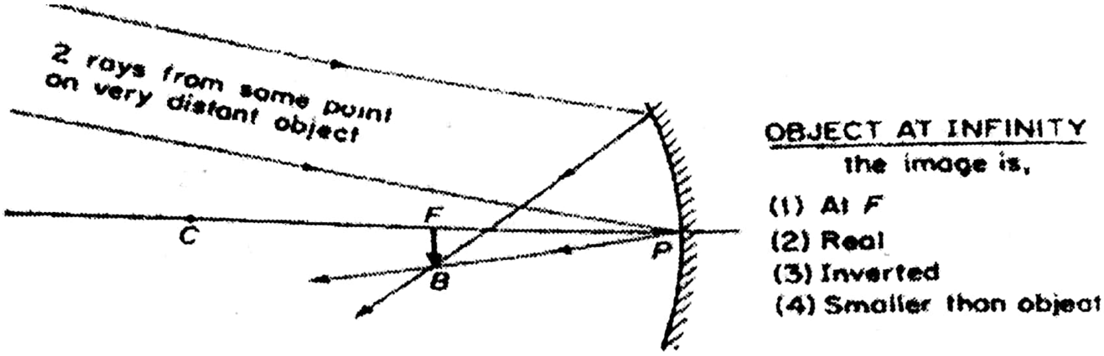
The image is at C, inverted, real and the same size of object.

1.Object at F



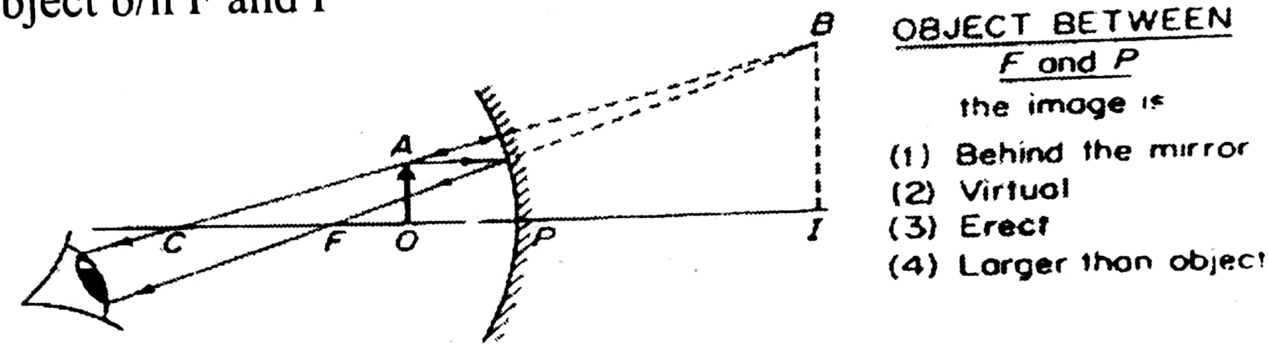
The images is at infinity

Object at infinity



The image is at F, real ,inverted and diminished.

Object b/n F and P



The image is behind the mirror, erect, virtual and magnified.

NB

Conjugate foci are any pair of points such that an object placed at one of them gives rise to a real image at another.

The use of full and dotted lines in ray diagrams is an accepted convention. Full lines are used to represent real rays, objects and images while dotted lines are used for virtual rays and images.

A real image is formed by the actual intersection of rays, where as a virtual image is one formed by the apparent intersection of rays when their directions have been produced backwards. The real image practically can be formed on a screen while virtual image cannot.

Uses of Converging Mirror

1. In solar furnace as it brings light rays to a focus
2. In torchlight behind the bulbs as reflectors
3. Used as shaving or make-up mirrors to give an enlarged image
4. Used by dentists for examining teeth.

Images formed by a convex (diverging) mirror

Convex (Diverging) Mirrors: They diverge light rays in different directions and the rays appear to have come from a point behind the mirror. The inside is painted and having their reflecting silvered side curved outwards.

Unlike the concave mirror which can produce either real or virtual images according to the position of the object, the convex mirror, gives virtual images only. They are always erect and diminished and are formed between P and F. (behind the mirror)

Thus properties of Images Formed by Convex Mirrors

Convex mirror produces only one type of image.

a. Image always smaller than object (Diminished).

b. Image always behind the mirror

c. Virtual

d. Lie between F and Pole.

Uses of Convex Mirrors

1. Used as driving mirrors to give wide field of view and erect image

Used in shops to give view behind shelves or racks of goods and also to detect shoplifting

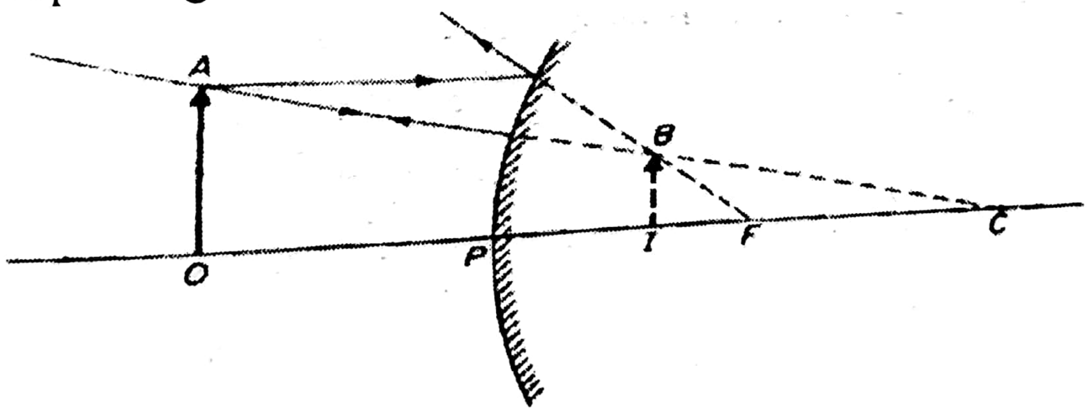


Image formed by diverging mirror

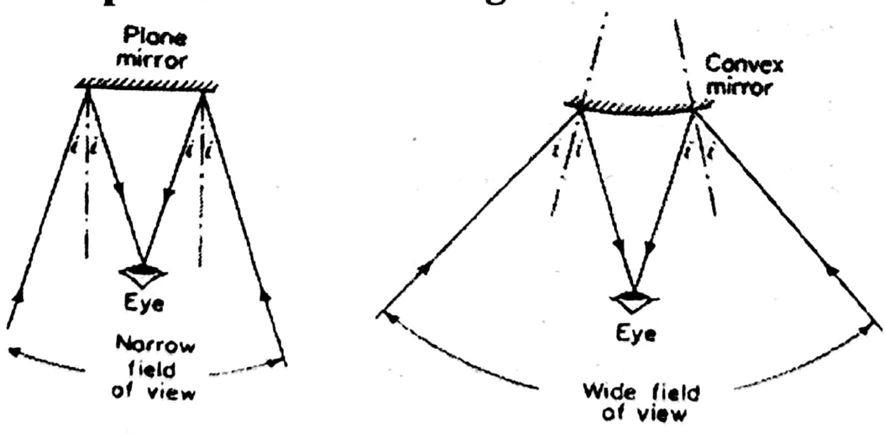
This mirror produces a wider field of view a diminished image and an erect image

- It is therefore used as a driving mirror
- Disadvantage is that the distance involve are distorted and cars seen in a convex back view will appear to be far away than they are.

Infinity	Real	At focus	Diminished, inverted
Between C and F	Real	Beyond C	Beyond C, real inverted. larger than object
Between focal point and optical centre	Behind the object same size of the lens	Virtual magnified erect	Magnifying glass
Beyond twice the focal	Between focal point and 2F	Real diminished inverted	Cameras
Between the focal length from the center of the lens	Beyond 2F	Real magnified inverted	
Twice the focal length from the center of the lens	At 2F	Real same size as the object inverted	Terrestrial telescope
Infinity	Focal point	Real diminished	

The nature of the image formed by a Concave mirror depends on the distance of the object from the mirror.

Why convex is preferred as driving Mirror.



Advantage of a convex driving mirror

Question

A man sits in an optician's chair, looking into a plane mirror which is 2m away from him and views an image of chart which faces the mirror 50cm behind his head. How far away from his eyes does the chart appear to be?

The mirror formula

For all spherical mirrors, the formula giving the relationship between the focal length, the image distance and the object distance is found to be

$$\frac{1}{f} = \frac{1}{u} = \frac{1}{v}$$

Where f is the focal length
u is the object distance from the pole
v is the image distance from the pole

Sign Convention

A sign convention is usually used to make the formula applicable to all spherical mirrors and various images formed.
There are two sign convention

1. Real – is – positive convention
2. Newcartesian convention

Real – is – positive
In this convention

a. distances of real objects, real images and real focal length from the pole of the mirror are positive
b. distances of virtual objects, virtual images and virtual focal lengths from the pole of the mirror are negative.

NB: focal length of converging mirror is +ve and – ve for convex

Example
An object is placed 20cm in front of a concave mirror of focal length 12cm. Find the nature and position of the image formed.

Soln.
Real – is – positive

u = + 20cm (real obj)
f = + 12 cm

$$\frac{1}{f} = \frac{1}{v} = \frac{1}{u}$$

$$\frac{1}{12} = \frac{1}{v} + \frac{1}{20}$$

$$\frac{1}{v} = \frac{1}{12} - \frac{1}{20} = \frac{2}{60}$$

V=+30cm
+sign means a real image

2. A convex mirror of focal length 18cm produces an image on its axis, 6cm away from the mirror.
Calculate the position of the object.

Solu
Real – is – positive
v=-6 (vitual image)
f=-18cm (convex mirror)

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

$$\frac{1}{-18} = \frac{1}{-6} + \frac{1}{u}$$

$$\frac{1}{-18} + \frac{1}{6} = \frac{1}{u}$$

$$\frac{1}{u} = \frac{2}{18}$$

A concave mirror has focal length of 2cm, if the object is placed 15cm from the pole of the mirror calculate the distance of the image.
(Ans −60cm virtual)
Calculate the distance of the image from a diverging mirror of focal length 10cm if the object is placed 20cm from the mirror
(ans −6.66 or −6.7cm virtual)

Magnification by spherical mirror.
The magnification that is associated with a spherical mirror is called linear or transverse or even internal magnification. It is

$$\textbf{Magnification (m)} = \frac{height\ of\ image\ (h1)}{height\ of\ object\ (ho)}$$

$$\text{Or m} = \frac{v}{u} = \frac{h1}{ho}$$

Examples

1. A concave mirror produces a real image 1 cm tall of an object 2.5cm tall placed 5cm from the mirror. Find the position of the image and the focal length of the mirror
<u>Soln</u>

$$\text{magnification} = \frac{1}{2.5} = \frac{v}{5}$$

Calculate f
v = +20cm both real
u = +5cm
From mirror formula
f = 4cm

1. An object 4cm in height is 10cm in front of the concave mirror. The image is 20cm in front of the mirror. Find the magnification of the since of the image (m = 2 $h_1 = m \times ho$ = 8cm).
2. An object is placed 20cm from a concave mirror of focal length 12cm. Calculate the position of the image. What is its nature? (The image distance is + 30cm. Therefore, it is real and 30cm in front of the mirror).

3. An object is placed 8cm in front of a concave mirror of focal length 12cm. Determine image distance.
4. An object is placed 10cm in front of a Concave mirror of focal length 15cm. Find the image position and the magnification.
5. An image is produced 3cm behind convex mirror of focal length 6cm. Find the position of the object.
6. A concave mirror produces a real image 2cm tall of a 3.4 cm item tall placed 6cm from the mirror. Find the position of the image and the focal length of the mirror.
7. A Convex mirror of a focal length 1 8cm produces an image on its axis, 6cm away from the mirror. Calculate the position of the object. (Answer u + 9cm)

Related past questions

1.A student holding a stick of length 15cm stands 3m in front of a large plane mirror.

a. Where is the image of the stick located? 1 mark

b. How long is the image of the stick? 1 mark

c. What is the distance between the student and her image? 1 mark

2. A man 1.60m tall stands 320cm in front of a pin-hole camera and is photographed using the camera. If the film is placed 10cm behind the pin-hole , calculate.

a. the magnification 2 marks

b. the height of the image 2 marks

3. A concave mirror has a focal length of 12cm. if an object is placed 6cm in front of the mirror, what is the image distance?

4. An object is placed 12.0cm from a concave mirror of focal length 10.0cm. Calculate:

a. the image distance from the mirror.

b. the magnification of the image produced.

5. An object 2cm in height is placed 20m in front of a curved mirror. The image is 40cm in front of the mirror. Find

i. the magnification 2 marks

ii. The size of the image 2 marks

iv. State one practical effect of dispersion in everyday life.

7. An object 4cm in height is placed 40cm in front of a curved mirror. The image is 60 cm in front of the mirror. Find.

i. the magnification 2 marks

ii. the size of the image 2 marks

8. An object 2cm in height is placed 20cm in front of a curved mirror. The image is 40cm in front of the mirror. Find

i. the magnification

2 marks

ii. the size of the image

2 marks

9. A convex mirror has a focal length of 12 cm. if an object is placed 6.0 cm in front of it, where will be the image position?

10. A student holding a stick of length 15cm stands 3m in front of a large plane mirror.

a. Where is the image of the stick located?

1 mark

b. How long is the image of the stick?

1 mark

c. What is the distance between the student and her image? 1 mark

11. A man 169cm tall stands 320cm in front of a pin-hole camera and is photographed using the camera. If the film is placed 10cm behind the pin-hole, calculate.

a. the magnification 2 marks

b. the height of the image 2 marks

12. A concave mirror has a focal length of 12cm. if an object is placed 6cm in front of the mirror, what is the image distance?

13. An object is placed 12.0cm from a concave mirror of focal

length 10.0cm. Calculate:

a. the image distance from the mirror.

b. the magnification of the image produced.

14. A concave mirror has a focal length of 12cm. if an object is placed 6cm in front of the mirror, what is the image distance?

84. An object is placed 12.0cm from a concave mirror of focal length 10.0cm. Calculate:

a. the image distance from the mirror.

b. the magnification of the image produced.

15. State

a. the laws of reflection

b. snell's law

16. A man 180cm tall stands 360cm in front of a pin-hole camera and is photographed using camera. If the film is placed 20cm behind the pin-hole, calculate the

a. magnification

b. height of the image 5 marks

17. State whether the following statements are True or False

I. The speed of sound depends on the density of the medium in which it travels.

ii. The speed of sound does not depend on the temperature of medium.

iii. Sound can be reflected but not refracted.

iv. Reflection of sound is noticeable when echoes are heard.

18. A ray of light is incident at 60^0 in air to a glass plane surface. Find the angle of refraction if the reflective index of the glass is 1.5.

19. Sound cannot be transmitted through a vacuum. Name three material media sound needs for its transmission.

4 marks

19. Sound wave is a transverse wave. True / False

4 marks

20. A ray of light incident at 50^0 in air to a glass plane surface. Find the reflective index of the glass, if the angle of refraction is 30.7^0.

21. For a smaller magnification, the distance of the object from pinhole should be larger than the distance between the pinhole and the screen.