PHYSICS

MATRICULATION

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X

Untouchability is a sin
Untouchability is a crime
Untouchability is inhuman

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PREFACE

As a teacher of Physics, I have always found myself inspired by the words of Professor D.S. Kothari, a renowned Physicist who often said to his students, “You must regard yourself fortunate that you have got a chance to study Physics, for Physics a fundamental and exciting science, is the basis of all sciences”. This book has been meticulously designed to provide a seamless transition to the Higher Secondary course. The enriched contents will accelerate the desire to probe into the concepts. The challenging presentation of physical ideas aim at developing the spirit of enquiry, to enhance creativity and aesthetic sense. Each concept has been explained clearly, in simple and lucid language in order to amplify the students’ scientific temper for problem solving and critical thinking. The systematic and progressive explanations and illustrations, evolve a logical approach and rational analysis, enabling the students to master the essence of science in general and physics in particular.

The salient features of this book are

* The thorough explanation of concepts lead the students gradually and methodically from the known to the unknown.
* The concepts explained are based on daily life situation.
* ‘Let us muse upon’ - provided at the end of each chapter serve as a ready reckoner for quick revision.
* Every chapter has a number of thought provoking questions.

The information given under ‘Know it yourself’ is only to enhance the knowledge of the students and not for evaluation.

Dr. N. Vijayan
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CONTENTS

1. MECHANICS

'Joy in looking and comprehending is nature's most beautiful gift', said Albert Einstein.

In the world around us, we see a falling apple, an orbiting satellite, a speeding race car, an acrobat balancing on a bar. This is what 'Mechanics' is all about.

Mechanics is that branch of physics which deals with the conditions of rest or motion of bodies around us. Statics is that branch of mechanics which deals with the science of forces balancing one another. Dynamics is that branch of mechanics which deals with the motion of bodies under the action of forces.

The falling apple reminds us of Sir Isaac Newton. He was Einstein's predecessor in understanding gravity. His theories of gravity help us to explain the fall of an apple or the path of a satellite. Albert Einstien represents the human spirit and creative drive in all of us. Now it is your turn to experience the excitement and challenge of Physics.

In this chapter, we shall study about the fundamental concepts of centre of gravity, projectile motion and circular motion.

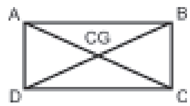
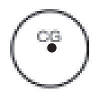
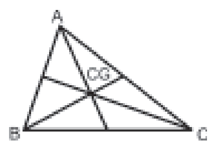
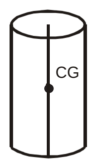
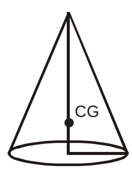
1.1 Centre of gravity

All objects are made up of tiny particles. Each particle has a mass of negligible volume. These particles behave as if their mass is concentrated at some point. The point at which their mass appears to act or is concentrated is called its 'centre of mass'. When the shape of the object is regular, then the centre of mass is its geometric centre.

When an object falls towards the earth, every particle of the object is pulled by the force of gravity and the object behaves as if all that force is concentrated at one point in the object. This point is called the 'centre of gravity'

The centre of gravity of an object is a fixed point through which the entire weight of the object acts, irrespective of the position of the object.

TABLE 1.1 Centre of gravity of regular objects

No.	Name of the object	Figure denoting the position of the centre of gravity	Position of the centre of gravity of the object
1.	Uniform rod.		At the midpoint of the rod.
2.	Rectangle.		At the point of intersection of the diagonals.
3.	Circular ring, disc, solid sphere, hollow sphere.		At its geometric centre.
4.	Triangle.		At the point of intersection of the medians. This point is called the centroid.
5.	Right cylinder.		At the midpoint of its axis, h/2 from the base where 'h' is the height of the cylinder.
6.	Solid cone.		At a point on the axis, h/4 from the base where 'h' is the height of the cone.

1.2 Illustrations for the stability of bodies

(a) A man carrying a bucket of water in his right hand, leans towards his left. He does it to keep the vertical line through the centre of gravity fall between his legs.

(b) The bottom of a ship is made heavy, to keep the centre of gravity as low as possible. The cargo is kept at the base of the ship and this makes the ship stable.

(c) In the 'Leaning Tower' of Pisa in Italy, the vertical line through the centre of gravity falls within the base of the tower. Thus the tower does not fall and remains stable. (Fig. 1.1).

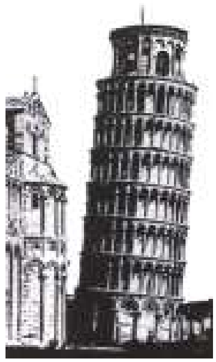


Fig. 1.1 The leaning tower of Pisa

(d) A student carrying a school bag and climbing up a flight of stairs always leans forward to maintain his stability.

(e) 'Tanjore - dolls' and 'Hit-me' dolls have a broad and heavy base to enable them to come back to a vertical position when they are knocked down. (Fig. 1.2).

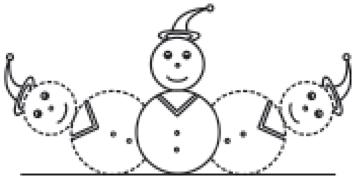


Fig. 1.2 Tanjore doll.

Conditions for the stability of bodies

From the above illustrations it is understood that the following conditions are necessary for an object to be stable.

(i) The base of the body should be broad.

(ii) The centre of gravity should be as low as possible.

(iii) The vertical line through the centre of gravity should fall within the base.

1.3 Free fall

Galileo stated "In the absence of air resistance, all bodies fall at the same acceleration, which is approximately 9.8 m s^{-2}".

The value of acceleration due to gravity at different locations are given below.

TABLE 1.2

Location	Acceleration due to gravity (m s^{-2})
1. At the equator	9.780
2. At the poles	9.832
3. At Chennai	9.782
4. At the surface of the earth (average)	9.8
5. At the centre of the earth	zero

An object is said to have a free fall when it falls vertically under the influence of gravity alone, free from air resistance.

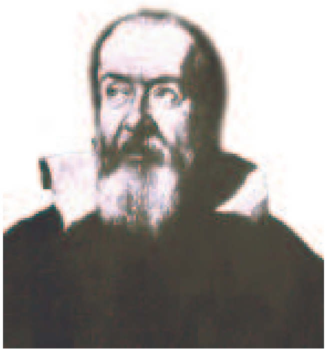
Examples

(i) Fruits like ripe mangoes falling from a tree.

(ii) A skydiver with an unopened parachute.

(iii) Bungee jumper.

Imagine a body falling from a certain height. In each succeeding second of its fall, it is seen that the velocity of the body increases by 9.8 m s^{-1}. Initially the velocity of the body is zero . As it descends down, the velocity increases and reaches a maximum value on reaching the ground.



Galileo Galilei

1.3.1 Newton's feather and coin experiment

A dry leaf, a feather or a sheet of paper may flutter to the ground, while, a stone or a coin falls rapidly. The fact that air resistance is responsible for these different accelerations is explained with the 'Feather and coin' experiment performed by Sir Isaac Newton.

Newton took a long glass tube as shown in Fig. 1.3 and dropped a feather and a coin simultaneously into it. He noticed that the coin travelled much faster than the feather because of the air inside the tube.

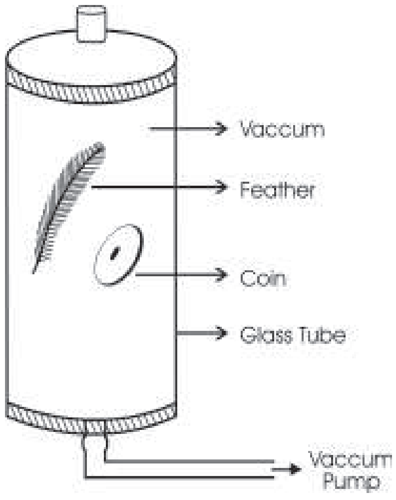


Fig. 1.3 Feather and coin experiment

Then the air from the glass tube was removed with the help of a vacuum pump. When the experiment was repeated, the coin and the feather reached the other end of the tube at the same time.

From this experiment he proved that in the absence of air, all objects fall with the same acceleration. Thus Galileo's statement was proved by Newton.

Sir Isaac Newton

The velocity of a freely falling object (under the influence of the force of gravity) increases at a constant rate. Hence, it is said to be accelerated. This acceleration is known as 'acceleration due to gravity' and it is denoted as 'g'. The average value of 'g' has been found to be 9.8 m s^{-2}.

1.3.2 Equations of motion for a freely falling object

When an object is dropped from a certain height

initial velocity $u = 0$

acceleration due to gravity $a = +g$

displacement $s = h$

$$v = u + at \text{ becomes } v = gt$$

$$s = ut + \frac{1}{2} at^2 \text{ becomes } h = \frac{1}{2} gt^2$$

$$v^2 = u^2 + 2as \text{ becomes } v^2 = 2gh$$

When an object is thrown vertically up,

initial velocity $= u$

acceleration due to gravity $a = -g$

displacement $s = h$

final velocity $v = 0$ at the maximum height

$$u = gt$$

$$h = ut - \frac{1}{2} gt^2$$

$$u^2 = 2gh$$

Problems

1. A cat steps off a ledge and falls to the ground in 2 seconds

   (i) what is its velocity when it reaches the ground?

   (ii) What is its average velocity?

time taken $t = 2$ s

acceleration due to gravity $g = 9.8$ m s^{-2}

(i) velocity $v = gt = 9.8 \times 2 = 19.6$ m s^{-1}

(ii) average velocity $= \dfrac{\text{initial velocity} + \text{final velocity}}{2}$

$$= \frac{0 + 19.6}{2} = 9.8 \text{ m s}^{-1}$$

2. An object released from a certain height, hits the ground with a velocity of 49 m s^{-1}. What is the height from which it is released?

initial velocity $u = 0$

final velocity $v = 49$ m s^{-1}

acceleration due to gravity $g = 9.8$ m s^{-2}

$$v^2 = 2gh$$

$$49 \text{ x } 49 = 2 \times 9.8 \times h$$

$$\therefore h = \frac{49 \times 49}{2 \times 9.8}$$

$$h = 122.5 \text{ m}$$

3. A ball is thrown up with a velocity of 19.6 m s^{-1}. Find the maximum height reached and the time taken to reach it.

initial velocity $u = 19.6 \text{ m s}^{-1}$

final velocity $v = 0$

acceleration due to gravity $g = 9.8 \text{ m s}^{-2}$

$$a = -g$$

$$u^2 = 2gh$$

we know that $h = \dfrac{u^2}{2g} = \dfrac{19.6 \times 19.6}{2 \times 9.8} = 19.6 \text{ m}$

$$h = 19.6 \text{ m}$$

we know that $u = gt$

$$t = \frac{u}{g} = \frac{19.6}{9.8} = 2 \text{ s}$$

1.4 Projectile motion

An object thrown with an initial velocity horizontally or at an angle less than 90^0 under the action of the earth's gravity is called projectile.

A few examples of projectile are (i) a bullet fired from a gun (ii) a stone thrown horizontally from the top of a building (iii) a bomb dropped from an aeroplane and (iv) a shotput or a javelin thrown by a sportsman.

What is the path taken by a coin when it is pushed horizontally off the edge of a table? (as shown in Fig 1.4). It takes a curved path undergoing both horizontal and vertical motion.

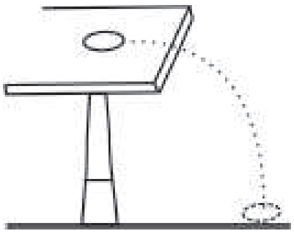


Fig. 1.4 coin falling from a table

Consider a body A which is allowed to fall freely and another body B which is projected horizontally with a velocity u from the same height and at the same time as shown in Fig. 1.5. The body A which is falling freely and the body B which is projected horizontally from the same height and at the same time will reach the ground simultaneously, at different points. The two bodies at any instant will be at the same vertical height above the ground.

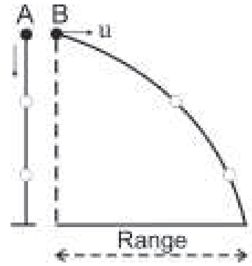


Fig. 1.5 Free fall and projectile motion

Range of a projectile is the horizontal distance between the point of projection and the point where the projectile hits the ground.

1.4.1 Path of a projectile

Consider an object thrown with a horizontal velocity 'u' from a point P which is at a certain height from the ground as shown in Fig. 1.6. As it undergoes vertical and horizontal motion, it has a vertical and horizontal velocity.

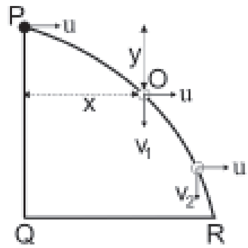


Fig. 1.6 Path of a projectile

The vertical velocity increases due to the force of gravity. But the horizontal velocity remains constant throughout its motion.

Let us assume that the object moves from P to O in a time interval 't'.

Horizontal displacement of the particle $\quad x = ut \quad$ ——— (1)

Since the initial vertical velocity is zero, the vertical displacement of the particle $\quad y = \frac{1}{2} gt^2 \quad$ ——— (2)

from equation (1) $\quad t = \frac{x}{u}$

substituting this in equation (2) $\quad y = \frac{1}{2} gt^2$

$$y = \frac{1}{2} g\left(\frac{x}{u}\right)^2 = \frac{1}{2} g \cdot \frac{x^2}{u^2}$$

$$y = \frac{g}{2u^2} \cdot x^2$$

$$y = k \cdot x^2 \qquad \text{where } k = \frac{g}{2u^2}$$

(since u and g are constants k is also a constant)

This is the equation of a parabola. Thus, the path of a projectile is a parabola.

Problem

1. A body is thrown horizontally from the top of a building. It falls on the ground after 1.5 s at a distance of 5 m from the building. Calculate (a) the height of the building (b) the horizontal velocity?

$$\text{time taken } t = 1.5 \text{ s}$$

$$\text{range } x = 5 \text{ m}$$

$$\text{acceleration due to gravity } g = 9.8 \text{ m s}^{-2}$$

$$h = \frac{1}{2} g t^2$$

$$h = \frac{1}{2} \times 9.8 \times 1.5 \times 1.5$$

$$\text{height of the building } h = 11.025 \text{ m}$$

$$\text{range} = \text{horizontal velocity} \times \text{time taken}$$

$$\text{i.e. } x = u\,t$$

$$\text{horizontal velocity } u = \frac{x}{t} = \frac{5}{1.5} = 3.33 \text{ m s}^{-1}$$

2. An aeroplane, flying horizontally at a height of 1960 m with a velocity of 125 m s^{-1} aims to hit an enemy target. Find at what distance from the tank, the pilot will release the bomb in order to hit the tank.

$$\text{acceleration due to gravity, } g = 9.8 \text{ m s}^{-2}$$

$$\text{height from the ground, } h = 1960 \text{ m}$$

Since the initial vertical velocity is zero,

$$h = \frac{1}{2} g t^2$$

$$1960 = \frac{1}{2} \times 9.8 \times t^2$$

$$t^2 = \frac{1960}{4.9} = 400$$

$$\therefore t = 20 \text{ s.}$$

$$\text{horizontal distance} = \text{horizontal velocity} \times \text{time taken}$$

$$= 125 \times 20 = 2500 \text{ m.}$$

The bomb should be released at a distance of 2500 m from the tank.

1.5 Types of motion

There are different types of motion. They are

(i) linear or translatory motion. (ii) vibratory motion

(iii) circular motion (iv) random motion and

(v) oscillatory motion

A child sliding down a sliding board, an aeroplane on the runway, a speeding train, a man walking down a straight road are examples of objects which move in a straight line. This is called linear motion.

Circular motion

(i) *Rotatory motion* The rotating blades of a fan, a potter's wheel, the spinning earth, a merry-go-round and a giant wheel move about their axes. Such a motion is called rotatory motion.

(ii) *Revolving motion* The motion of the moon round the earth, the motion of an electron around the nucleus are examples of 'revolving motion'.

The movement of a particle in a circular path is called circular motion.

1.5.1 Angular displacement and angular velocity

Let us consider an object moving in a circular path with uniform speed about a fixed point O as centre. When the object moves from A to B, the radius OA sweeps an angle θ at the centre as shown in Fig. 1.7.

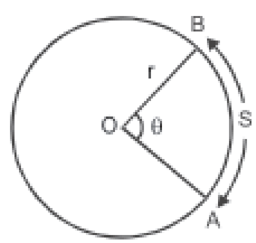


Fig. 1.7 Circular motion

Angular displacement of the object is measured by the angle swept by the radius at the centre, as the particle is moving along the circumference of the circle.

The unit of angular displacement is radian. One radian is the angle subtended at the centre of a circle by an arc whose length is equal to the radius of the circle.

Angular velocity of an object is the rate of change of angular displacement.

The object moves from A to B in time 't'. During this time the radius sweeps an angle θ at the centre as shown in Fig. 1.7.

$$\text{angular velocity, } \omega = \frac{\text{angular displacement}}{\text{time}}$$

$$\omega = \frac{\theta}{t}$$

The unit of angular velocity is radians per second. (rad s^{-1})

Angular acceleration is the rate of change of angular velocity.

$$\text{Angular acceleration, } \alpha = \frac{\text{Change in angular velocity}}{\text{time}}$$

$$\alpha = \frac{\omega - \omega_o}{t}$$

where ω_o and ω are the initial and final angular velocities in a time interval 't'. The unit of angular acceleration is rad s^{-2}.

1.5.2. Relation between linear velocity and angular velocity

Consider a body moving along the circumference of a circle of radius 'r' with linear velocity 'v' and angular velocity 'ω'. It covers AB in a time interval 't'.

The linear velocity of the body $v = \frac{AB}{t} = \frac{s}{t}$ -------(1)

$s = r\,\theta$ -----(2) (one radian corresponds to r.
$\therefore$ θ radian corresponds to rθ)

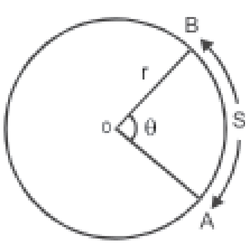


Fig. 1.8 Circular motion

substituting equation (2) in (1)

$$v = \frac{s}{t} = \frac{r\theta}{t} \quad \text{-------(3)}$$

$$v = r\,\omega, \text{ since } \omega = \frac{\theta}{t}$$

linear velocity = radius of the circle × angular velocity

1.5.3. Angular momentum

Angular momentum of a particle is defined as the moment of linear momentum of the particle.

$$\text{The moment of linear momentum} = mv \times r$$
$$= mr\omega \times r, \quad (\because v = r\omega)$$
$$= mr^2\omega$$
$$= I\,\omega$$

where $I = mr^2$ is called the moment of inertia of the rotating particle. **Moment of inertia is the measure of inertia of the particle in circular motion and it is equal to the product of the mass of the particle and the square of its distance from the axis of rotation.**

$\therefore$ Angular momentum, $L = I\,\omega$

Angular momentum = moment of inertia × angular velocity

The unit of angular momentum is kg $m^2\,s^{-1}$

TABLE 1.3. Comparison of linear and angular motion

No.	Linear motion	Angular motion
1.	Linear displacement is 's'	Angular displacement is 'θ'
2.	Linear velocity, $v = \frac{s}{t}$	Angular velocity, $\omega = \frac{\theta}{t}$
3.	Linear acceleration, $a = \frac{v - u}{t}$	Angular acceleration, $\alpha = \frac{\omega - \omega_o}{t}$
4.	Mass 'm' is the measure of inertia in linear motion	Moment of inertia $I = mr^2$, is the measure of inertia in circular motion.
5.	Linear momentum, $p = mv$	Angular momentum, $L = I\,\omega$

1.6 Centripetal force

A stone is tied to a string and rotated in a circular path. The pull of our hand on the string is towards the centre of the circular path traced by the stone. The tension in the string provides the centripetal force. If the string is suddenly released, the stone will go off in a direction tangential to the circle.

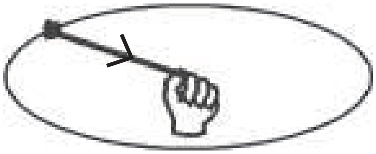


Fig. 1.9

When a satellite moves in a circular path around the earth, the gravitational force between the earth and the satellite provides the necessary centripetal force. For a car taking a curve, the frictional force on the tyres and the ground provides the required centripetal force.

The external force required to make a body move along a circular path with uniform speed and directed towards the centre is called centripetal force.

Let us consider an object of mass 'm', moving along a circular path of radius 'r' with an angular velocity ω and linear velocity 'v'. As the body moves along the circular path, the direction of velocity changes at every point and hence it has an acceleration, which is directed towards the centre. This acceleration is called centripetal acceleration.

$$\text{Centripetal acceleration } a = \frac{v^2}{r}$$

$$\text{Centripetal force } F = \text{mass} \times \text{acceleration}$$

$$= m \times \frac{v^2}{r} = \frac{mv^2}{r}$$

$$\text{Centripetal force } \mathbf{F} = \mathbf{m\,r\,\omega^2} \quad \left(\because v = r\omega\right)$$

Problem

1. A particle undergoing circular motion of radius 7 cm completes one revolution in 0.2 s. Calculate its angular velocity and linear velocity.

The angle swept in one revolution $\theta = 2\pi$ radian

radius of the circle $r = 7\text{cm} = 0.07\text{ m}$

time taken $t = 0.2\text{s}$

angular velocity $\omega = \dfrac{\theta}{t} = \dfrac{2\pi}{0.2} = 10\,\pi\text{ rad s}^{-1}$

linear velocity $v = r\omega$

$v = 0.07 \times 10\pi = \dfrac{0.07 \text{ x } 10 \text{ x } 22}{7}$

linear velocity $\mathbf{v = 2.2\ m\ s^{-1}}$

2. A body of mass 2 kg undergoes circular motion in a path of radius 1.4 m with an angular velocity of 3.14 rad s^{-1}. Calculate its centripetal acceleration and centripetal force.

mass of the body $m = 2\text{ kg}$

radius of the circle $r = 1.4\text{ m}$

angular velocity $\omega = 3.14\text{ rad s}^{-1}$

centripetal acceleration $a = r\omega^2$

$= 1.4 \times 3.14 \times 3.14$

$= 13.8\text{ m s}^{-2}$

centripetal force $F = mr\omega^2$

$= 2 \times 1.4 \times 3.14 \times 3.14$

centripetal force $\mathbf{F = 27.60\ N}$

3. A giant wheel rotates with a linear velocity of 20 m s^{-1} at a point on its circumference. If the diameter of the wheel is 100 m, what is the centripetal acceleration at that point?

$$\text{diameter of the wheel} = 100 \text{ m}$$

$$\text{radius } r = 50 \text{ m}$$

$$\text{velocity} = 20 \text{ m s}^{-1}$$

$$\text{centripetal acceleration } a = \frac{v^2}{r} = \frac{20 \times 20}{50}$$

$$\text{centripetal acceleration} = \mathbf{8 \text{ m s}^{-2}}$$

4. Calculate the centripetal force on a 1 kg rock whirling at a speed of 5 m s^{-1} in an arc of radius 1.5 m.

$$\text{mass of the rock} = 1 \text{ kg}$$

$$\text{speed of the rock} = 5 \text{ m s}^{-1}$$

$$\text{radius of the arc} = 1.5 \text{ m}$$

$$\text{centripetal force } F = \frac{mv^2}{r}$$

$$= \frac{1 \times (5)^2}{1.5}$$

$$= \frac{1 \times 5 \times 5}{1.5}$$

$$\text{centripetal force } \mathbf{F} = \mathbf{16.67 \text{ N.}}$$

Let us muse upon

- The study of moving objects under the action of force is called dynamics and the study of forces on bodies at rest is called statics.
- The centre of gravity of an object is a fixed point through which the entire weight of the object acts, irrespective of the position of the object.
- The acceleration due to gravity decreases with increasing altitude and it decreases with depth.
- The stability of a body is decided by the position of the centre of gravity. A body will be stable if the vertical line through the centre of gravity falls within the base
- A projectile is defined as a body which is given an initial velocity and then allowed to move under the action of gravity.
- The Range of a projectile is the horizontal distance between the point of projection and the point where the projectile hits the ground.
- The movement of a particle in a circular path is called circular motion.
- Angular displacement of an object is measured by the angle swept by the radius at the centre as the particle moves along the circumference of a circle
- The unit of angular displacement is radian. One radian is defined as the angle subtended at the centre of the circle by an arc whose length is equal to its radius.
- Angular velocity of an object is the rate of change of angular displacement.
- The relation between linear and angular velocity is $v = r\omega$.
- Angular momentum of a particle is defined as the moment of linear momentum of the particle about the axis of rotation.
- The moment of inertia is defined as the measure of inertia of a rotating particle and is equal to the product of the mass of the particle and the square of its distance from the axis of rotation.
- The external force required to make a body move along a circular path with uniform speed and directed towards its centre is called centripetal force.
- When a body moves along a circular path, the direction of velocity changes at every point and hence it has an acceleration which is directed towards the centre. This acceleration is called centripetal acceleration.

Self evaluation

1.1. The centre of gravity of a triangular body lies at its

(a) centroid (b) orthocentre (c) vertex (d) circumcentre

1.2. The average value of acceleration due to gravity is

(a) $9.8 ms^{-2}$ (b) $9.8 cms^{-2}$ (c) $19.8 ms^{-2}$ (d) $8.9 ms^{-2}$

1.3. A man carrying a cement bag on his back up a slope will

(a) lean backward (b) lean forward (c) walk straight

(d) lean towards his left.

1.4. When an object falls vertically the initial velocity is

(a) more than $9.8\ m\ s^{-1}$ (b) less than $4.6\ m\ s^{-2}$ (c) $2\ m\ s^{-1}$

(d) zero.

1.5. A ball is thrown vertically up, then the velocity at its maximum height is

(a) more than $9.8\ m\ s^{-1}$ (b) zero (c) less than $9.8\ m\ s^{-2}$

(d) $9.8\ m\ s^{-1}$

1.6. The force between the moon and the earth which acts as a centripetal force keeping the moon in its orbit is

(a) an elastic force (b) gravitational force (c) electrical force

(d) nuclear force.

1.7. An object released from a height of 19.6 m strikes the ground with a velocity of

(a) $7\ m\ s^{-1}$ (b) $9.8\ m\ s^{-1}$ (c) $19.6\ m\ s^{-1}$ (d) $15\ m\ s^{-1}$

1.8. A marble is thrown up vertically with an initial velocity of $9.8\ m\ s^{-1}$. The maximum height reached is

(a) 9.8 m (b) 8.9 m (c) 4.9 m (d) 19.6 m

1.9. The angular velocity of the seconds hand of a wrist-watch is

(a) $\frac{\pi}{15}$ rad s^{-1} (b) $\frac{\pi}{30}$ rad s^{-1} (c) $\frac{\pi}{60}$ rad s^{-1} (d) $\frac{\pi}{90}$ rad s^{-1}

1.10. A cycle wheel 0.6 m radius is moving with an angular velocity of 10 rad s^{-1}. Its linear velocity is

(a) $2\ m\ s^{-1}$ (b) $60\ m\ s^{-1}$ (c) $10\ m\ s^{-1}$ (d) $6\ m\ s^{-1}$

1.11. What is centre of mass?

1.12. Define the term centre of gravity.

1.13. Where does the centre of gravity of a rectangular cardboard lie?

1.14. At what position does the centre of gravity of a cylindrical tin lie?

1.15. Mention the conditions for the stability of bodies.

1.16. When do we say an object is in free fall? Mention some examples.

1.17. With the help of a diagram explain Newton's 'Feather and coin' experiment.

1.18. Write the equations of motion for
(a) a freely falling object (b) an object thrown vertically up.

1.19. Define a projectile. Give some examples of projectile.

1.20. Why does a ball released from a moving bus take a parabolic path?

1.21. Define the term range of a projectile.

1.22. A boy throws a water-balloon from a certain height on a passerby. What is the path taken by the water-balloon?

1.23. Show that the path of a projectile is a parabola.

1.24. What is circular motion? Give some examples.

1.25. Define angular displacement and mention its unit.

1.26. What is angular velocity? Give its formula and unit.

1.27. Define angular acceleration. Write its formula and unit.

1.28. Derive the relation between linear velocity and angular velocity.

1.29. Define angular momentum and derive its formula.

1.30. Tabulate the differences between linear and angular motion.

1.31. Give two examples of objects moving under the influence of centripetal force and hence define it.

1.32. What is centripetal acceleration? Give an expression for centripetal force.

1.33. What are the different types of motion?

1.34. Define moment of inertia.

1.35. Compare the motion of a freely falling body with that of a projectile.

1.36. An aeroplane flying horizontally with a velocity of 100 m $s^{-1,}$ releases a bomb at a height of 490 m. Find the time taken by the bomb to reach the ground.

1.37. A marble is thrown up vertically with an initial velocity of 29.4 m s^{-1}. How high will it rise and how long will it take to reach that height ?

1.38. Calculate the angular velocity of the earth about its own axis.

1.39. A fighter pilot flies the aircraft in a circular path of radius 200 m. If the aircraft flies with the speed of 400 km hr^{-1} determine the centripetal acceleration.

1.40. A force of 150 N is required to break a 3m long nylon cord. An object of mass 1.2 kg is fixed to one end of the cord and whirled around. Determine the maximum speed with which it can be whirled around without breaking the cord.

1.41. What speed should the rim of a 50 m diameter space station travel, so that its inhabitants experience an acceleration of 10 m s^{-2} ?

1.42. A body is dropped from a certain height. What is the velocity of the body at the third second of its fall ?

1.43. A ball is released from a certain height. Calculate the vertical distance covered by the ball at the sixth second of its fall.

1.44. To estimate the height of a bridge across the river, a stone is dropped freely in the river from the bridge. The stone takes 2s to touch the water surface. Calculate the height of the bridge from the water level.

1.45. A merry-go-round completes 3 revolutions in one minute. Calculate its angular velocity.

1.46. The centripetal force acting on a body of mass 5 kg, undergoing circular motion of radius 1m is 500 N. Calculate (a) its linear velocity (b) its angular velocity.

1.47. A soft ball is dropped from a height of 10m. How long does it take for the ball to reach the ground?

1.48. A toy car is dropped from the top of a building. It reaches the ground in 3 s. Calculate (a) the velocity with which it strikes the ground (b) the height of the building.

Answers

1.1. (a)	**1.2.** (a)	**1.3.** (b)	**1.4.** (d)	**1.5.** (b)
1.6. (b)	**1.7.** (c)	**1.8.**(c)	**1.9.**(b)	**1.10.**(d)

1.36. 10 s.

1.37. 44.1 m, 3 s.

1.38. $\frac{\pi}{43200}$ rad s^{-1}.

1.39. 61.73 m s^{-2}

1.40. 19.36 m s^{-1}.

1.41. 15.8 m s^{-1}.

1.42. 29.4 m s^{-1}.

1.43. 176.4 m.

1.44. 19.6 m.

1.45. 0.314 rad s^{-1}.

1.46. 10 m s^{-1}, 10 rad s^{-1}.

1.47. 1.43 s.

1.48. 29.4 m s^{-1}, 44.1 m.

2. LIGHT

In one of the greatest theoretical developments of the nineteenth century, James Clark Maxwell predicted that the change in both electric and magnetic fields cause electro magnetic disturbances that travel through space. It is similar to the spreading water waves created by a pebble thrown into a pool. The disturbance caused by electric and magnetic fields propagates in a direction perpendicular to both the electric and the magnetic fields as shown in Fig. 2.1

James Clark Maxwell

Oscillating electric and magnetic fields perpendicular to each other cause disturbances in space. These disturbances propagate in a direction perpendicular to both the electric and the magnetic fields and are called electromagnetic waves.

They are transverse in nature and do not require a material medium for propagation. They transfer energy from one point to another.

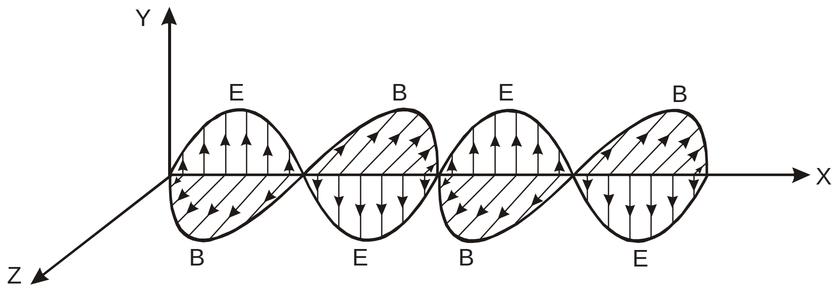


Fig . 2.1 Electromagnetic waves

Two decades after Maxwell's prediction in 1888, Heinrich Hertz produced electromagnetic waves by means of oscillating electric charges. Moreover he conducted numerous experiments to demonstrate that they behaved like light waves, satisfying all the phenomena of light.

The inference from Hertz experiments was that light waves are electromagnetic waves. They are the visible part of the electromagnetic spectrum and occupy a very small band in it.

Hertz

Velocity of electromagnetic waves

Maxwell arrived at an equation to find the value of the velocity of electromagnetic waves. It is given by

$$c = \frac{1}{\sqrt{\mu_o \varepsilon_o}}$$

where μ_o is the permeability of free space and ε_o is the permittivity of free space. The value of velocity of electromagnetic waves is found to be $c = 3 \times 10^8$ m s^{-1}

2.1 Electromagnetic spectrum

Electromagnetic waves in the range of wavelength from a few kilometre down to 10^{-14} m constitute the electromagnetic spectrum. The corresponding range of frequency is in the order of a few hertz to 10^{22} Hz.

Classification of electromagnetic spectrum

The electromagnetic spectrum is classified as

(i) Gamma rays
(ii) X-rays
(iii) Ultra-violet rays
(iv) Visible light
(v) Infra-red rays
(vi) Microwaves and
(vii) Radio waves

Brief descriptions of the electromagnetic spectrum are given below in the increasing order of wavelength.

Gamma rays These are emitted by radioactive nuclei and have wavelength between 10^{-14}m and 10^{-10}m. They are highly penetrating and cause serious damage if absorbed by living tissues. Those working near such radiations must be protected using aprons made of lead.

X-rays They were discovered by Roentgen in 1895. X-rays are produced when fast moving electrons are suddenly stopped by elements of high mass number like molybdenum or tungsten. Their wavelength ranges from 10^{-10}m to 3×10^{-8} m. X – rays are used for diagnostic purposes

Ultra-violet rays Their wavelength ranges from 6×10^{-10}m to 3.8×10^{-7}m. Sun is a natural source of ultraviolet rays. Most of these rays are absorbed by the ozone layer in the stratosphere.

Visible light This is the most familiar form of electromagnetic waves. It is emitted by incandescent solids, sun, stars and fluorescent lamps. The wavelength range is from 3.8×10^{-7}m to 7.8×10^{-7}m and it consists of seven colours namely Violet, Indigo, Blue, Green, Yellow, Orange and Red (VIBGYOR)

Table 2.1 Wavelength range of different colours

Colour	Wavelength $\mathring{A}$ (10^{-10}m)
Violet	3800 — 4400
Indigo	4400 — 4600
Blue	4600 — 5000
Green	5000 — 5700
Yellow	5700 — 5900
Orange	5900 — 6200
Red	6200 — 7800

Infra-red rays Their wavelength range is from 7.8×10^{-7}m to 3×10^{-5}m. They are used in physiotherapy for the treatment of arthritis.

Micro waves Their wavelength ranges from 10^{-3} m to 0.3 m. They are generated by electronic devices like magnetron, klystron and travelling wave tube. They are used in telegraph, telephone, television and radar communication systems and also in micro wave ovens.

Radio waves They are produced by accelerating electric charges through conducting wires. They are used in radio and television transmission and cell phones. Their wavelength range is from 10 m to 10^4 m.

The frequency range of radio waves goes up to 10^9 Hz. FM band (frequency modulation) is from 88 MHz to 108 MHz. AM band (amplitude modulation) ranges from 550 kHz to 1600 kHz. Television occupies frequency bands on either side of the FM region. The allocation of frequency ranges for various broadcasting stations is done at the international level.

Know it yourself

1888	—	Hertz produced electro magnetic waves of wavelength about 6m.
1895	—	J.C. Bose, an Indian scientist produced electromagnetic waves of wave length ranging from 5 mm to 25 mm.
1899	—	G. Marconi was the first to transmit electromagnetic waves and establish wireless communication across the English Channel.

Problem

1. Calculate the frequency of a wave of wave length 150 m.

$$\text{wavelength } \lambda = 150 \text{ m}$$

$$\text{velocity } c = 3 \times 10^{8} \text{ m s}^{-1}$$

$$c = \upsilon\lambda$$

$$3 \times 10^{8} = \upsilon \times 150$$

$$\text{frequency } \upsilon = \frac{3 \times 10^{8}}{150} \text{ Hz}$$

$$= 2 \times 10^{6} \text{ Hz}$$

$$\text{frequency } = \mathbf{2 \text{ MHz.}}$$

2.What is the wavelength range covered by the AM radio band with frequencies in the range of 550 kHz to 1600 kHz?

$$\text{Frequency range} = 550 \text{ kHz} \quad \text{to} \quad 1600 \text{ kHz}$$

$$= 550 \times 10^{3} \text{ Hz to } 1600 \times 10^{3} \text{ Hz.}$$

$$c = 3 \times 10^{8} \text{ m s}^{-1}$$

$$\text{Wavelength } \lambda = \frac{c}{\upsilon}$$

$$\therefore \text{ Wavelength range} = \frac{3 \times 10^{8}}{550 \times 10^{3}} \text{ m to } \frac{3 \times 10^{8}}{1600 \times 10^{3}} \text{ m}$$

$$\text{Wavelength range} = \mathbf{545.5 \text{ m} \quad to \quad 187.5 \text{ m}}$$

2.2 The visible spectrum

For centuries, it had been known that glass and precious stones glittered in bright colours when white light is passed through them. In the middle of the seventeenth century, Newton investigated this systematically.

Newton's experiment

Newton made a small circular hole in one of the window shutters of his room in Cambridge. When the sun's rays passed through this hole, they made a circular patch on the opposite wall. On placing a prism in front of the hole an elongated coloured patch of light was seen on the wall.

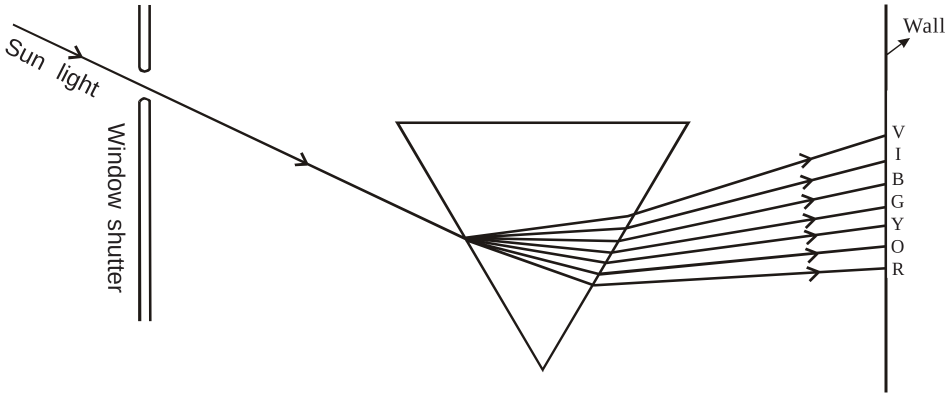


Fig. 2.2. Newton's experiment with a prism

Newton called this coloured patch as spectrum and noted that the colours were in the order of Violet, Indigo, Blue, Greeen, Yellow, Orange and Red as shown in Fig. 2.2.

The splitting of white or any composite light into its constituent colours on passing through a prism is called dispersion.

Refraction through a prism

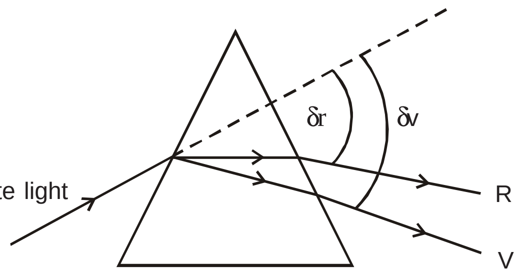


Fig. 2.3. Angle of deviation

When a ray of light passes through a prism, it is deviated from its initial path as shown in Fig. 2.3. **The angle between the incident ray and the**

emergent ray is called the angle of deviation. The emergent ray is bent towards the base of the prism.

For a given prism, the **angle of deviation of each colour depends on**

(i) its **speed** in the prism

(ii) the **refractive index, μ** of the prism and

(iii) **its wavelength, λ**

Since the speed, refractive index and wavelength are different for different colours, each colour is deviated through a different angle. Of all the colours, violet is deviated the most and red the least.

Recombination of white light

Two identical prisms of the same material are arranged side by side such that one is upright and the other is inverted as shown in Fig. 2.4.

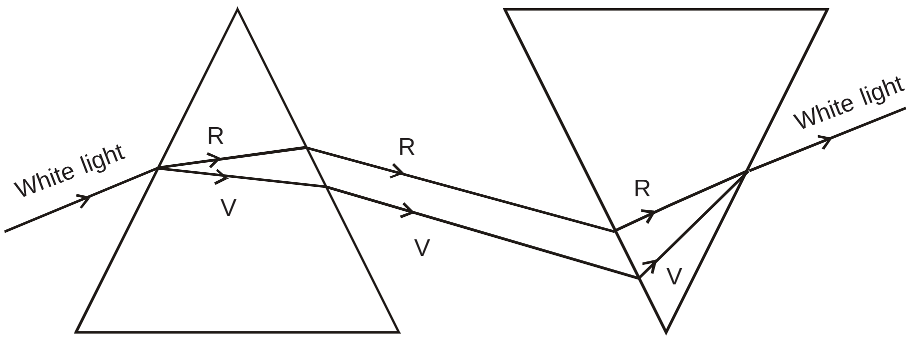


Fig. 2.4. Recombination of colours into white light

A narrow beam of white light is made to fall on the first prism. The emergent coloured rays are made incident on the second prism. Coloured rays on passing through the second prism emerge as white light.

Since the downward deviation of the colours by the first prism is equal and opposite to the upward deviation by the inverted prism, recombination of colours takes place. This not only shows that white light is made up of seven colours but also that the colours are not contributed by the prism which separates them.

Pure and impure spectrum

In the spectrum obtained from a prism, there is overlapping of colours as each colour merges into the other as shown in Fig. 2.5. **A spectrum in which there is overlapping of colours is called an impure spectrum.**

A pure spectrum is one in which the various colours obtained on the screen are distinctly separated from each other so that there is no overlapping of colours.

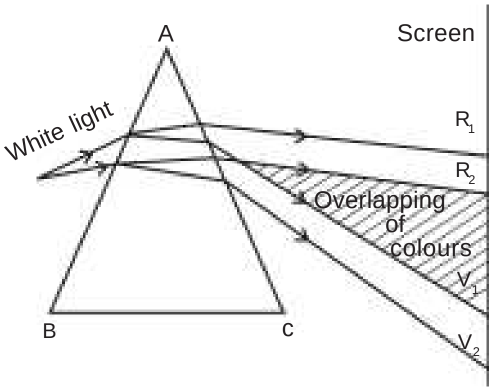


Fig. 2.5. Impure spectrum

Conditions for producing a pure spectrum

(i) The beam of light to be dispersed should be from a narrow slit.
(ii) The beam incident on the prism should be a parallel beam.
(iii) The prism must be in the position of minimum deviation.
(iv) The emergent beam should be brought to focus using a converging lens.

Experiment to produce a pure spectrum

White light from a source is made to pass through a very narrow slit S. A convex lens L_1 is placed in front of the slit such that the slit is at its principal focus. The rays are rendered parallel by the lens and are made to

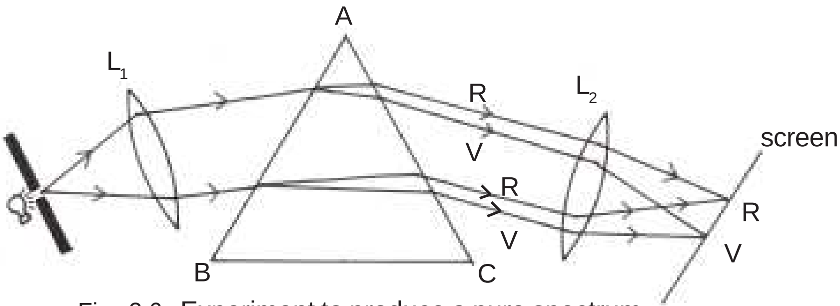


Fig . 2.6. Experiment to produce a pure spectrum

fall on the refracting face AB of the prism ABC, kept in the position of minimum deviation. The rays are dispersed by the prism and each colour emerges as a parallel beam as shown in Fig. 2.6.

A convex lens L_2 is placed on the other side of the prism and a screen is placed at the focus of the lens L_2. A pure spectrum is obtained on the screen.

2.3 Primary and secondary colours

It is found that by projecting any two of red, green and blue light in varying proportions on a white screen, almost all colours of light can be obtained, but red, green and blue colours cannot be obtained by mixing two other colours. **Primary colours are those which cannot be obtained by mixing other colours.** Red, green and blue are primary colours. **Secondary colours are those obtained by adding any two of the three primary colours.**

Complementary colours

A primary colour and the secondary colour obtained by mixing the other two primary colours together produce white. **Two colours (a primary and a secondary colour), which produce white light on mixing are called complementary colours.**

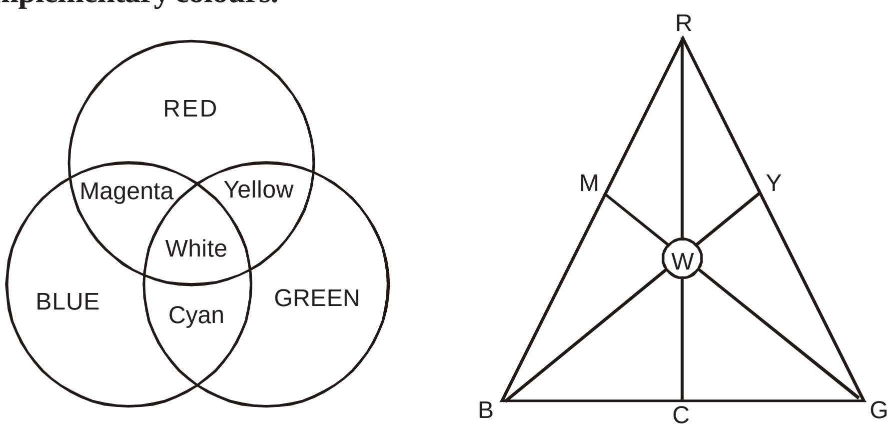


Fig 2.7. Mixing of colours

Red	+	Cyan	$\rightarrow$	White
Green	+	Magenta	$\rightarrow$	White
Blue	+	Yellow	$\rightarrow$	White

Blue and yellow on mixing give white. This is the reason why laundry blue is added, to enhance the whiteness of clothes which have become yellow after long use.

Colour mixing

The colours that we see around us are the colours reflected or transmitted by the bodies. These colours may be spectral colours or combination of colours obtained by mixing two colours. There are two methods of mixing in which different colours are obtained. They are by (i) addition and (ii) subtraction.

(i) ***Addition of colours***

The secondary colours magenta, cyan and yellow are obtained by mixing or adding two primary colours. This is called colour mixing by addition.

(ii) ***Subtraction of colours***

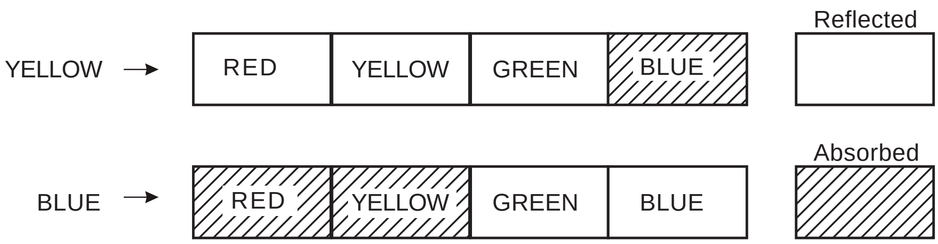
Paints and dyes are pigments which are colouring matter. Pigment colours are different from spectral colours. Pigments reflect some colours and absorb the remaining colours.

When two paints are mixed together more colours are absorbed than reflected. So the final colour of the mixture is the colour they both reflect. It is not the same as what is obtained when light beams overlap.

Example: Yellow light + Blue light $\rightarrow$ White light

Yellow paint + Blue paint $\rightarrow$ Green paint

This is because pigments in common use are impure colours. When illuminated by white light, yellow paint reflects red, yellow and green and absorbs blue. Blue paint reflects blue and green, absorbs yellow and red as illustrated below.



The only colour they both reflect is green. Hence, the mixture of yellow and blue pigments looks green. Between them they absorb (subtract) red, yellow and blue from white light. This process is known as colour mixing by subtraction. Cyan, yellow and magenta form primary pigments.

Colour of objects in white light

The colour of a body is that which it reflects. When white light is incident on the body, it reflects its own colour and it absorbs all the other colours.

(eg.) A green leaf reflects green and absorbs the other colours.

A red rose reflects red and absorbs all the other colours.

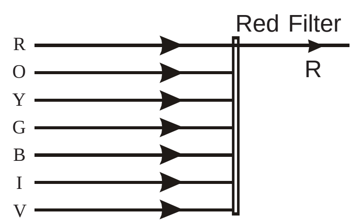
If a body reflects all the colours that fall on it, it appears white.

If a body absorbs all the colours that fall on it, it appears black. So the black is the absence of all colours.

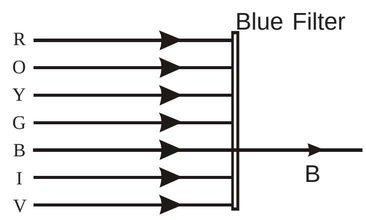
Colour filters

Filters are pieces of coloured glass, plastic or sheets of gelatine which allow only certain colours to pass through them as shown in Fig. 2.8.

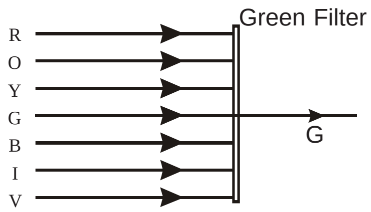
A red filter transmits only red and absorbs all the other colours.



A blue filter transmits only blue and absorbs all the other colours.



A green filter transmits only green and absorbs all the other colours.



A yellow filter transmits not only yellow but also red, orange and green and absorbs the other colours.

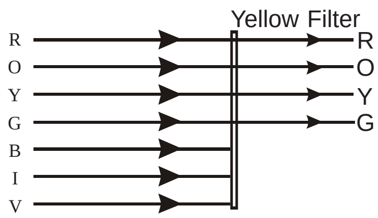


Fig. 2.8. White light passing through colour filters

2.4 Infra-red rays

Infra-red rays were detected by William Herschel, the astronomer, in 1800. They are emitted by the sun and all hot bodies. **The radiations beyond the red region of the visible spectrum are called infra-red rays.** Their wavelength ranges from 7.8×10^{-7} m to 3×10^{-5} m.

Properties of infra-red rays

(i) They travel in straight lines with the velocity of light.

(ii) They obey the laws of reflection and refraction.

(iii) They heat up the bodies on which they fall.

(iv) They are absorbed by glass but are not absorbed by rock salt.

(v) They penetrate through mist, fog and haze.

(vi) They are scattered less because of their long wavelength.

Detection

Infra-red rays are detected using their heating property with the help of

(i) a thermopile and (ii) a thermometer having its bulb blackened.

Uses of infra-red rays

(i) Infra-red rays are used in physiotherapy for the treatment of arthritis.

(ii) They are used in long distance, aerial and night photography and to photograph in mist and fog.

(iii) Infra-red telescope is used for seeing in the dark.

(iv) They are used in the study of structure and nature of chemical bonds of materials.

(v) Infra-red satellite pictures help us to identify water sources on the earth. Water absorbs infra-red radiation. Hence, lakes and river appear dark in these photographs.

Greenhouse effect and Global warming

Glass allows visible light to pass through but not infra-red rays. During the day, sunlight passes into the greenhouse. Greenhouse is a building constructed mainly of glass to grow and protect plants. During the daytime the sun light passes into the green house and is absorbed by the walls, earth, plants and so on. This absorbed visible light is re-radiated as infra-red radiation, which cannot escape the enclosure. The trapped infra-red radiation causes the temperature of the interior to rise. As a result, the greenhouse is warm inside.

Carbon-dioxide, methane, nitrous oxide and ozone in the earth's atmosphere act like the glass in the greenhouse. These gases are called green house gases. They allow the visible light from the sun to pass through but not much of the infra-red rays. The visible light that reaches the earth's surface is absorbed and re-radiated as infra-red radiation . This IR radiation is trapped and absorbed by the earth's atmosphere. This results in warming up of the earth's atmosphere.

Heating up of the earth's atmosphere due to infra-red radiation re-radiated from the earth's surface and absorbed by the greenhouse gases present in the atmosphere is called greenhouse effect.

As fossil fuels are burnt, a large amount of carbon-dioxide is released into the atmosphere, which absorbs Infra-red radiations from the surface of the earth. This raises the temperature of the earth. Consequently the polar ice-caps would melt raising the sea level. This is of great concern to the whole world, as the coastal areas are likely to be submerged.

Ultra-violet rays

The radiations lying beyond the violet end of the visible spectrum are called ultra-violet rays. This part of the spectrum was detected by J. Ritter in 1801. Ultra-violet rays are emitted by electric sparks, carbon arcs, mercury vapour lamp with a quartz cover and the sun.

Properties

(i) Ultra-violet rays can pass through quartz.

(ii) They travel in straight lines with the velocity of light.

(iii) They obey the laws of reflection and refraction.

(iv) They affect photographic plates.

(v) They cause fluorescence in substances like zinc sulphide, fluorspar, quinine sulphate solution, etc.

Detection

They are detected by their property of causing fluorescence. A thin tube containing a solution of quinine sulphate is found to fluoresce with bluish light when placed in the path of ultra-violet rays.

Uses of ultra-violet rays

(i) Ultra-violet rays are used for sterilising surgical instruments.

(ii) They are used in forensic science to detect forgeries, alteration of legal documents, adulteration in food and counterfeit currency.

(iii) Vitamin D is produced in plants and humans when exposed to ultra-violet rays in small doses.

(iv) Bottled drinking water is purified and made free from disease producing bacteria by treating it with ultra-violet rays.

Depletion of the ozone layer

Ultra-violet rays cause suntan, but over exposure to ultra-violet rays of short wavelength, causes skin diseases and premature ageing. These rays from the sun do not reach the earth in large amounts as the ozone layer in the stratosphere absorbs them. But, the ozone layer is being depleted by chlorofluorocarbons emitted by refrigerants. This is of great concern to mankind.

Know it yourself

Laundry whitening agents contain small quantities of a certain substance which fluoresces with a bluish white light when ultra-violet rays fall on them. This enhances the whiteness of clothes.

2.5 Photoelectric effect

When light of suitable frequency is incident on a metal surface, electrons are ejected from the metal. This phenomenon is called photoelectric effect. The electrons ejected from the metal are called photo electrons.

Experimental arrangement to demonstrate photoelectric effect

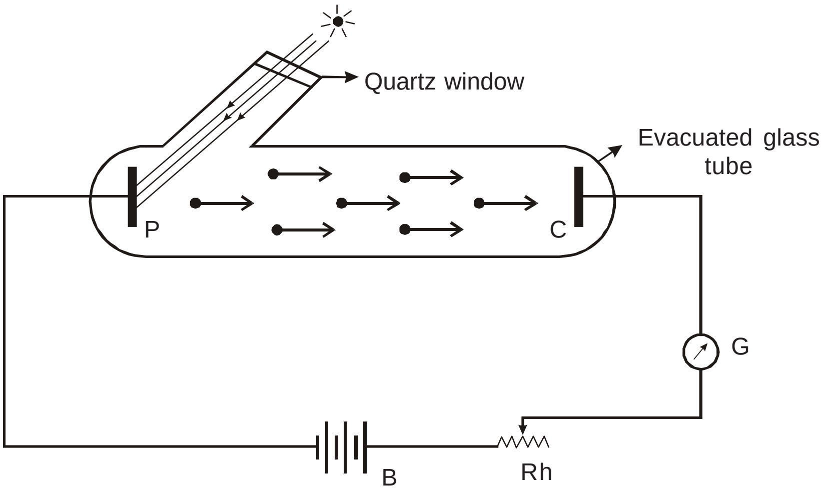


Fig 2.9. Experimental arrangement to demonstrate photoelectric effect.

The apparatus consists of an evacuated glass tube in which a photo-sensitive plate P is placed at one end and a collecting electrode C at the other end. A quartz window W is sealed on to the glass tube which permits the ultra-violet light to pass through and irradiate the plate P. A battery B and galvanometer G are connected across the plates P and C as shown in the Fig. 2.9. The plate C is maintained at a positive potential with respect to P.

Ultra-violet light is allowed to be incident on the plate P. The galvanometer shows deflection indicating the flow of current. When the plate C is connected to the negative terminal of the battery there is no deflection in the galvanometer.

It is clear from the above experiment that when ultra-violet rays are incident on the plate P, electrons are emitted. These electrons are called photoelectrons and the current is called photoelectric current.

Photoelectric current depends on

(i) intensity of the incident radiation

(ii) frequency of the incident radiation and

(iii) potential difference between the cathode and the anode.

Einstein's photoelectric equation

Metals have a large number of free electrons, which wander throughout the body of the metal. However, these electrons are not free to leave the surface of the metal. A minimum amount of energy is required to liberate an electron from the surface of the metal.

According to Einstein, light consists of bundles of energy called photons. The energy of each photon is $h\upsilon$, where h is Planck's constant and υ is the frequency of light. The value of Planck's constant $h = 6.625 \times 10^{-34}$ J s. When a beam of light is incident on the surface of the metal, each photon of energy $h\upsilon$ liberates a free electron

The minimum energy required for releasing an electron from the surface of the metal is $h\upsilon_0$, which is equal to the work function of the metal. The frequency υ_0 is the threshold frequency.

The remaining energy ($h\upsilon - h\upsilon_o$) appears as kinetic energy of the electron. If the electron does not lose energy due to internal collision, then

$$\frac{1}{2} m v^2_{max} = h\upsilon - h\upsilon_o$$

This equation is known as Einstein's photo electric equation.

Laws of photo electric emission

1. For light of any given frequency, the photoelectric current is directly proportional to the intensity of light provided the frequency is above the threshold frequency.

2. For a given photosensitive material, there is a certain minimum frequency called threshold frequency below which the emission of photoelectrons stops completely, no matter, how great the intensity of light may be.

3. Photoelectric emission is an instantaneous process. As soon as the frequency of light exceeds the threshold frequency, the emission starts immediately without any apparent time lag.

4. The maximum kinetic energy of the photo electrons is directly proportional to the frequency of light but is independent of its intensity.

2.6 Dual nature of light

The most difficult question to answer regarding light has proved to be, whether it light consists of a stream of particles or waves. The characteristics of particles are that at any given instant they have energy and momentum, while the characteristics of waves are wavelength and frequency.

During interference, diffraction and polarisation, light behaves like a wave. During the other phenomena of absorption, emission of light and photoelectric effect, light behaves like a stream of particles. Hence, light has a dual nature.

2.6.1. de Broglie's matter waves

In 1924, the French scientist Louis de Broglie reasoned the following concept from the fact that nature is symmetrical. According to him, if nature allows light to behave particle-like and wave-like, matter should also be allowed to behave particle-like and wave-like. Particle in motion is associated with a wave called matter wave or de Broglie wave.

Wavelength of matter waves

According to quantum theory, the energy associated with each photon,

$$E = h\upsilon \qquad \ldots\ldots(1)$$

According to Einstein, when a mass m is completely converted into energy,

$$E = mc^2 \text{ where c is the velocity of light.} \qquad \ldots\ldots(2)$$

From (1) and (2),

$$h\upsilon = mc^2$$

$$\frac{hc}{\lambda} = mc^2 \quad \left(\text{since } \upsilon = \frac{c}{\lambda}\right)$$

$$\lambda = \frac{h}{mc} \qquad \ldots\ldots(3)$$

For a particle with a velocity v, the equation (3) becomes

$$\lambda = \frac{h}{mv}$$

$$\lambda = \frac{h}{p} \quad (\because p = mv, \text{ the momentum of the particle})$$

Here λ is called de - Broglie wave length.

Problem

Calculate de - Broglie wave length of an electron moving with a velocity of 10^6 ms^{-1}.

$$\text{velocity } v = 10^6 \, ms^{-1}$$

$$\text{de - Broglie wave length } \lambda = \frac{h}{mv} = \frac{6.625 \times 10^{-34}}{9.1 \times 10^{-31} \times 10^6}$$

$$\lambda = 7.3 \times 10^{-10} \, m$$

2.7 Scattering of light

Tyndall was the first to study experimentally the scattering of light. When a parallel beam of light passes through a gas or liquid, a part of it appears in directions other than that of the incident light. This phenomenon is called scattering of light. The scattering is due to absorption of light by the molecules of the medium and its re-radiation in different directions. Scattering of light is of two types

(i) ***Coherent scattering*** If the scattered light has the same wavelength as the incident light it is called coherent scattering. Example: Rayleigh's scattering.

(ii) ***Incoherent scattering*** If the scattered light has a wavelength different from that of the incident light, it is called incoherent scattering. Example: Raman scattering.

Rayleigh's scattering Rayleigh studied the scattering of light by air molecules. He found that the amount of scattering depends on the wavelength of the light and also the size of the particle which causes scattering.

Rayleigh's scattering law states that **the amount of scattering of light is inversely proportional to the fourth power of its wavelength.**

$$A \propto \frac{1}{\lambda^4}$$

Problem

Compare the amounts of scattering of a beam of violet light of wavelength 3800 Å and a beam of red light of wavelength 7600 Å when they pass through the same medium.

Amount of violet light scattered = A_1

Amount of red light scattered = A_2

Wavelength of violet light = λ_1

Wavelength of red light = λ_2

According to Rayleigh's scattering law,

$$\frac{A_1}{A_2} = \frac{1/\lambda_1^4}{1/\lambda_2^4}$$

$$= \frac{\lambda_2^4}{\lambda_1^4}$$

$$= \frac{(7600)^4}{(3800)^4} = 2^4 = 16$$

Scattering of violet light is 16 times that of red.

Colour of the sky

The sky appears blue due to scattering of sunlight by the air molecules in the atmosphere. According to Rayleigh's scattering law, light of shorter wave length scatters more. Blue light being of shorter wave length is scattered to a greater extent than red light. This causes the sky to appear blue.

At sunrise and sunset, rays of the sun have to travel a larger part of the atmosphere than at noon. Therefore, most of the blue light is scattered away and only the red light, which is least scattered reaches the observer. Hence, the sun appears reddish at sunrise and sunset.

Red having the longest wavelength of visible light is scattered the least. It can travel longer distances than other colours without appreciable loss of intensity due to scattering. It can be seen as a bright red light at a much longer distance than the other colours. This is why red is used to indicate danger and warning.

2.8 Raman effect

Sir C.V. Raman

A new type of molecular scattering entirely different from Rayleigh's scattering was discovered by Sir C.V. Raman in 1928. When an intense beam of monochromatic light is passed through a substance, the light is scattered and the scattered light contains other frequencies in addition to that of the incident light. This is known as Raman effect. For the above discovery Sir C.V. Raman was awarded Nobel Prize on 10th December 1930.

When the scattered radiation is examined by a spectroscope, a number of new lines are observed on both sides of the parent line corresponding to incident frequency. The new lines are called Raman lines. The lines having lesser frequencies than that of incident light are called Stokes lines.The lines having higher frequencies than that of incident light are called Antistokes lines.

The difference between the frequency of any Raman line and the frequency of the parent line is known as Raman shift. For a given scattering material, the Raman shifts are the same, whatever be the frequency of the incident light.

Raman shift is used to analyse the chemical composition of different substances and also to classify them according to their molecular structure.

Know it yourself

The colour of the sea The blue colour of the sea is partly due to reflection from the blue sky and partly by scattering of light by the water molecules. Near the shore the sea is green because of the sand in suspension which scatters blue and green light and also due to the reflection of yellow light from the sand.

Activity

1. Using the computer, try colour mixing. You will be surprised that you can produce upto 50,000 colours

2. Take three torch lights. Cover the glass of the first with red, the second with blue and the third with green cellophane paper. Flash the red and blue light at the same spot on a white screen. What colour do you observe on the overlapped region of the screen?

3. Similarly. observe the overlapped region due to blue and green light and then due to red and green light. Finally flash all the three colours on the same spot. What do you observe in each case?.

It is observed that,

Case 1	:	Red	+	Blue	$\rightarrow$	Magenta
Case 2	:	Blue	+	Green	$\rightarrow$	Cyan (peacock blue)
Case 3	:	Green	+	Red	$\rightarrow$	Yellow
Case 4	:	Red	+	Blue + Green	$\rightarrow$	White

Thus magenta, cyan and yellow are secondary colours.

Let us muse upon

- ☞ The theoretical prediction of electromagnetic waves was first made by James Clark Maxwell.
- ☞ Hertz was the first scientist to produce the electromagnetic waves experimentally.
- ☞ The velocity of electromagnetic waves is given by $c = \upsilon \lambda$
- ☞ The FM radio uses electromagnetic waves of frequency ranging from 88 MHz to 108 MHz.
- ☞ The AM radio uses electromagnetic waves of frequency ranging from 550 kHz to 1000 kHz.

- The splitting of white or any composite light into its constituent colours on passing through a prism is called dispersion.
- The angle between the incident ray and the emergent ray is called the angle of deviation.
- The angle of deviation of each colour depends on speed, refractive index of the prism and its wavelength.
- Violet is deviated the most and red the least.
- A spectrum in which there is overlapping of colours is called an impure spectrum.
- A spectrum in which there is no overlapping of colours is called a pure spectrum.
- Primary colours are those colours which cannot be obtained by mixing any other combination of colours.
- Secondary colours are those colours that are produced by mixing any two primary colours.
- Complementary colours are those two colours which when added together gives white.
- When an object reflects all the colours of white light, the object appears white.
- When an object absorbs all the colours of white light, the object appears black.
- Heating up of the earth's atmosphere due to infra-red radiation re-radiated from the earth's surface and absorbed by the greenhouse gases present in the atmosphere is called greenhouse effect.
- When light of suitable frequency is incident on a metal surface, electrons are ejected from the metal. This phenomenon is called photoelectric effect. The electrons ejected from the metal are called photo electrons.

- The minimum energy required to liberate an electron from the surface of the metal is called work function. It is equal to $h\upsilon_o$ where h is Planck's constant and υ_o is the minimum frequency of radiation. This frequency is known as threshold frequency.
- If scattered light has the same wavelength as the incident light, it is called coherent scattering or Rayleigh's scattering.
- If scattered light has a wavelength different from that of the incident light, it is called incoherent scattering.
- Rayleigh's scattering law states that the amount of scattering of light is inversely proportional to the fourth power of its wavelength.

Self evaluation

2.1. Electromagnetic waves were experimentally produced at first by

(a) Maxwell (b) Hertz (c) Planck (c) Faraday

2.2. The property which is common to X-rays, gamma rays, IR rays, UV rays and visible light is that,

(a) they all have similar wavelengths. (b) they are all damaging to health.

(c) they all travel with the same velocity in vacuum.

(d) they are all affected by electric and magnetic fields.

2.3. A VHF radio station broadcasts at a frequency of 90 MHz. The wave length of the wave broadcast by the station is,

(a) 0.30 m (b) 3.3 m (c) 27×10^{15}m (d) 12×10^{14}m

2.4. A copper plate is heated to 100^0C. It cools by emitting

(a) α rays (b) IR rays (c) UV rays (d) Gamma rays

2.5 1 $\mathring{A}$ is equal to

(a) 10^{-7}m (b) 10^{-9}m (c) 10^{-10}m (d) 10^{-12}m

2.6 The wavelength 5×10^{-7}m corresponds to

(a) IR spectrum (b) X rays spectrum

(c) visible spectrum (d) UV spectrum

2.7. The wave length range of visible spectrum is

(a) 3.8×10^{-7}m to 7.8×10^{-7}m (b) 7.8×10^{-7}m to 3.8×10^{-5}m

(c) 6×10^{-10}m to 4×10^{-7}m (d) 1×10^{-10}m to 3×10^{-8}m

2.8. Which of the following is correct ?

(a) red + green $\rightarrow$ cyan (b) red + blue $\rightarrow$ magenta

(c) green + blue $\rightarrow$ white (d) red + blue $\rightarrow$ green

2.9. The ratio of the wavelength of two colours is 2:3. The ratio of the amount of these colours scattered by air molecules is

(a) 2:3 (b) 3:2 (c) $2^4 : 3^4$ (d) $3^4 : 2^4$

2.10. Blue of the sky is due to

a) dispersion of light (b) refraction of light

(c) deviation of light (d) scattering of light

2.11. The particles emitted during photoelectric emission are

(a) α particles (b) electrons

(c) protons (d) neutrons

2.12. The number of photoelectrons emitted during photoelectric emission depends on the

(a) frequency of the incident light (b) intensity of the incident light

(c) potential difference between cathode and anode

(d) all the above

2.13. The maximum kinetic energy of photoelectrons depends on

(a) frequency of light (b) intensity of light

(c) applied voltage (d) all the above

2.14. Which colour deviates the most on passing through a prism?

(a) Red (b) Blue (c) Green (d) Orange

2.15. The complementary colour of yellow light is

(a) red (b) blue (c) green (d) orange

2.16. What is an electromagnetic wave?

2.17. Mention any two properties of electromagnetic waves.

2.18. Give the uses of microwaves.

2.19. How are radio waves produced? Mention their applications.

2.20. What is dispersion?

2.21. Define angle of deviation. On what factors does it depend?

2.22. What is a pure spectrum? Mention the conditions for obtaining it.

2.23. Explain with a neat diagram, how a pure spectrum is produced.

2.24. What are primary colours?

2.25. What are secondary colours? Give examples.

2.26. What are complementary colours? Give examples.

2.27. Explain the two methods of colour mixing.

2.28. What are primary colours in pigments?

2.29. What are the properties of IR rays?

2.30. What is green house effect?

2.31. Mention the properties of UV rays.

2.32. Give the uses of UV rays.

2.33. What is the cause for the depletion of the ozone layer? How does it affect mankind?

2.34. Define photoelectric effect.

2.35. Describe an experiment to study photoelectric emission.

2.36. Derive Einstein's photoelectric equation.

2.37. State the laws of photoelectric emission.

2.38. On what factors does the photoelectric current depend?

2.39. Define work function.

2.40. Derive an expression for de–Broglie wave length.

2.41. State Rayleigh's scattering law.

2.42. Why does the sky appear blue?

2.43. The sun appears reddish during sun set or sun rise. Why?

2.44. Write a short note on Raman effect.

2.45. Signals warning danger use red light. Give reason.

2.46. Calculate the momentum of a particle associated with a wave of wavelength 2 Å.

2.47. The work function of a photosensitive material is 26.5 x 10^{-17} joule. Calculate the threshold frequency.

2.48. What is the energy of a photon of frequency 7.5 x 10^{14} Hz ?

2.49. Calculate the wavelength associated with a particle of mass 5 x 10^{-24} kg moving with a velocity 2 x 10^{7} ms^{-1}.

2.50. When a mass of one gram is completely converted into energy how much energy is released?

Answers

2.1. (b)	**2.2.** (c)	**2.3.** (b)	**2.4.** (b)	**2.5.** (c)
2.6. (c)	**2.7.** (a)	**2.8.**(b)	**2.9.**(d)	**2.10.**(d)
2.11. (b)	**2.12.** (b)	**2.13.** (a)	**2.14.**(b)	**2.15.** (b)

2.46. 3.313 x 10^{-24} kg ms^{-1} **2.47.** 4 x 10^{17} Hz

2.48. 4.969 x 10^{-19}J **2.49.** 6.625 x 10^{-18} m

2.50. 9 x 10^{13} Joule

3. ELECTRICITY

In 1820, the Danish scientist Hans Christian Oersted discovered that a current carrying conductor has a magnetic field associated with it and established the magnetic effect of electric current. This discovery provided the first link between electricity and magnetism. In 1821, the French scientist Ampere showed that a current carrying conductor placed in a magnetic field experiences a mechanical force. This is called mechanical effect of electric current.

3.1 Mechanical effect of current

The mechanical effect of an electric current can be demonstrated by the following experiment.

A light metal roller CD is placed on two metallic rails. This is placed between the poles of a strong magnet which is kept along the magnetic meridian

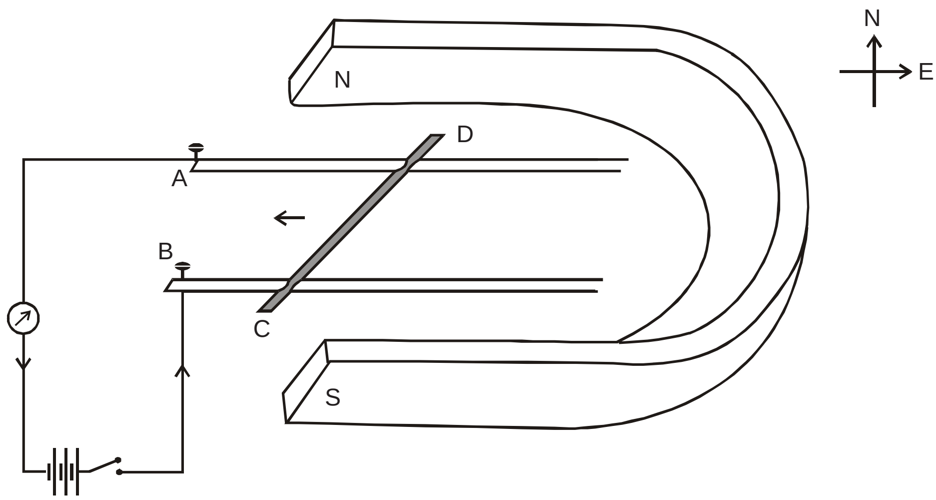


Fig. 3.1. Mechanical effect of electric current

as shown in fig. 3.1. The ends of the metallic rails are connected to a battery, tap key and an ammeter in series. When the key is pressed the current flows along BCDA and the roller moves towards the West. When the direction of flow of current is reversed, the roller moves towards the East.

The following inferences are made from this experiment.

(i) The current carrying conductor placed in a magnetic field experiences a mechanical force.

(ii) The direction of the force is perpendicular to the direction of both the magnetic field and the current flowing through the conductor.

Fleming's left hand rule (Motor rule)

Since this rule is applied in the electric motor, it is also called **the motor rule**. Fleming's left hand rule is used to find the direction of the mechanical force on a current carrying conductor placed in a magnetic field.

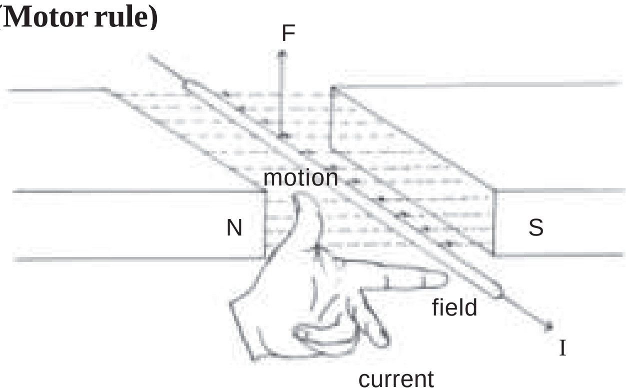


Fig. 3.2. Fleming's left hand rule

Stretch the first three fingers of the left hand mutually at right angles to each other. If the forefinger represents the direction of the magnetic field and the middle finger represents the direction of the current, then the thumb represents the direction of the force.

Magnitude of the mechanical force

The magnitude of the mechanical force 'F' acting on a current carrying conductor held perpendicular to the direction of the magnetic field is proportional to the current 'I' and the length 'ℓ' of the conductor.

i.e. $F \propto I$

$F \propto \ell$

$\therefore$ $F \propto I\ell$

$$\mathbf{F = B I \ell}$$

where B is the magnetic field or magnetic induction.

The force is maximum when the conductor is perpendicular to the field and is zero when it is parallel to the field.

Problem

A straight wire of length 0.2 m stretched horizontally carries an electric current of 10 A from East to West in a magnetic field of induction 10^{-3} tesla, directed vertically downwards. Find the magnitude and direction of the force.

$$\ell = 0.2\ \text{m}$$

$$I = 10\ \text{A}$$

$$B = 10^{-3}\ \text{T}$$

$$F = B I \ell$$

$$= 10^{-3} \times 10 \times 0.2\ \text{N}$$

$$\text{force } F = 2 \times 10^{-3}\ \text{N}$$ and it acts towards the South.

3.2 Loudspeaker

Loudspeaker converts electrical energy into sound energy. It works on the principle that a current carrying conductor placed in a magnetic field experiences a force.

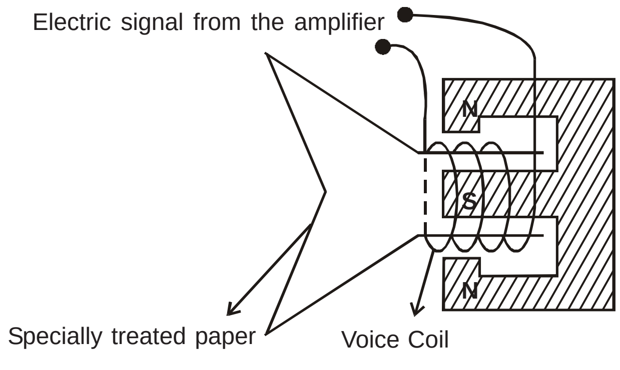


Fig. 3.3 Loudspeaker

The loudspeaker consists of a specially shaped permanent magnet. A thin cylindrical insulated voice coil is placed such that it is free to move in the radial field of the magnet as shown in Fig. 3.3. The coil is attached to a specially treated paper in the form of cone.

The amplified electric signals are passed through the voice coil. The coil experiences a force which makes it move to and fro. The motion of the coil causes the cone to vibrate, thus causing the surrounding air molecules to vibrate. Due to this vibration, sound is reproduced with the original frequency.

3.3 Galvanometer

Galvanometer is an instrument for detecting the current flowing in an electric circuit. It is based on the principle that a current carrying conductor placed in a magnetic field experiences a force. There are two types of galvanometer.

1. Moving coil galvanometer.
2. Moving magnet galvanometer.

Moving coil galvanometer is further classified into suspended coil galvanometer and pivoted coil galvanometer.

3.3.1 Pivoted moving coil galvanometer

The essential parts of the pivoted type moving coil galvanometer are

(i) a powerful horse-shoe magnet
(ii) insulated rectangular coil
(iii) cylindrical soft - iron core
(iv) springs and
(v) pointer and scale

It consists of a rectangular coil ABCD of a large number of turns of insulated copper wire wound on a frame of a non-magnetic material like aluminium. A soft-iron cylinder is placed inside the coil. This coil is pivoted between two bearings X and Y and placed between two concave poles N and S of a permanent horse-shoe magnet. The coil is free to rotate in the cylindrical gap between the poles of the magnet. There are two phosphor-bronze hair springs S_1 and S_2 to provide a restoring couple.

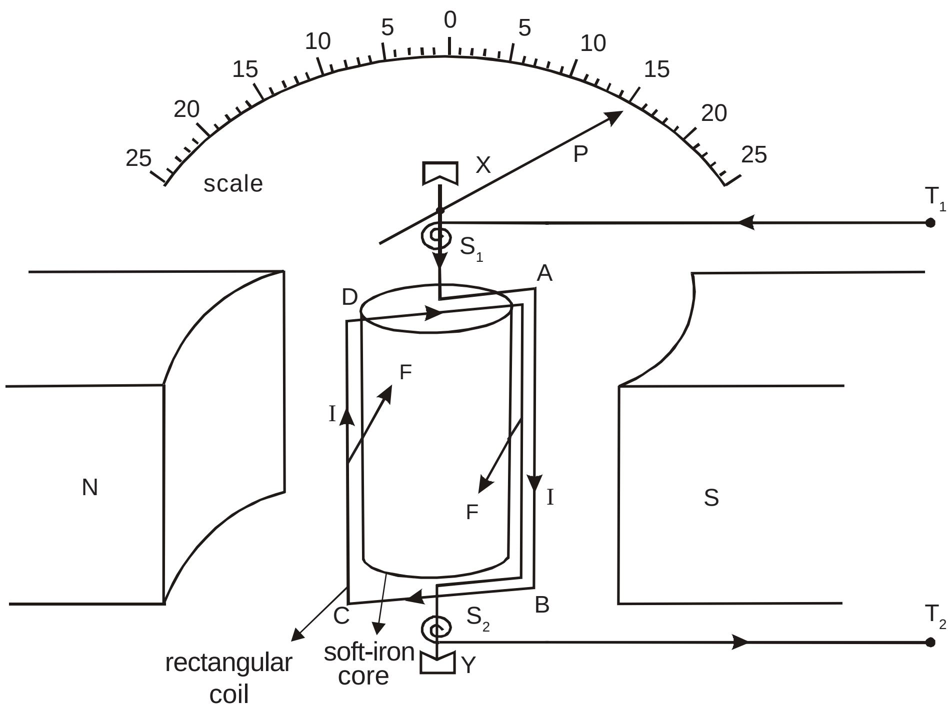


Fig. 3.4. Moving coil galvonometer

A pointer P is attached to the coil and can move on a calibrated scale. The current to be detected is passed through terminals T_1 and T_2 and it flows through the coil.

When the current passes through the coil, the vertical sides AB and CD experience equal and opposite force, according to Fleming's left hand rule. These forces constitute a deflecting couple. This deflecting couple rotates the coil until it is balanced by the restoring couple provided by the springs S_1 and S_2. The deflection of the coil is indicated by the pointer on the graduated scale. This deflection is proportional to the current.

The galvanometer is converted into an ammeter by connecting a low resistance in parallel with it. This low resistance is called as shunt. The galvanometer is converted into a voltmeter by connecting a high resistance in series with it.

3.4 Electric motor

An electric motor is a device which converts electrical energy into mechanical energy. The principle of the electric motor is based on the mechanical effect of current, i.e, a current carrying conductor placed in a magnetic field experiences a mechanical force.

D C Motor

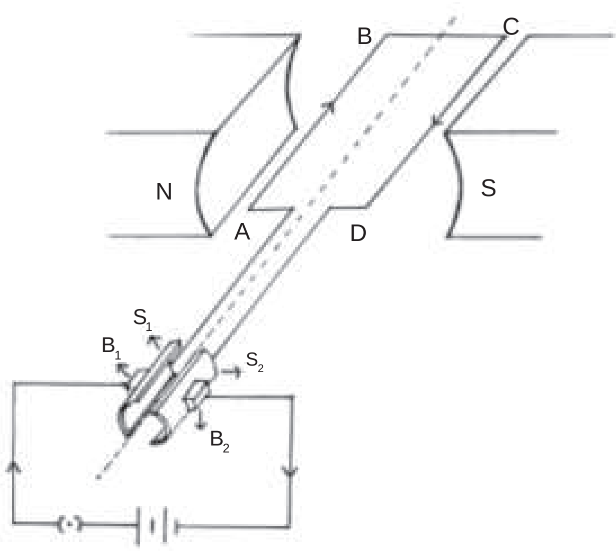


Fig. 3.5. D C motor

The essential parts of a D C motor are

(i) Field magnet The field magnet is a powerful magnet.

(ii) Armature The armature ABCD is a rectangular coil of wire wound on a soft-iron core and placed between the poles of the magnet. It is capable of rotating about its axis.

(iii) Split rings (Commutator) The split rings also known as commutator is made of copper. The ends of the coil are connected to the split rings S_1 and S_2 which are capable of rotating with the coil.

(iv) Carbon brushes Two carbon brushes B_1 and B_2 are in contact with the split rings. They are connected to the battery.

When the circuit is closed, current flows in the arms AB and CD of the coil in opposite direction. According to Fleming's left hand rule AB experiences a downward force and CD experiences an upward force, equal in magnitude and opposite in direction. These two forces constitute a couple which rotates the coil in the anticlockwise direction till S_1 and S_2 come in contact with B_2 and B_1 respectively. Now the direction of the current and hence the direction of force on AB and CD is reversed. AB experiences an upward force and CD a downward force. Again the couple rotates the coil in the anticlockwise direction. Thus the coil continues to rotate in the anticlockwise direction as long as the current flows in it.

The power of a D C motor can be increased by,

(i) increasing the number of turns in the coil.

(ii) increasing the strength of current and

(iii) increasing the strength of the magnetic field.

3.5 Magnetic flux and magnetic induction

Magnetic flux

The total number of magnetic lines of force crossing a given area is known as the magnetic flux. It is denoted by ϕ.

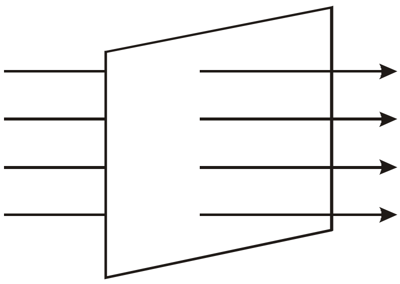


Fig. 3.6. Magnetic flux

Magnetic field in a region is characterised by magnetic lines of force.

The SI unit of magnetic flux is weber (Wb). It is a scalar quantity.

Magnetic induction

The total number of magnetic lines of force crossing per unit area held normal to the surface is called magnetic induction. It is denoted by B

$$\text{(i.e.)}\ B = \frac{\phi}{A}$$

The SI unit of magnetic induction is tesla (T). It is a vector quantity.

1 tesla = 1 Wb m^{-2}

Problem

Calculate the magnetic flux linked with a coil of area 0.5 cm^2 placed at right angle to a magnetic field of induction 0.1 tesla.

$$A = 0.5\ \text{cm}^2$$
$$= 0.5 \times 10^{-4}\ \text{m}^2$$
$$B = 0.1\ \text{tesla}$$
$$\text{Magnetic flux } \phi = B\,A$$
$$= 0.1 \times 0.5 \times 10^{-4}\ \text{Wb}$$
$$\text{Magnetic flux } \phi = \mathbf{5 \times 10^{-6}\ weber}$$

3.6 Electromagnetic induction

After the discovery of the magnetic effect of current in 1831, Michael Faraday succeeded in proving the reverse effect. He produced induced emf by the effect of a varying magnetic field.

Faraday's experiments

A coil is connected to a sensitive galvanometer. There is a deflection in the galvanometer when a magnet is moved towards the coil. When the magnet is moved away from the coil, the deflection is in the opposite direction.

The same effect is observed when the magnet is kept stationary and the coil is moved towards or away from the magnet. The current obtained due to the relative motion between the coil and the magnet is called **induced current** and the corresponding emf (electromotive force) is known as **induced emf.**

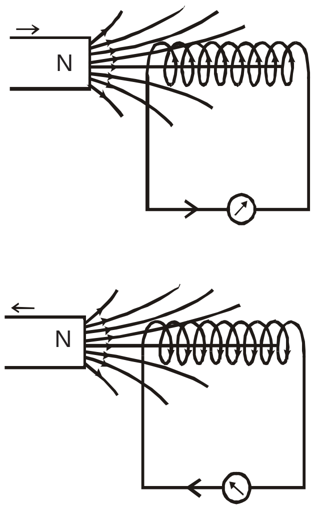


Fig. 3.7.

When the magnetic flux linked with a coil changes, an emf is induced in it. This phenomenon is called electromagnetic induction.

The induced emf depends on the

(i) number of turns of the coil.

(ii) magnetic induction and

(iii) relative speed between the magnet and the coil.

3.7 Laws of electromagnetic induction

Faraday's Laws

1. Whenever there is a change in the magnetic flux linked with a coil an emf is induced in it.

2. The magnitude of the induced emf is equal to the rate of change of flux linked with the coil.

If the flux changes from ϕ_1 to ϕ_2 in time interval t, then

$$\text{induced emf } e = \left(\frac{\phi_2 - \phi_1}{t}\right)$$

Lenz's law

Lenz's law states that the induced current flows in such a direction that it opposes the change or cause that produces it.

$$e = -\left(\frac{\phi_2 - \phi_1}{t}\right)$$

If there are N turns in the coil, then the induced emf

$$e = -N\left(\frac{\phi_2 - \phi_1}{t}\right)$$

Lenz's law - In accordance with the law of conservation of energy.

As the magnet is brought towards the coil, the number of magnetic lines of force linked with the coil changes producing an induced emf. According to Lenz's law the direction of the induced emf is to oppose the motion of the magnet. Hence work has to be done against it to move the magnet further.

This work is converted into electrical energy. On the contrary, if the direction of the induced emf were to help the motion of the magnet, the magnet will begin to move faster producing electrical energy. i.e. electrical energy is produced without any external work being done, which is impossible according to the law of conservation of energy. Therefore the induced current acts in a direction to oppose the motion of the magnet.

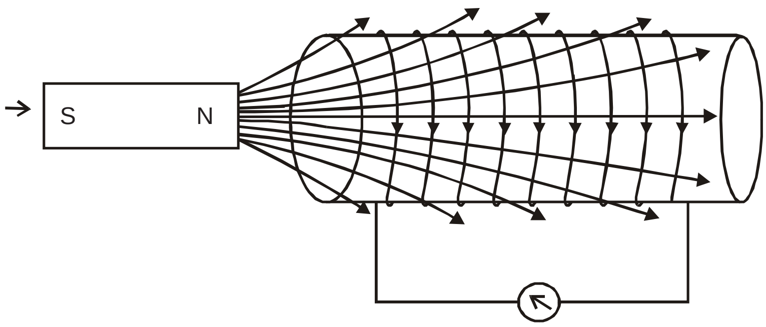


Fig 3.8.

Problem

Find the emf induced in a coil of 100 turns, if the flux linked with the coil changes from 0.5 Wb to 1 Wb in 0.02 s

$\phi_1 = 0.5$ Wb, $\phi_2 = 1$ Wb, $t = 0.02$ s $N = 100$ turns

$$e = -N\left(\frac{\phi_2 - \phi_1}{t}\right)$$

$$e = -100\left(\frac{1 - 0.5}{0.02}\right)$$

$$= -\frac{100 \times 0.5}{0.02}$$

$$e = -2.5 \times 10^3 \text{ V}$$

Here, negative sign signifies Lenz's law

3.8 Fleming's right hand rule

Stretch the first three fingers of the right hand mutually at right angles to each other. **If the forefinger represents the direction of the magnetic field and the thumb represents the direction of the motion of the conductor, then the middle finger represents the direction of the induced current.** This rule is also known as the **generator rule**.

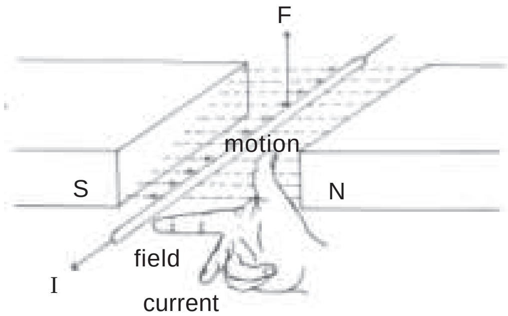


Fig. 3.9. Fleming's right hand rule

3.9 Applications of electromagnetic induction

3.9.1 Microphone

The microphone works on the principle of electromagnetic induction. It converts sound wave into electrical signals which vary in amplitude and frequency in accordance with the sound wave.

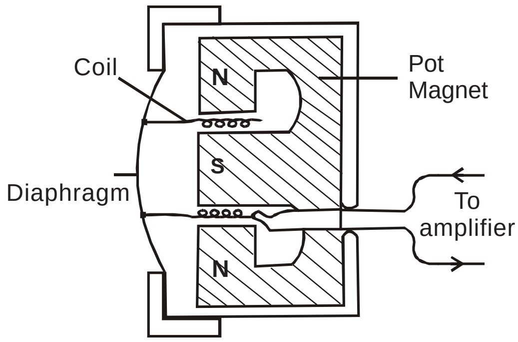


Fig. 3.10. The Microphone

The microphone has a diaphragm with a thin coil of wire attached to it as shown in Fig. 3.10. The coil is placed in a strong radial field of a cylindrical pot magnet. Sound waves cause the diaphragm and the coil to vibrate. As the coil vibrates in the magnetic field, a varying emf is induced in it. This emf is amplified and then connected to the loudspeaker. Thus sound variations are converted into electrical variations with the help of a microphone.

3.9.2 Generator

A generator is a device used to convert mechanical energy into electrical energy. There are two types of generator - A C generator and D C generator.

A C generator

The A C generator works on the principle of electromagnetic induction. The essential parts of A C generator are

(i) **Field magnet** It is a powerful horse-shoe magnet.

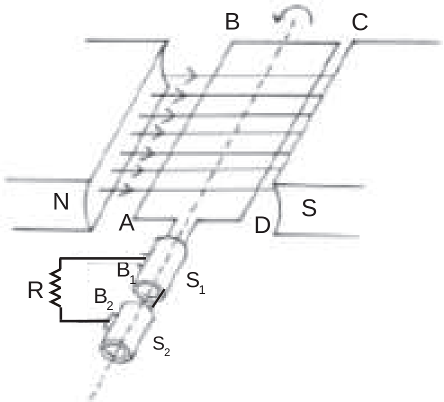


Fig. 3.11. A C generator

(ii) **Armature** It is a rectangular coil ABCD of many turns wound on a soft-iron core. It is placed between the poles of the powerful magnet. The armature is capable of being rotated about its axis perpendicular to the magnetic field.

(iii) **Slip rings** The ends of the coil are connected to two hollow metallic cylinders called slip rings S_1 and S_2.

(iv) **Carbon brushes** B_1 and B_2 are two carbon brushes which are always in contact with the slip rings.

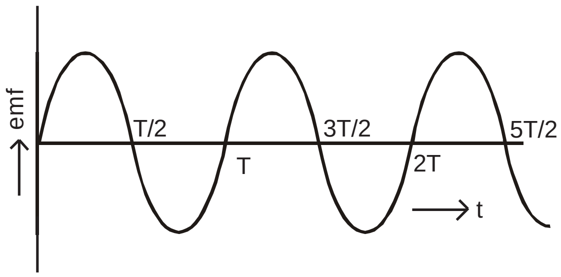


Fig. 3.12. Alternating emf

When the coil is rotated about an axis perpendicular to the direction of the magnetic field, there is a continuous change in the magnetic flux linked with it.

An emf is induced in the armature. The emf varies from zero to maximum and then from maximum to zero for every half rotation of the coil. During the second half rotation the direction of the induced emf is reversed as shown in Fig. 3.12.

The cycle is repeated as long as the armature is rotated. The direction of the induced emf at any instant is given by Fleming's right hand rule.

3.9.3 D C generator

The D C generator converts mechanical energy into electrical energy. It works on the principle of electromagnetic induction. It is used to deliver a unidirectional current.

The essential parts of the D C generator are

(i) **Field magnet** It is a powerful horse-shoe magnet.

(ii) **Armature** It is a rectangular coil ABCD of many turns wound on a soft-iron core. It is placed between the poles of the horse-shoe magnet and is capable of being rotated about an axis perpendicular to the magnetic field.

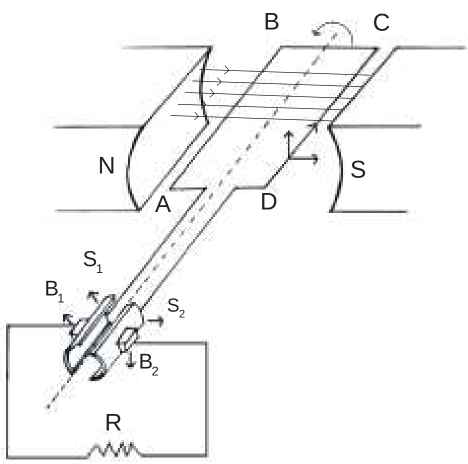


Fig. 3.13. D C generator

(iii) **Split ring or commutator** The two ends of the coil are connected to the split rings S_1 and S_2. They are used to reverse the current.

(iv) **Carbon brushes** Carbon brushes B_1 and B_2 make contact with the split rings S_1 and S_2. The induced current passes to the external circuit through B_1 and B_2.

During the first half rotation of the armature, the induced current increases to a maximum from zero and then decreases to zero. If the armature is rotated in the anti-clockwise direction, B_2 becomes negative and B_1 positive. During the second half rotation, the split rings change their contact with the brushes. Though the current in the coil is reversed B_2 remains negative and B_1 positive. As a result, unidirectional current flows in the external circuit as shown in Fig. 3.14.

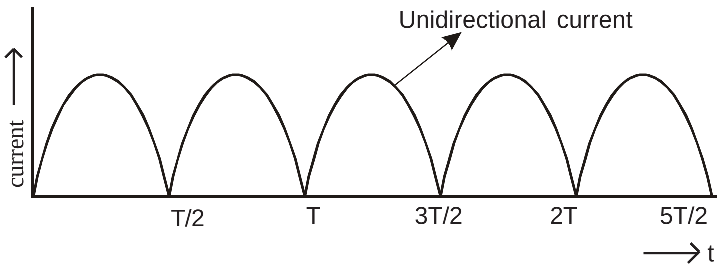


Fig. 3.14. Unidirectional current

The emf obtained from an A C or D C generator can be increased by

(i) increasing the number of turns of the coil.
(ii) using a soft iron core.
(iii) increasing the speed of rotation and
(iv) using a strong field magnet.

Comparison of A C and D C

Alternating current changes its direction periodically and it can be transmitted over a long distance at a low cost, while direct current is unidirectional and transmitting it over a long distance is difficult and expensive.

3.9.4 Transformer

A transformer is an electric device used to transfer electrical energy from one circuit to another. It is used to step up or step down AC voltage. It works on the principle of electromagnetic induction.

The transformer consists of insulated copper coils wound on either side of a laminated soft-iron core as shown in Fig.3.15.

The input A C voltage is applied to the primary coil P and the output is drawn from the secondary coil S.

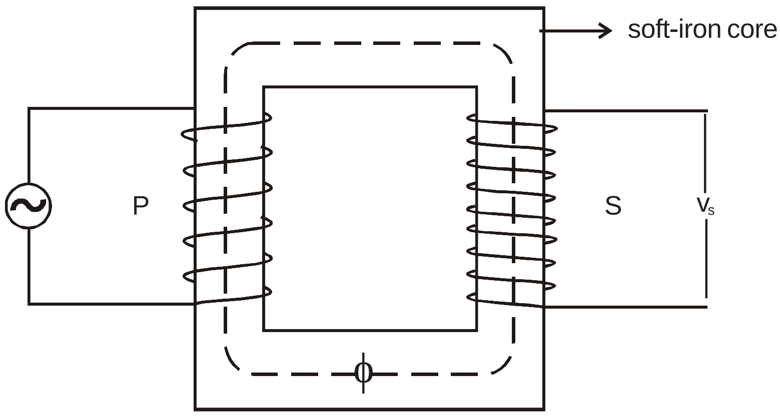


Fig. 3.15 Transformer

The alternating current in the primary coil produces a varying magnetic flux. This magnetic flux links not only the primary coil but also the secondary coil. According to the phenomenon of electromagnetic induction the varying magnetic flux sets up an induced emf in the secondary coil.

N_p and N_s are the number of turns, V_p and V_s are the voltages and I_p and I_s are the current in the primary and secondary coils respectively.

Since the same change of flux is linked with the primary and the secondary coil, the induced emf in each turn of the primary and secondary coils is the same.

(i.e.) $$\frac{V_p}{N_p} = \frac{V_s}{N_s}$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \qquad \ldots\ldots\ldots (1)$$

In an ideal transformer, input power is equal to output power.

input voltage $\times$ input current = output voltage $\times$ output current.

$$V_P \times I_P = V_S \times I_S$$

$$\frac{V_s}{V_p} = \frac{I_p}{I_s} \qquad \ldots\ldots\ldots (2)$$

From (1) and (2) $$\frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p} = K$$

where K is called turns ratio or transformer ratio.

If $K > 1$, it is a step up transformer. In this case, the voltage is increased and the current is decreased.

If $K < 1$, it is a step down transformer. In this case the voltage is decreased and the current is increased.

3.10 Electric power transmission - Role of transformers

Electricity is generated at thermal, hydro and nuclear power stations, which are situated far from the towns. It has to be transmitted and distributed to the consumers.

The electric power from the generating station is transmitted to the various consumer points using transmission lines. As current flows through the transmission lines, it heats up the conductor and electric energy is dissipated in the form of heat equal to $I^2 R t$.

In order to minimise this power loss, the electric power should be transmitted at high voltage and low current. Hence, the voltage is stepped up at the generating station using a step-up transformer.

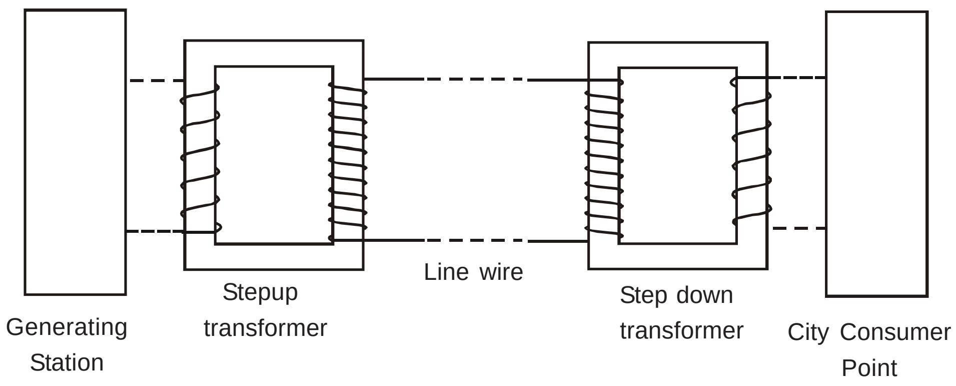


Fig. 3.16. Electric power transmission

The stepped up voltage cannot be supplied to consumers, as all the electric appliances are designed to operate at a lower voltage of 220 V for domestic appliances and 440 V for industries. Using step - down transformer the voltage is stepped down, with the corresponding increase in current and power is delivered to the consumer at the required voltage.

Problem

1. In a step-up transformer the number of turns in the primary and secondary are in the ratio of 1000 and 2000 respectively. If the primary current is 10 A, calculate the secondary current.

$$N_p = 1000$$

$$N_s = 2000$$

$$I_p = 10 \text{ A}$$

$$\frac{N_s}{N_p} = \frac{I_p}{I_s}$$

$$\frac{2000}{1000} = \frac{10}{I_s}$$

$$I_s = \frac{10 \text{ x } 1000}{2000}$$

$$= \frac{10}{2}$$

secondary current I_s = 5 A

2. A transformer in a distribution station reduces AC voltage from 36,000 V to 2400 V. The primary coil has 15000 turns. What is the number of turns in the secondary?

input Voltage V_p = 36000 V

output Voltage V_s = 2400 V

number of turns in the primary N_p = 15000

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$\frac{2400}{36000} = \frac{N_s}{15000}$$

$$N_s = \frac{15000 \times 2400}{36000}$$

number of turns in the secondary $\mathbf{N_s}$ **= 1000**

3. The primary current in an ideal transformer is 5 A. When the primary voltage is 90 V. Calculate the voltage across the secondary when a current of 0.9 A is drawn from it.

$$\text{primary current, } I_p = 5 \text{ A}$$

$$\text{primary Voltage, } V_p = 90 \text{ V}$$

$$\text{secondary current, } I_s = 0.9 \text{ A}$$

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

$$V_s = \frac{5}{0.9} \times 90$$

$$\text{secondary voltage } \mathbf{V_s} = \mathbf{500\ V}$$

4. A transformer in a radio changes the 240 V AC mains voltage to 12 V. What is the turns ratio?

$$\text{turns ratio} \quad \frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{12}{240} = 0.05$$

3.11 Electric power

The rate at which electrical energy is consumed in an electric circuit is known as electric power.

The voltage rating and the power rating are specified on every electrical appliance. e.g. An electric bulb is marked as 240 V, 60 W.

The SI unit of electric power is **watt (W). The power is said to be one watt if one joule of energy is consumed by an electrical appliance in one second.**

The other units of power in common use are megawatt (MW) and horse power (H P) where

$$1 \text{ MW} = 10^6 \text{ W}$$

$$1 \text{ HP} = 746 \text{ W}$$

The commercial unit of electric energy is kilowatt hour(kWh). It is also referred to as a unit.

Kilowatt hour is defined as the electrical energy consumed by an electric circuit at the rate of one kilowatt in one hour.

$$\text{Energy} = \text{Power} \times \text{time}$$

$$1 \text{ kilowatt hour} = 1 \text{ kilowatt} \times 1 \text{ hour}$$

$$= 1000 \times 60 \times 60 \text{ J}$$

$$\mathbf{1\ kWh = 3.6 \times 10^6\ J}$$

Problem

1. What is the cost of using a 100 W lamp for 6 hours, at the rate of Rs. 2/- per unit.

$$\text{energy consumed} = \text{Power} \times \text{time}$$

$$= 100 \text{ W} \times 6 \text{ hour}$$

$$= \frac{100}{1000} \text{ kW} \times 6 \text{ hour}$$

$$= 0.6 \text{ kWh or unit}$$

$$\text{cost per unit} = \text{Rs.}2/-$$

$$\therefore \text{ total cost} = \text{Rs. } 0.6 \times 2$$

$$= \textbf{Rs. 1.20}$$

2. Calculate the cost of energy consumed for the period from May 1 to June 30 at the rate of Rs.2/- per unit, from the data given below.

Appliances	Number	duration /day (hour)
60 W lamp	6	4
100 W lamp	4	3
750 W electric iron	1	2
1000 W water heater	1	2
60 W fan	2	10

total energy consumed per day

$$= (6 \times 60 \times 4) + (4 \times 100 \times 3) + (1 \times 750 \times 2) + (1 \times 1000 \times 2) + (2 \times 60 \times 10)$$

$$= 1440 + 1200 + 1500 + 2000 + 1200$$

$$= 7340 \text{ Wh}$$

$$= 7.34 \text{ kWh}$$

total number of days $= 31 + 30 = 61$

total energy consumed $= 61 \times 7.34$ unit

$= 447.74$ unit

cost per unit = Rs.2/-

$\therefore$ total cost = Rs. 447.74×2

= **Rs. 895.48**

Activity

1. Fill in the blank boxes below

Appliance	Power (W)	Power (kW)	Duration of use (hr).	Energy consumed (kWh)
Electric kettle	3000		$\frac{1}{2}$	
Tube light	50		10	
Vacuum cleaner	500		$\frac{3}{4}$	
Washing machine			6	3
Electric iron	750		$1\frac{1}{2}$	
Immersion heater	1200		2	

2. Draw a block diagram to indicate the electric connection from the pole outside your house to the lamp on your study table.

3. Find the importance of earthing and neutral wire for electrical connections.

4. Draw a block diagram to indicate the public address system for the transmission of sound in your school.

Let us muse upon

- Hans Christian Oersted discovered the magnetic effect of electric current.
- Fleming's left hand rule is used to find the direction of the mechanical force on a current carrying conductor placed in a magnetic field.
- The force on a current carrying conductor is maximum when it is held perpendicular to the magnetic field and zero when it is parallel to the field.
- Loud speaker converts electrical energy into sound energy.
- Loudspeaker works on the principle of mechanical effect of current.
- The galvanometer is an instrument used for detecting current flowing in an electric circuit.
- The galvanometer is converted into an ammeter by connecting a low resistance in parallel with it.
- The galvanometer is converted into a voltmeter by connecting a high resistance in series with it.
- Electric motor is a device which converts electrical energy into mechanical energy.
- The total number of magnetic lines of force crossing a given area is known as the magnetic flux.
- The total number of magnetic lines of force crossing unit area held normal to the magnetic lines is called magnetic induction.
- Michael Faraday discovered the phenomenon of electromagnetic induction
- When the magnetic flux linked with a coil changes, an emf is induced in it. This phenomenon is called electromagnetic induction.

- ☞ The magnitude of the induced emf is equal to the rate of change of flux linked with the coil.
- ☞ The induced current flows in such a direction that it opposes the change or cause that produces it.
- ☞ The direction of induced emf at any instant is given by Fleming's right hand rule.
- ☞ Microphone converts sound energy into electrical energy.
- ☞ Generator is a device used to convert mechanical energy into electrical energy
- ☞ Transformer is an electric device used to transfer electrical energy from one circuit to another.
- ☞ In an ideal transformer, input power is equal to output power.
- ☞ The ratio of number of turns in secondary coil to the number of turns in the primary coil is called turns ratio.
- ☞ The rate at which electrical energy is consumed in an electric circuit is known as electric power.
- ☞ The power is said to be one watt if one joule of energy is consumed by an electrical appliance in one second.

Self evaluation

3.1. Electrical energy is converted into mechanical energy in a

(a) dynamo (b) transformer (c) motor (d) microphone

3.2. A galvanometer is converted into an ammeter by connecting

(a) a low resistance in series. (b) a low resistance in parallel

(c) a high resistance in series (d) a high resistance in parallel

3.3. The output and input voltages in a transformer are 25V and 5V respectively. The transformer ratio is

(a) 30 (b) 125 (c) 5 (d) 1/5

3.4. A transformer is used to convert 240V into 12V . If there are 2000 turns in the primary coil, the number of turns in the secondary coil is,

(a) 100 (b) 120 (c) 200 (d) 24000

3.5. Which of the following is based on electromagnetic induction ?

(a) transformer (b) galvanometer

(c) loudspeaker (d) motor

3.6. The working of the galvanometer is based on

(a) magnetic effect of electric current

(b) mechanical effect of electric current

(c) electromagnetic induction

(d) heating effect of electric current

3.7. The direction of induced current is given by

(a) Lenz's law (b) Faraday's law

(c) Fleming's left hand rule (d) None of the above

3.8. Explain the function of a loudspeaker with a neat diagram.

3.9. State Faraday's laws of electromagnetic induction.

3.10. Draw the diagram of a galvanometer and explain its construction and working

3.11. Explain the construction and working of a transformer.

3.12. Explain the role of transformers in the transmission of power.

3.13. State Lenz's law and explain how it is in accordance with the law of conservation of energy.

3.14. Describe an experiment to show the mechanical effect of current.

3.15. State Fleming's left hand rule.

3.16. On what factors does the magnitude of the force on a current carrying conductor in a magnetic field depend?

3.17. Name the two types of galvanometer.

3.18. How will you convert a galvanometer into an ammeter?

3.19. How will you convert a galvanometer into a voltmeter?

3.20. Describe the construction and working of an electric motor.

3.21. Define magnetic flux. Give its unit.

3.22. Define magnetic induction. Give its unit.

3.23. Explain Faraday's experiment on electromagnetic induction.

3.24. State Fleming's right hand rule.

3.25. Write a short note on microphone.

3.26. What are the essential parts of an AC generator?

3.27. Describe the construction and working of an AC generator.

3.28. Write a short note on DC generator.

3.29. Distinguish between alternating current and direct current.

3.30. Define turns ratio.

3.31. Define electric power.

3.32. Define one kilowatt hour

3.33. 100kW of power is being supplied to a factory through wires of resistance 0.1Ω. Calculate the power loss in the wires if the power is transmitted at (a) 230V (b) 10000V.

3.34. Find the number of turns in the secondary coil of a transformer having 3000 turns in the primary coil. It operates from a 240V A C supply to give an output of 8V for a door bell.

3.35. An immersion heater works on 230 V and draws 4 A of current. If the cost of 1kWh is Rs.2/- find the cost of running it for 15 minutes every day for 30 days.

3.36. In a house two electric lamps each and of 40 W is used for 6 hours, three fans of 60W each is used for 7 hours and an electric oven of 800 W is used for 2 hours per day. Calculate the cost of energy consumed for 30 days if the rate per unit is Rs. 2.

3.37. A conductor of length 25 cm is placed perpendicular to a magnetic field of induction 0.5 x 10^{-3} tesla. Calculate the force on the conductor, if a current of 1.5 A flows through the conductor.

3.38. The magnetic flux linked with a coil changes from 0.3 Wb to zero in 1.2 second. Calculate the induced emf.

Answers

3.1. (c)	**3.2.** (b)	**3.3.** (c)	**3.4.** (a)
3.5. (a)	**3.6.** (b)	**3.7.** (a)	
3.33.(18.9 kw, 10 w)	**3.34.** (100)		
3.35.(Rs. 13.80)	**3.36.** (Rs. 200.40)		
3.37. (1.87 x 10^{-4} N)	**3.38.** (0.25 V)		

4. PROPERTIES OF MATTER

Matter is made up of molecules and atoms. It exists in three states namely solid, liquid and gas. The three states of matter can be explained on the basis of interatomic or intermolecular forces. The force of attraction between any two molecules is called intermolecular force. The three states of matter differ from each other because of the difference in the magnitude of the intermolecular forces. The interatomic force is so strong in solids that its atom cannot move freely. That is why, the solid has a definite shape and size. In the case of liquids, the intermolecular force is relatively small and hence the molecules are free to move inside the whole volume of the liquid. The liquid has a definite volume, but no definite shape. Intermolecular force is very weak in gases and hence, the molecules of a gas may be considered as free particles. They keep on colliding against each other and move in a random manner. A gas has neither a definite shape nor a definite volume.

4.1 Solids

At ordinary temperature, solids possess a definite shape and volume. The properties of the solid depend on the arrangement of atoms in it. Based on their internal structure, solids are classified into two types – crystalline and amorphous.

4.1.1 Crystalline solid

In crystalline solids, the atoms are arranged in a regular, repeated and periodic pattern. This orderly arrangement of atoms resembles that of brick laying by masons. Examples of crystalline solids are diamond, quartz, rocksalt, mica, sugar, metals, etc.

4.1.2 Amorphous solid

In an amorphous solid, the atoms are arranged in a disorderly manner. The best example for an amorphous solid is glass. Other examples are plastic materials, wood, etc.

4.1.3 Elasticity

When an external force 'F' of sufficient magnitude is applied on a body of mass 'm', the body acquires an acceleration 'a' such that $a = F/m$ (Newton's II law of motion)

However, if the body is not free to move, the external force acting on the body will change the relative position of the molecules. Due to this change, the body may suffer a deformation. This external force is known as deforming force.

As the body is deformed, internal forces are set up within the body, which tends to bring the body back to the original shape. The force developed within the body on account of relative molecular displacement is called internal force or elastic force or restoring force. Under the influence of this restoring force, the body regains its original shape after the deforming force is removed. Such bodies are called elastic bodies. **Elasticity is the property of the material of a body by virtue of which the body regains its original shape when the deforming force is removed.**

There are a few bodies, which do not show any tendency to recover their original shape after the removal of deforming force. Such bodies are called plastic bodies. **The property by virtue of which the body does not regain its original shape after the removal of the deforming force is called plasticity.**

Restoring force developed in an elastic body during deformation is quantitatively equal to the external force applied to cause the deformation. **The stress is defined as the restoring force developed per unit area of the body. Its unit is N m^{-2}**

If there is a change in the shape of a body by the application of a deforming force, then the body is said to be **strained. The strain produced in a body is defined as the ratio of change in dimension to its original dimension.**

The maximum value of stress within which a body regains its original state is called elastic limit.

Hooke's law

This law was proposed by Robert Hooke, the founder of the Royal Society in 1676. He showed that the extension of an elastic body is directly proportional to the force that produces it, provided the extension is within the elastic limit.

Hooke's law states that within the elastic limit of the body, the stress is proportional to the strain produced.

$$\text{i.e. } \frac{\text{stress}}{\text{strain}} = \text{a constant.}$$

This constant is known as **modulus of elasticity.**

4.2 Liquids - types of intermolecular force

There are two types of intermolecular forces

1. **Force of cohesion** It is the force of attraction between the molecules of the same substance. The cohesive force is very strong in solids, weak in liquids and extremely weak in gases.

Example We can suspend a heavy load by the thin steel wire because of the strong force of cohesion between the atoms of steel wire.

2. **Force of adhesion** It is the force of attraction between the molecules of two different substances.

Examples

i. It is because of the force of adhesion, that ink sticks to paper while writing.

ii. Strong adhesive force is shown by materials like cement, gum and paints to walls.

Water wets glass because the force of cohesion between the water molecules is less than the force of adhesion between water and glass molecules. At the same time, mercury does not wet glass because the force of adhesion between mercury and glass molecules is less than the force of cohesion between the mercury molecules.

4.2.1 Molecular range and sphere of influence

The molecular range is defined as the maximum distance upto which a molecule can exert an appreciable force of attraction on another molecule. It is of the order of 10^{-9} m for liquids.

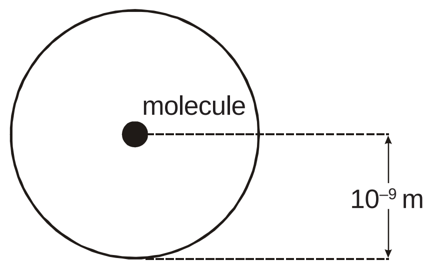


Fig. 4.1 Sphere of Influence

The sphere of influence is defined as the imaginary sphere drawn with a particular molecule as centre and molecular range as radius. The molecule at the centre exerts a force of attraction on all the molecules lying within the sphere of influence.

4.2.2 Surface tension

The free surface of a liquid, at rest behaves like a stretched elastic membrane so as to possess minimum surface area. This behaviour of the liquid is due to a property called surface tension. The phenomenon of surface tension can be easily understood from the following illustrations.

4.2.3 Illustrations of surface tension of liquids

(i) An insect walks on the surface of water without getting wet. There is a slight depression on the surface of water. The force of surface tension does not act horizontally but along an inclined direction. The vertical component of the force of surface tension balances the weight of the insect as in fig: 4.2.

Fig. 4.2 Insect walks on water surface

2. If a greased sewing needle is gently placed on the surface of water, it floats. The water surface below the needle gets slightly depressed. The vertical component of the force of surface tension balances the weight of the needle as in fig: 4.3.

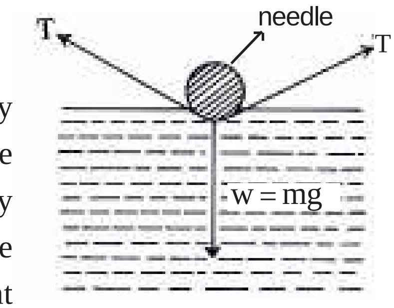


Fig. 4.3 Needle floats

3. When a painting brush is dipped in water, its hairs spread out. If the brush is taken out, its hairs will cling together as the free surface of water film between the hairs contract due to surface tension as in fig: 4.4.

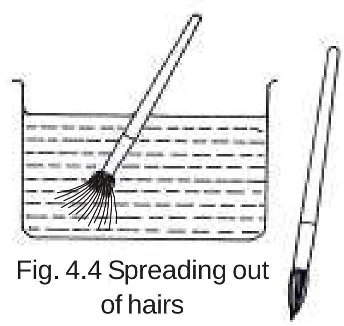


Fig. 4.4 Spreading out of hairs

4.2.4 Molecular theory of surface tension

Consider three molecules A, B and C of a liquid in a container. The molecule A is attracted equally in all directions by the neighbouring molecules. So the net force acting on this molecule is zero. As the number of neighbouring molecules in the lower part of the spheres B and C are more than the number in the upper part, there is a net downward force on these molecules. Here the molecule C experiences maximum downward force. This downward force will try to move the molecules inside the liquid. If a molecule from the interior is to be brought to the surface of the liquid, work must be done against this downward force. This work done on the molecule is stored as potential energy on the surface of the liquid.

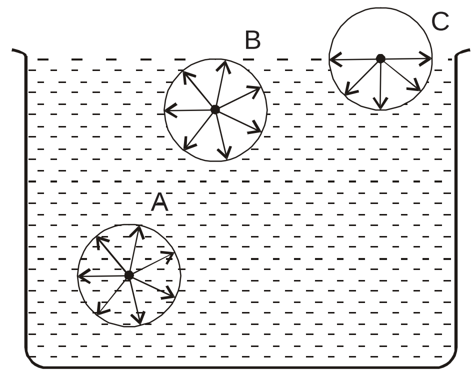


Fig. 4.5 Forces in a liquid

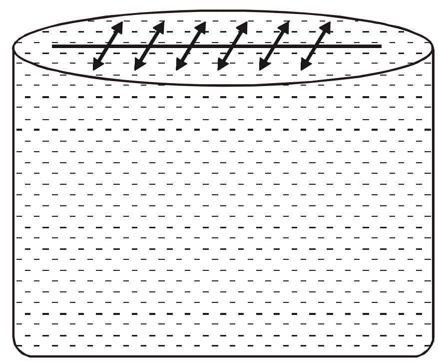


Fig. 4.6 Surface tension

For equilibrium, a system must possess minimum potential energy. Consequently the free surface tends to have the least area, decreasing the number of molecules on the surface and thus making the surface behave like a stretched elastic membrane.

The surface tension is measured as the force acting per unit length. This force is always tangential to the liquid surface. Thus, **surface tension is defined as the force per unit length acting perpendicular to an imaginary line drawn on the liquid surface, tending to pull the surface apart along the line. Its unit is Nm^{-1}.**

4.2.5 Factors affecting surface tension

i. Variation of surface tension by impurities

The presence of impurities of any kind on the surface of a liquid will affect the surface tension. Depending upon the nature of impurities, the surface tension of the liquid either increases or decreases.

A highly soluble substance like sodium chloride increases the surface tension. But sparingly soluble substances like phenol or soap reduce the surface tension.

If a piece of camphor is placed on the surface of water, the surface tension decreases at the point where it is placed. At other points on the surface of water, the surface tension is more. Due to this, there is a forward force making the camphor piece to move. This happens until the entire surface of water is contaminated and then the motion of the camphor ceases.

ii. Variation of surface tension with temperature

The surface tension of a liquid decreases with rise in temperature. There is a particular temperature at which the surface tension of a liquid becomes zero. This temperature is called critical temperature of that liquid.

4.2.6 Application of surface tension in day-to-day life

i. During a storm, the waves are rough on the sea. The sailors pour tins of thick oil around their boats or ships. As the surface tension of oil is lesser than that of water, the addition of oil decreases the surface tension and hence reduces the intensity of the waves.

ii. Mosquitoes breed on the surface of free water. The layer of water due to surface tension supports them. Oil has lesser surface tension than water. When the oil is sprayed on the surface of water, due to the higher surface tension of water, the oil is stretched in all directions as a thin film. As the surface tension of oil is less, the mosquitoes cannot breed on it. Therefore, to prevent the breeding of mosquitoes in rainy season, oil is sprayed on the surface of water in pools and ponds.

iii. Dirty clothes having grease and oil stains cannot be washed with water unless some detergent or soap is added. Water does not wet greasy dirt, but when a detergent is added, the surface tension of water-oil system is drastically reduced. Now water can wet greasy dirt to make washing easier.

4.3 Capillarity

When a capillary tube is dipped in water, the water rises up in the tube. When the same capillary tube is dipped in mercury, the mercury is depressed below the free surface of the mercury in the container. **The phenomenon of rise or fall of a liquid in a capillary tube is known as capillarity.**

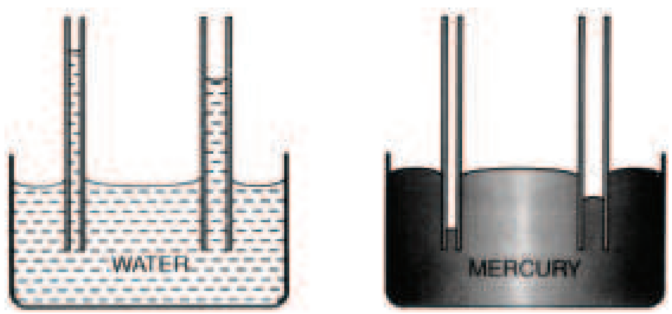


Fig. 4.7 Capillarity

4.3.1 Illustrations of capillarity

i. The oil in a wick rises up through the narrow spaces between the threads of the wick, which act as fine capillary tubes.

ii. A blotting paper absorbs ink by capillary action. The pores of the blotting paper act as capillaries.

iii. The action of a cotton towel in soaking up the moisture from hands or the body is due to capillary action of cotton in the towel.

iv. Walls get damped in rainy season due to the absorption of water by the bricks due to capillary action.

v. A pen nib is split at the tip to provide a narrow capillary tube and the ink is drawn up to the point continuously due to capillarity.

vi. Roots, trunk, branches and leaves of a tree possess fine capillaries. Water rises upto the top of the tree by capillarity.

4.4 Viscosity

Solid surfaces in contact exert a frictional force on each other, when one surface moves on the other. In a similar way, the relative motion of the layers of liquid is restricted by friction. This frictional force between the layers of the liquid is known as viscous force. **The property of a liquid by virtue of which it opposes the relative motion between its different layers is known as viscosity of the liquid.** Viscosity differs from liquid to liquid. The greater the viscosity the less easy it is for the fluid to flow.

4.4.1 Coefficient of viscosity

Newton found that the viscous force between the layers of a liquid is

(i) directly proportional to the area of the liquid layers in contact

(ii) directly proportional to their relative velocity and

(iii) inversely proportional to the distance between them

If A is the area of contact between the two layers, v_1 and v_2 their respective velocities and 'x' the distance between them, then the viscous force.

$$F \propto A$$
$$\propto v_2 - v_1$$
$$\propto 1/x$$
$$F \propto \frac{A\ (v_2 - v_1)}{x}$$

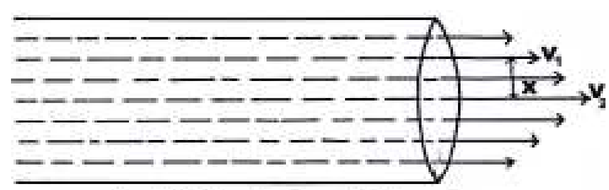


fig 4.8 Coefficient of Viscosity

$$F = \frac{\eta\ A (v_2 - v_1)}{x} \quad \text{---------} \quad (1)$$

Where η is a constant known as the coefficient of viscosity.

$\frac{v_2 - v_1}{x}$ is called the velocity gradient

From the equation (1)

If A = 1 square unit and $\frac{v_2 - v_1}{x}$ = 1 unit

then $F = \eta$

Thus, coefficient of viscosity of a liquid is numerically equal to the viscous force acting tangentially between two layers of a liquid having unit area of contact and unit velocity gradient normal to the direction of flow of the liquid. Its unit is Nsm^{-2}

4.4.2 The flow of a fluid through a pipe

The rate at which a fluid flows through a pipe depends on

i. the viscosity of the fluid

ii. the dimensions of the tube

iii. the pressure difference between the ends

The rate of flow of a fluid is of greater importance in our lives since, it governs things like the flow of blood through blood vessels in our body, the transmission of gas, water or oil through pipe lines for long distances.

4.4.3 Streamline flow

Consider a path of flow of liquid in a pipe along ABC. Let v_1, v_2 and v_3 be the velocities of the liquid at three different points, A, B and C respectively.

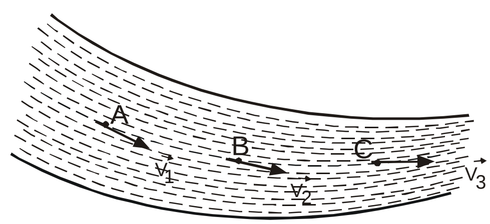


Fig. 4.9 Streamline flow

The flow of liquid in the pipe is said to be streamlined if

(i) all the particles crossing the point A have the same velocity v_1.

(ii) all the particles crossing the point B have the same velocity v_2, but v_2 may or may not be equal to v_1.

(iii) similarly all the particles arriving at the point C have the same velocity v_3.

Thus streamline flow of a liquid is defined as that flow in which every particle of the liquid follows exactly the same path of its preceding particle and has the same velocity in magnitude and direction as that of its preceding particle while crossing through a point.

4.4.4 Turbulent flow

The flow is streamlined as long as the velocity of the liquid does not exceed a limiting value.When the external pressure causing the flow of liquid increases, the motion of the liquid takes place with a velocity greater than the limiting value and the flow of liquid loses all its orderliness. This type of flow is called turbulent flow.

Critical velocity of a liquid is the velocity below which the motion of the liquid is streamlined and above which the motion becomes turbulent.

4.4.5 Reynold number

Reynold number is a mere number, which determines whether the flow of a liquid through a pipe is streamlined or turbulent. Reynold number K is given by

$$K = \frac{\rho v D}{\eta}$$

where η is the coefficient of viscosity of the liquid, ρ is the density of the liquid, v is the average velocity of the liquid through the pipe and D is the diameter of the pipe.

If the value of Reynold number lies between 0 to 2000, the flow of liquid is streamlined. For value of K above 3000, the flow of liquid is turbulent and for values of K between 2000 to 3000, the flow of liquid is unstable and may change from one type to the other.

4.4.6 Difference between streamline flow and turbulent flow

Streamline flow	Turbulent flow
1. The velocity of the fluid is steady.	1. The velocity of the fluid is unsteady.
2. The velocity of every particle crossing a particular point is the same.	2. The velocity of every particle crossing a particular point is different.
3. The velocity of the fluid is less than the critical velocity.	3. The velocity of the fluid is greater than the critical velocity.
4. There is no mixing of various layers with one another.	4. There is always mixing of various layers with one another.

Problem

1. What would be the maximum velocity of water in a pipe of diameter 10 cm so that the flow is stream lined ? Coefficient of viscosity is 1×10^{-3} Nsm^{-2} .

For a streamline flow of maximum velocity, the Reynold number, K = 2000.

$$\text{coefficient of viscosity } \eta = 1 \times 10^{-3} \text{ Ns m}^{-2}$$

$$\text{density of water } \rho = 10^{3} \text{ kg m}^{-3}$$

$$\text{diameter of pipe } D = 10 \times 10^{-2} \text{ m}$$

$$K = \frac{\rho v D}{\eta}$$

$$v = \frac{K\eta}{\rho D} = \frac{2000 \times 1 \times 10^{-3}}{10^{3} \times 10 \times 10^{-2}}$$

$$\text{maximum velocity } v = 2 \times 10^{-2} \text{ ms}^{-1}$$

4.5 Bernoulli's theorem

Bernoulli's theorem relates the velocity of a fluid at a point and the pressure of the fluid at that point. It is just the application of work-energy theorem. According to work energy theorem, the work done by a force acting on a system is equal to the change in kinetic energy of the system.

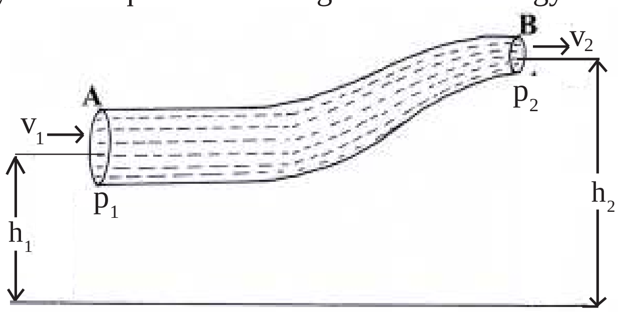


Fig. 4.10 Bernoulli's principle

Consider the streamlined flow of a liquid through a pipe as shown in fig 4.10. As the liquid flows through the pipe, depending upon the position of the liquid, there are three types of energy possessed by the liquid during its flow.

Kinetic energy

Let m be the mass of liquid that flows through the pipe with a velocity v.

Kinetic energy of the liquid = $\frac{1}{2}mv^2$

Kinetic energy per unit mass of the liquid = $\frac{v^2}{2}$

Potential energy

If h is the height from the ground, then the potential energy is given by mgh.

Potential energy per unit mass = gh

Pressure energy

If p is the pressure exerted on the liquid of cross sectional area a, then the force acting on the liquid surface is given by

F = pa ($\because$ pressure = force / area)

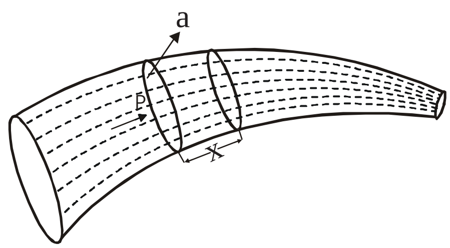


Fig. 4.11 Pressure energy

Under the influence of this force, the liquid is driven through a small displacement x, The work done is given by

$$w = F\,x = p.a.x$$

$$w = pV \;(\because \text{volume } V = a\,x)$$

this work done is stored as the pressure energy.

$$\text{pressure energy} = pV = p\,m/\rho$$

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

$$\text{pressure energy per unit mass} = p/\rho$$

The three types of energy possessed by the liquid at two different points in the pipe (fig. 4.10) are as follows:

at A: potential energy per unit mass $= gh_1$

kinetic energy per unit mass $= \frac{1}{2} v_1^2$

pressure energy per unit mass $= p_1/\rho$

total energy at A $= p_1/\rho + gh_1 + \frac{1}{2} v_1^2$

at B: potential energy per unit mass $= gh_2$

kinetic energy per unit mass $= \frac{1}{2} v_2^2$

pressure energy per unit mass $= p_2/\rho$

total energy at B $= p_2/\rho + gh_2 + \frac{1}{2} v_2^2$

Bernoulli's theorem states that the sum of the energies possessed by a flowing liquid at any point is constant provided the flow of liquid is steady.

$$\text{total energy at A} = \text{total energy at B}$$

$$p_1/\rho + gh_1 + \frac{1}{2}v_1^{\,2} = p_2/\rho + gh_2 + \frac{1}{2}v_2^{\,2}$$

$$\text{(ie) } p/\rho + gh + \frac{1}{2}v^2 = \textbf{constant}$$

This is known as Bernoulli's equation.

From the above equation, it is understood that when a fluid is in motion, the pressure within the fluid varies with the velocity of the fluid if the flow is streamlined. **The pressure within a fast moving fluid is lower than that in a similar fluid moving slowly. This is known as Bernoulli's principle.**

4.5.1 Applications of the Bernoulli's principle

1. Lift of an aeroplane The shape of an aircraft wing is designed in such a way that the velocity of the air above the wing is greater than that below it. A region of low pressure is therefore created above the wing and so the air craft experiences an upward force known as lift.

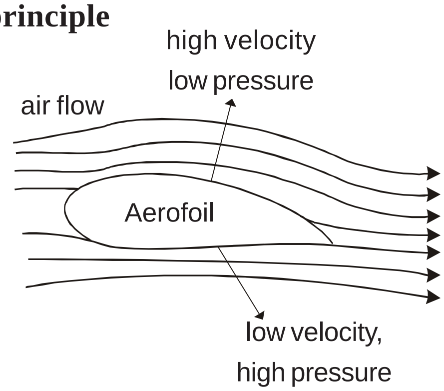


Fig. 4.12 Aerofoil

2. Atomiser or sprayer: It is used to spray liquid. When the rubber balloon is pressed, the air in the horizontal tube passes with a large velocity near the nozzle. According to Bernoulli's principle, the pressure in the tube will be reduced. But the pressure in the container is equal to the atmospheric pressure. This pressure difference makes the liquid rise in the vertical tube. The liquid is blown away through the nozzle with a high velocity in the form of fine spray.

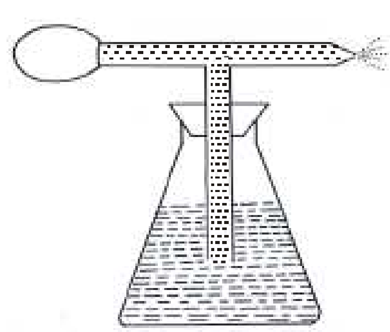


Fig. 4.13 Atomiser

3) Bunsen burner

In a Bunsen burner, the gas comes out of the nozzle with high velocity. According to Bernoulli's principle, the pressure in the stem of the burner decreases. So, air from the atmosphere rushes into the burner. The mixture of air and gas moves up the burner and burns.

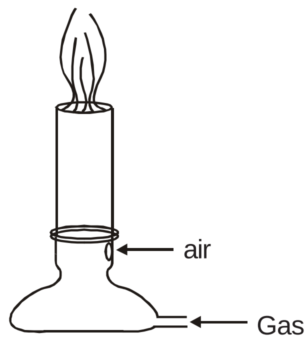


Fig : 4.14. Bunsen burner

Activity

1. Pour equal volumes of water and honey in two similar funnels. It will be observed that water flows out of the funnel very quickly. On the other hand, honey is slow in flowing down. This difference in the behaviour of two liquids indicates that the viscosity of the two liquids have different values.

2. In order to visualize practically streamline and turbulent flow, take a horizontal narrow glass tube. Place a small piece of soluble colouring matter like crystals of potassium permanganate at one end of the tube. Connect this end to a water tap.Open the tap so that water flows out of the tube slowly. A coloured line is observed along the axis of the tube. The flow of liquid through the tube is streamlined. Now open the tap fully. You will observe that the colour spreads out through the entire liquid. The flow of liquid through the tube now becomes turbulent.

Let us muse upon

- There are two types of solids namely crystalline and amorphous.
- The external force which changes the relative position of the molecules of the body is called deforming force.
- The property of the materials by virtue of which a body regains its original shape when the deforming force is removed is called elasticity.
- The property by virtue of which the body does not regain its original shape after the removal of deforming force is called plasticity.
- The stress is defined as the restoring force developed per unit area of the body. Its unit is N m^{-2}
- The strain produced in a body is defined as the ratio of change in dimension to its original dimension.
- The maximum value of stress within which a body regains its original shape is called elastic limit.
- Hooke's law states that the stress acting on a body is proportional to the strain produced, within the elastic limit.
- The force of attraction between the molecules of the same substance is called cohesive force and the force of attraction between the molecules of different substances is called adhesive force.
- The maximum distance upto which a molecule can exert an appreciable force of attraction on another molecule is called molecular range.
- Surface tension is defined as the force per unit length acting perpendicular to an imaginary line drawn on the liquid surface, tending to pull the surface apart along the line.
- The phenomenon of rise or fall of a liquid in a capillary tube is known as capillarity.

☞ Coefficient of viscosity of a liquid is numerically equal to the viscous force acting tangentially between two layers of liquid having unit area of contact and unit velocity gradient normal to the direction of flow of the liquid.

☞ Critical velocity of a liquid is the velocity below which the motion of the liquid is streamlined and above which the motion becomes turbulent.

☞ The pressure within a fast moving fluid is lower than that in a similar fluid moving slowly.

☞ Reynold number is a mere number, which determines whether the flow of liquid through a pipe is streamlined or turbulent.

Self evaluation

4.1 Intermolecular force of attraction exists between the molecules separated by a distance of about

a) 10^{-3} m b) 10^{-5} m c) 10^{-9} m d) 10^{-6} m

4.2 The restoring force per unit area of a deformed body is known as

a) deforming force b) stress c) strain d) elastic limit

4.3 Bernoulli’s theorem is a consequence of the law of conservation of

a) momentum b) energy c) mass

d) angular momentum

4.4 An object entering the earth’s atmosphere at a high velocity catches fire due to

a) viscosity of air b) the heat content of the atmosphere

c) the atmospheric pressure d) the higher force of gravity

4.5 For a streamlined flow, the value of Reynold number is

a) above 3000 b) above 2000 c) below 2000 d) below 3000

4.6 The velocity of every liquid particle crossing a particular point inside a pipe is the same. The Reynold number for this type of flow will be ranging from

a) 2000 to 3000 b) 0 to 2000 c) 2500 to 3500 d) 2000 to 2500

4.7 The unit of coefficient of viscosity is

a) $N\ s\ m^{-2}$ b) $N\ s^{-1}\ m$ c) $N\ s\ m^{-1}$ d) $N\ s^{-2}\ m$

4.8 Why are cotton dresses preferred in summer?

4.9 Why do small pieces of camphor dance about on the surface of water?

4.10 State Bernoulli's principle.

4.11 On what factors does the rate of flow of a liquid through a pipe depend?

4.12 Explain molecular theory of surface tension.

4.13 Define coefficient of viscosity.

4.14 Distinguish between streamline and turbulent flow.

4.15 Explain the phenomenon of capillarity with suitable examples.

4.16 Explain a few applications of Bernoulli's principle.

4.17 Why are bubbles emitted when a piece of chalk is immersed in water?

4.18 How do the insects run on the surface of water?

4.19 The nib of the pen is split. Why?

4.20 Why is oil poured to calm sea waves?

4.21 Explain the applications of surface tension in day–to-day life.

4.22 Water is flowing with a velocity of 15 cm s^{-1} in a tube of diameter 1.1 cm. Find the Reynold number. Coefficient of viscosity of water is 10^{-3} N s m^{-2}.

Answers

4.1 (c)	**4.2** (b)	**4.3** (b)	**4.4** (a)	**4.5** (c)
4.6 (b)	**4.7** (a)	**4.22** (K = 1650)		

5. MODERN PHYSICS

The nature of matter has been a subject of great speculation since early times. It was felt that phenomena like evaporation, diffusion, emission, absorption of radiation and all chemical reactions could be explained only if the constituents of matter are known.

5.1 Atomic structure

In an attempt to explain certain experimental facts about matter, various atomic theories were suggested.

5.1.1 Dalton's atomic theory

The first scientific theory about the constituents of matter was given by John Dalton in 1803. According to this theory matter consists of very small particles called atoms which cannot be sub-divided, destroyed or created. The atoms of the same substance are identical and differ from the atoms of other substances. He further said that atoms retain their individuality in all types of chemical combinations.

5.1.2 Prout's atomic theory

In 1815, Prout proposed that atoms of all elements were made up of hydrogen atoms. Since many of the elements were found to have atomic weights that were not exact multiples of the hydrogen atom, this theory was discarded.

5.1.3 Electrical nature of matter

When Michael Faraday conducted experiments on passing electricity through liquids, he established the electric nature of matter, i.e. matter is composed of positive and negative charges. Faraday had no idea about the structure of the atom and was unaware of the origin of these positive and negative charges in matter.

5.1.4 Thomson's model of an atom

J.J. Thomson in 1910 conducted an experiment by passing electricity through gases at reduced pressure. This experiment showed the existence of negatively charged particles in an atom. He named these particles as 'electrons'. It was during the same period the discovery of natural radioactivity proved that an atom consists of equal quantities of positive and negative charges, thus concluding that an atom is electrically neutral. Since the arrangement of the electrons in an atom remained unknown, as J.J. Thomson attempted to give a structure to an atom.

According to Thomson's atom model, an atom is a sphere of radius, about 10^{-10}m. The positive charges are uniformly distributed in the entire sphere and electrons are embedded in it.

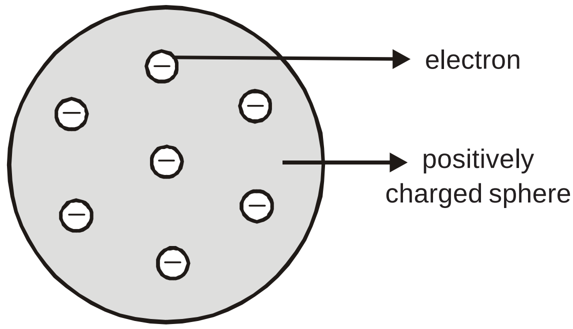


Fig. 5.1 Thomson's atom model

Since the distribution of electrons within the sphere of positive charges resemble the plums in a pudding, J.J. Thomson's atom model is referred to as the **Plum-Pudding model.**

5.1.5 Alpha - particle scattering

Based on the suggestion of Rutherford, Geiger and Marsden performed an experiment on the scattering of α -particle from a thin gold foil. A schematic diagram for the scattering of α - particles is shown in the figure given below:

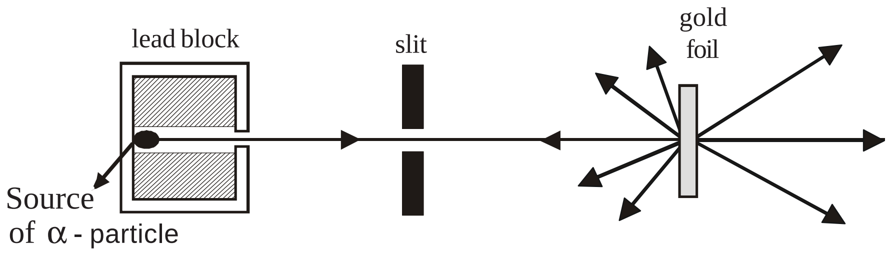


Fig. 5.2 Rutherford's α - particles scattering experiment

A source of α - particle is placed in the cavity of a lead block. A narrow beam of α - particles is obtained by placing a slit in the path of the α - particles.

It is observed that most of the α - particles pass through the foil without any deviation showing that most of the space in the atom is empty. Some α - particles were found to scatter through a small angle and a few α - particles were deflected through a large angle. A few turned back towards the source itself.

Based on the scattering of α - particle, the following inferences were made

i. The entire positive charge of the atom is concentrated in a small portion at the centre of the atom called the nucleus.

ii. The space around the nucleus is almost empty.

5.1.6 Rutherford's model of an atom

According to this model proposed by Rutherford in 1911 the entire positive charge and the whole of its mass is concentrated in a tiny central core called nucleus.

The nucleus is surrounded by a suitable number of electrons such that the total negative charge is equal to the positive charge in the nucleus. These electrons revolve in various circular orbits around the nucleus.

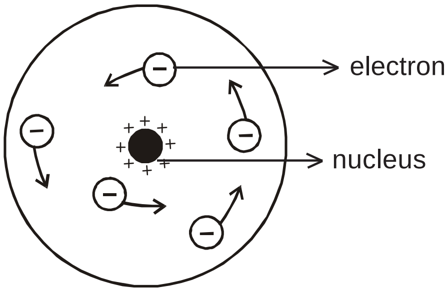


Fig. 5.3 Rutherford's atom model

Rutherford's assumed that the necessary centripetal force for the electrons to revolve around the nucleus is provided by the electrostatic force of attraction between the electrons and the nucleus.

5.1.7 Bohr's model of an atom

Neil Bohr, a Danish physicist in 1913, presented an improved atom model. The entire concept of Bohr's atom model is based on the following postulates.

Postulates of Bohr's atom model

1. Electrons in an atom revolve around the nucleus under the action of the electrostatic force of attraction in a circular orbit.

2. An electron can revolve only in a few discrete and permitted orbits. While moving along these orbits an electron does not radiate energy. These non-radiating orbits are called stationary orbits.

3. When electrons revolve in the permissible non-radiating orbit, they possess a definite angular momentum (L = momentum x radius of the orbit) whose value is an integral multiple of $h/2\pi$, where h is Planck's constant.

4. An atom will radiate energy only if the electron jumps from an orbit of higher energy (E_2) to another orbit of lower energy (E_1). The difference in energy ($E_2 - E_1$) determines the frequency of radiation.

i.e $E_2 - E_1 = h\nu$, where ν is called frequency of radiation.

Bohr could apply these postulates only for simple atoms like hydrogen and gave satisfactory explanation for the emission of spectral lines from a hydrogen atom. However, this atom model could not explain the fine structure of spectral lines.

5.2 Model of the nucleus

There were various models of the nucleus proposed by scientists from time to time. A brief description of a few such nuclear models are summarised below.

5.2.1 Alpha particle model

In this model, the nucleus is supposed to have sub-groups in the form of α- particles. Each sub-group has two protons and two neutrons.

5.2.2 Liquid drop model

According to this model, the nucleus is analogous in certain respects to the charged liquid drop.The following analogy holds good between liquid drop and nucleus.

(i) A liquid drop is spherical due to surface tension and the nucleus is also assumed to be spherical in shape.

(ii) The splitting up of a liquid drop is similar to that of nuclear fission.

(iii) In the case of liquids, the intermolecular forces hold a liquid drop together, and in the nucleus nuclear forces hold the nucleons (proton and neutron) together.

5.2.3 Nuclear structure

The atomic nucleus was discovered in 1911 by Rutherford and his associates as a result of their experiment on scattering of α - particles by thin gold foils. Nucleus is a small positively charged sphere present at the centre of the atom. The radius of the nucleus is of the order of 10^{-14} m and is nearly 10,000 times smaller than the radius of the atom. A nucleus accounts for almost the whole mass of the atom. A study of various nuclear phenomena such as radioactivity reveals that the nucleus is not a composite body but contains two types of particles, namely neutrons and protons.

Proton

It is an elementary particle. It has a positive charge equal in magnitude to the charge of an electron i.e. 1.602×10^{-19} C. Its mass is 1.67×10^{-27} kg and is 1836.1 times the mass of an electron.

Neutron

It is also an elementary particle. It is electrically neutral and has no charge. Its mass is 1.675×10^{-27} kg and is 1838.6 times the mass of an electron. It is slightly heavier than a proton.

Mass number

The total number of nucleons (protons and neutrons) in the nucleus of the atom is called the mass number of the atom and is denoted by A.

Atomic number

The total number of protons in the nucleus of an atom is called the atomic number of the atom and is denoted by Z.

If N represents the number of neutrons in the nucleus, then

$$Z + N = A$$
$$N = A - Z$$

A nucleus is represented symbolically as $_{Z}X^{A}$, where X is the chemical symbol of an element, Z is the atomic number and A is the mass number.

5.2.4 Properties of nucleus

(i) All nuclei are positively charged. The magnitude of the positive charge is an integral multiple of the charge of an electron (ie) q = Ze where Z is the atomic number and e, the charge of an electron.

(ii) More than 99.9% of the mass of an atom is concentrated in the nucleus. The density of an atomic nucleus is very high and it shows that the nuclear matter is in a highly compressed state.

(iii) The distribution of the positive charge is uniform and the nucleus is spherical in shape with a few exceptions.

(iv) The nuclear volume is found to be directly proportional to the total number of nucleons i.e. mass number 'A'.

i.e. volume α A

$$\frac{4}{3} \pi r^3 \;\alpha\; A$$

$$r^3 \;\alpha\; A$$

$$r \;\alpha\; A^{1/3}$$

$$r = r_0 A^{1/3}$$

This is the empirical formula for nuclear radius, where r_0 is the constant of proportionality equal to 1.3×10^{-15}m

5.3.1 Nuclear reaction

When the nucleus of an element is bombarded by an elementary particle or a lighter nucleus, it undergoes a change in composition, producing one or more nuclei of different elements. In this process, new lighter nuclei are formed along with the emission of elementary particles and some amount of energy.

A nuclear reaction is symbolically represented by

$$\mathbf{A + x \longrightarrow B + y + energy\ (Q)}$$

From the above equation, it is understood that a nucleus A is bombarded with an elementary particle 'x'. As the result of this bombardment, a new nucleus B is born along with the emission of another elementary particle 'y' and some energy Q.

Example

$$_{17}Cl^{35} + {}_{0}n^{1} \longrightarrow {}_{15}P^{32} + {}_{2}He^{4} + 0.935 \text{ MeV}$$

$_{17}Cl^{35}$ is bombarded with a neutron to give $_{15}P^{32}$ and an alpha particle with the release of energy 0.935 MeV (1eV = 1.602×10^{-19} J and 1MeV = 10^{6} eV).

Hence, a nuclear reaction is defined as the process of transformation of an atomic nucleus into another nucleus by its interaction with an elementary particle or a lighter nucleus.

5.3.2 Difference between nuclear reaction and chemical reaction.

Nuclear reaction	Chemical reaction
1. A new element or isotope of an element is produced during a nuclear reaction.	No new element is produced during a chemical reaction.
2. Nucleons take part in a nuclear reaction.	Electrons take part in a chemical reaction.
3. It is not affected by any external agents such as temperature, pressure, etc.	It is affected by external agents like temperature, pressure, etc.
4. A nuclear reaction is always irreversible .	Both reversible and irreversible reactions are possible in a chemical reaction.
5. Enormous amount of energy is released during nuclear reaction.	Energy released during chemical reaction is less.

5.3.3 Nuclear fission

In 1939, German scientists Otto Hahn and Strassman discovered that when a $_{92}U^{235}$ nucleus is bombarded by thermal neutrons, it splits up into two smaller nuclei of barium and krypton along with the release of three neutrons.

$$\mathbf{{}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{92}U^{236} \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_{0}n^{1} + Q}$$

The figure 5.4 shows that a $_{92}U^{235}$ nucleus undergoes distortion to attain the shape of a dumb-bell and then splits into Ba^{141} and Kr^{92} with the release of three neutrons. The total mass of the initial particle is always greater than the total mass of the product obtained during nuclear fission. The difference in mass is converted into energy. The energy released per fission of $_{92}U^{235}$ nucleus is found to be 200 MeV.

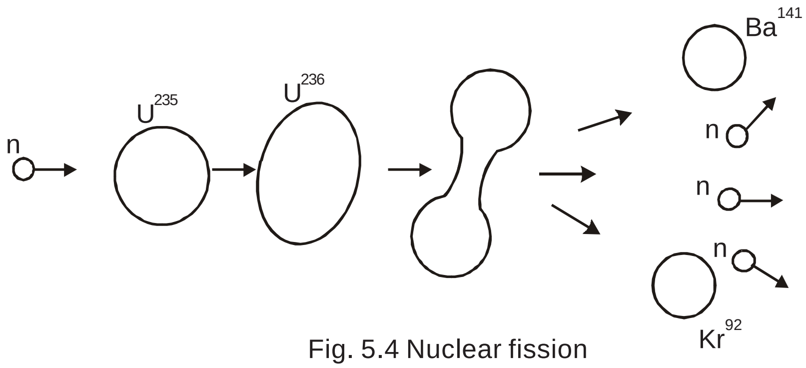


Fig. 5.4 Nuclear fission

The phenomenon of breaking up of a heavy nucleus into two or more lighter nuclei of comparable masses with the release of large amount of energy is called nuclear fission.

Know it yourself

1. It is experimentally observed that barium and krypton were not the only products of nuclear fission of uranium. Depending on the kinetic energy of the neutrons, isotopes of different elements in the atomic number ranging from **34 to 58** are obtained as fission products.

2. When fast moving neutrons pass through matter they are slowed down by sharing their kinetic energy with the atoms of the matter due to collision. This process of sharing of energy continues till the kinetic energy of the neutron is equal to the average kinetic energy of the atoms of the matter. The resulting neutron thus obtained is known as **thermal neutron** whose kinetic energy is less than 1 eV. Thermal neutron is efficient in causing a nuclear fission reaction.

Problem

Calculate the number of fissions that occur per second to produce a power of 1 MW. Given that 200 MeV energy is released per fission of $_{92}U^{235}$.

$$\text{energy released per fission} = 200\ \text{MeV} = 200 \times 10^{6}\ \text{eV}$$

$$1\ \text{eV} = 1.6 \times 10^{-19}\ \text{J}$$

$$\text{energy released per fission} = 200 \times 10^{6} \times 1.6 \times 10^{-19}\ \text{J}$$

$$= 3.2 \times 10^{-11}\ \text{J}$$

$$\text{energy required per second} = 1\ \text{MW} = 10^{6}\ \text{W}$$

$$= 10^{6}\ \text{J s}^{-1}$$

$$\text{number of fissions per second} = \frac{\text{energy required}}{\text{energy released per fission}}$$

$$= \frac{10^{6}}{3.2 \times 10^{-11}}$$

$$\textbf{number of fissions per second} = \mathbf{3.125 \times 10^{16}}$$

Know it yourself

Naturally occurring uranium consists of two isotopes. About 0.7 % is U^{235} and 99.3% is U^{238}. Experiments indicate that $_{92}U^{235}$ is a fissionable material.

5.3.4 Nuclear chain reaction

When $_{92}U^{235}$ nucleus splits up, it generally releases three neutrons which are likely to produce nuclear fission of three more $_{92}U^{235}$ nuclei. On an average a neutron per fission is either absorbed by non-fissionable material or escapes without hitting any other $_{92}U^{235}$ nuclei . The remaining two neutrons hit two other nuclei and produce some more neutrons and so on. The number of fissions taking place at each successive stage goes on increasing in geometrical progression.

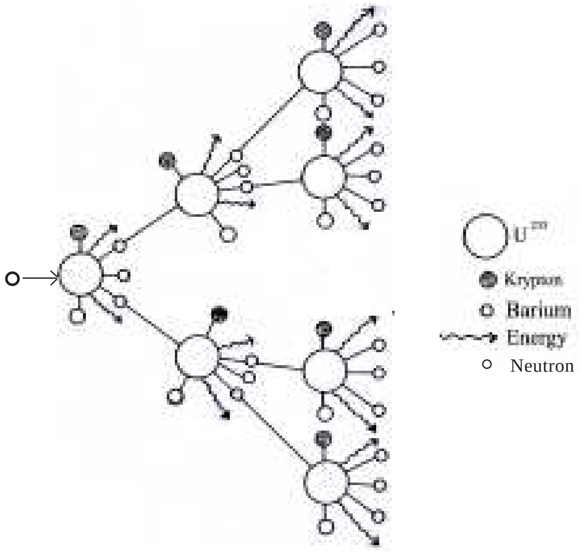


Fig. 5.5 Nuclear chain reaction

Nuclear chain reaction is a process in which if initially fission is induced in a single fissile nucleus, then all other fissile nuclei will automatically undergo fission by increasing the number of neutrons in geometrical progression.

Reproduction factor (k) It is an important parameter in nuclear fission reaction that determines whether the fission reaction is controlled or uncontrolled. **It is defined as the ratio of the number of neutrons present in a particular generation to the number of neutrons present in the preceding generation.**

From the figure 5.5, it is seen that the number of neutrons in the first generation is 1 and that in the beginning of the second generation is 2. Now the reproduction factor k = 2.

For an uncontrolled chain reaction	$k > 1$
For a controlled chain reaction	$k = 1$
For the reaction to stop	$k < 1$

5.3.5 Critical size

For a sustained nuclear chain reaction to take place, the size of the fuel is very important. If the size of the fuel is too small, then the liberated neutrons escape from the surface without producing further fission and the growth of the chain reaction ends. Therefore, there must be a minimum size of the nuclear fuel below which the chain reaction stops. This size is called **critical size**. The corresponding mass is called **critical mass**.

5.4 Uncontrolled chain reaction

Once a chain reaction is set up in a certain mass (above the critical mass), it will accelerate at a very fast rate and an enormous amount of energy is released in a very short time. Such an uncontrolled chain reaction forms the basic principle of an atom bomb.

Atom bomb

Two hemispheres of the same fissionable material U^{235} or Pu^{239} each of mass lesser than critical mass are kept apart by a distance as shown in the figure 5.6. When the bomb is to be exploded a third piece of U^{235} in the form of a cylinder is propelled, so that it will fuse together with the other two pieces. Since the total mass now is greater than the critical mass of the fissionable substance, the uncontrolled chain reaction takes place.

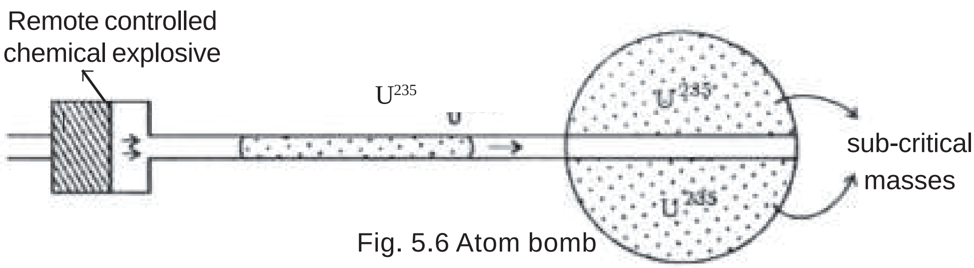


Fig. 5.6 Atom bomb

During the time of explosion, the temperature rises to millions of degree celsius and the pressure rises to millions of atmosphere. The explosion is accompanied by a violent and intense blast of visible light, ultra violet, and x-rays causing a blinding flash. In addition, a large amount of radioactive radiations and neutrons are also released.

5.5 Controlled chain reaction

The chain reaction is so vigorous and of such a short duration that the tremendous amount of energy released can cause a heavy destruction. The chain reaction can, however, be controlled by absorbing excess of neutrons released in the process of nuclear fission, so that on an average, a neutron from each fission reaction is left to produce further fission. Under these conditions, the number of fissions produced per second remains constant and the energy released does not go out of control. This energy can, therefore, be used for peaceful purposes. Such a chain reaction is called a controlled chain reaction.

5.5.1 Nuclear reactor

A nuclear reactor is a device in which the nuclear fission reaction is carried on as a perfectly controlled chain reaction, in a self-sustained manner. The main parts of a nuclear reactor are explained below.

Nuclear fuel

It is the fissionable material required for the fission process to take place. Commonly used fuels in the reactors are U^{235}, Pu^{239} and U^{233}.

Neutron source

A suitable neutron source is conveniently arranged to start the fission reaction in the reactor.

Moderator

It is found that the slow moving neutrons (thermal neutrons) are efficient in producing fission reaction. Moderators are used to slow down the fast moving neutrons. Heavy water or graphite is used as a moderator.

Control rods

In order to ensure that the rate of fission that takes place in the reactor is constant, the excess neutrons are absorbed with the help of control rods. Cadmium or boron strip is used as control rods.

Coolant

The enormous amount of heat energy released during fission is absorbed by coolants. Heavy water is used as a coolant. The heat absorbed by the coolant is transferred to the water in the heat exchanger. Due to this heat exchange, superheated steam is produced which rotates the turbines to generate electric power.

Neutron reflector

In order to prevent the escape of neutrons, a reflector is fixed around the fuel and the moderator.

Radiation shielding

In order to prevent the leakage of nuclear radiations, the reactor is usually surrounded by a thick lead lining which in turn is surrounded by a concrete wall of thickness of about 2 to 2.5 m.

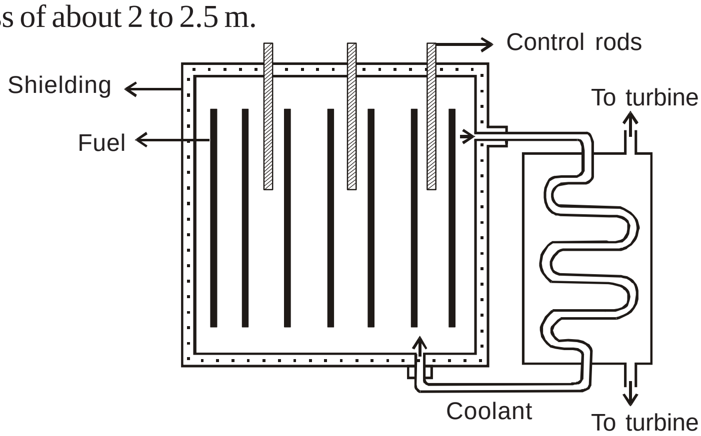


Fig. 5.7 Nuclear reactor

Uses

A nuclear reactor is generally used for the following purposes.

1. To generate electric power.
2. To produce radio isotopes.
3. To produce a neutron beam of high intensity which is used in nuclear research and in the treatment of cancer.
4. To produce radioactive plutonium from U^{238}, which is required for explosive producing explosion.

5.5.2 Reactors in India

After the establishment of the Atomic Energy Commission, India has built nuclear reactors at BARC, Mumbai. **Apsara, Cirus, , Dhruva and Purnima** are a few research purpose reactors. **Kamini**, at **IGCAR (Indira Gandhi Centre for Atomic Research), Kalpakkam is another research reactor.**

The operating nuclear power reactors in India are at Kalpakkam (Tamilnadu), Kakrapara (Gujarat), Kaiga (Karnataka), Tarapur (Maharashtra) and Kota (Rajasthan).

Fast breeder reactor

In this type of reactor, fission is caused by fast neutrons and thus no moderator is required. Here both fissionable ($_{92}U^{235}$) and fertile ($_{92}U^{238}$) materials can be used. The fast neutrons are absorbed by $_{92}U^{238}$ and gets converted into Pu^{239}, which is a fissionable material. These types of reactors, which **produce their own fuel during their operation, are called fast breeder reactors. We have one breeder** reactor in Kalpakkam.

5.5.3 Nuclear fusion

When two or more lighter nuclei fuse together to form a heavy nucleus, an enormous amount of energy is released. This process is called nuclear fusion.

In a fusion reaction, the mass of heavier nucleus formed is less than the total mass of lighter nuclei. The difference in mass is fully converted into energy , according to Einstein's mass - energy relation, $E = mc^2$, where m is the mass difference and c is the velocity of light. A nuclear fusion reaction takes place only at a very high temperature of about 10^7 K. The hydrogen bomb is based on the principle of the nuclear fusion reaction.

Example $_1H^2 + {}_1H^3 \longrightarrow {}_2He^4 + {}_0n^1 +$ energy

When deuterium fuses with tritium, helium is formed. As a result, a neutron is released accompanied by an energy of 17.6 MeV.

Let us muse upon

- Prout proposed that atoms of all elements were made up of hydrogen atom.
- J.J. Thomson first showed the existence of negatively charged particles (electrons) in an atom.
- The radius of an atom is found to be about 10^{-10} m.
- J.J. Thomson's atom model is referred as the plum-pudding model.
- The scattering of α - particle on a thin gold foil shows that positively charged matter is concentrated at the centre in a very small region called nucleus.
- Rutherford discovered the nucleus of an atom.
- The radius of the nucleus is of the order of 10^{-14} m and is nearly 10,000 times smaller than the radius of the atom.
- Mass number of an atom is defined as the sum of the number of protons and neutrons.
- The total number of protons in the nucleus of an atom is called the atomic number.
- The magnitude of the electric charge of the nucleus is an integral multiple of the charge of an electron. ($q = Z e$)
- The nuclear volume is found to be directly proportional to the total number of nucleons. (mass number)
- Nuclear reaction is defined as the process of transformation of an atomic nucleus into another nucleus by its interaction with an elementary particle or a lighter nucleus.

☞ The phenomenon of breaking up of a heavy nucleus into two or more lighter nuclei of comparable masses is called nuclear fission.

☞ Nuclear chain reaction is a process in which, if initially fission is induced in a single fissile nucleus, then all other fissile nuclei will automatically undergo fission by increasing the number of neutrons in geometrical progression.

☞ The ratio of the number of neutrons present in a particular generation in a chain reaction to the number of neutrons present in the preceding generation is called reproduction factor.

☞ The reactors which produce their own fuel during their operation are called breeder reactors.

☞ The process in which two or more light nuclei fuse together to form a heavy nucleus is called nuclear fusion.

Self evaluation

5.1 According to Prout's model, the atoms of all elements are made up of

(a) protons (b) protons and neutrons

(c) protons, neutrons and electrons (d) hydrogen atom

5.2 The radius of an atom is about

(a) 10^{-14} m (b) 10^{-12} m (c) 10^{-10} m (d) 10^{-15} m

5.3 Large angle scattering of α-particles shows that

(a) an atom is a positively charged sphere

(b) a positive charge is concentrated only at the centre of an atom.

(c) atom has no electrons

(d) negative charge is concentrated only at the centre of an atom.

5.4 The nuclear radius is

(a) 10^{-14} m (b) 10^{-10} m (c) 10^{-9} m (d) 10^{-7} m

5.5 Nuclear radius is __________ times smaller than the radius of the atom.

(a) 100 (b) 1000 (c) 10,000 (d) 2000

5.6 Electrons are embedded in a positively charged sphere. This was suggested by

(a) Thomson (b) Rutherford (c) Bohr (d) Dalton

5.7 The mass of a neutron is

(a) 9.11×10^{-31} kg (b) 1.66×10^{-27} kg

(c) 1.675×10^{-27} kg (d) 1.656×10^{-29} kg

5.8 The formula for nuclear radius is

(a) $r = A\, r_o^{1/3}$ (b) $r = r_0\, A^{1/2}$ (c) $r = r_0\, A^{1/3}$ (d) $r = r_0\, A^{-1/3}$

5.9 A chain reaction is possible when the mass of the fuel is greater than

(a) proton mass (b) neutron mass

(c) electron mass (d) critical mass

5.10 A controlled chain reaction takes place in

(a) atom bomb (b) nuclear reactor

(c) hydrogen bomb (d) all of these

5.11 The coolant used in a nuclear reactor is

(a) graphite (b) uranium (c) heavy water (d) water

5.12 What is Prout's atom model?

5.13 What is alpha-particle model of a nucleus?

5.14 Define mass number and atomic number.

5.15 Define nuclear fission.

5.16 What is critical mass?

5.17 What is a nuclear reaction? Give an example.

5.18 Describe Rutherford's α – particles scattering experiment.

5.19 Explain Bohr's model of an atom.

5.20 Give the properties of a nucleus.

5.21 Write a short note on an atom bomb.

5.22 Write a note on chain reaction.

5.23 Explain the liquid drop model of a nucleus.

5.24 Define reproduction factor.

5.25 Explain the essential parts of a nuclear reactor.

5.26 Distinguish between nuclear fission and fusion.

5.27 Find the radius of a nucleus of mass number 64.

5.28 If the energy released per fission is 200 MeV, calculate the number of fissions that takes place per second to produce a power of 10 kW.

Answers

5.1 (d)	**5.2** (c)	**5.3** (b)	**5.4** (a)	**5.5** (c)
5.6 (a)	**5.7** (c)	**5.8** (c)	**5.9** (d)	**5.10** (b)
5.11 (c)	**5.27.** (5.2×10^{-15} m)		**5.28.** (3.125×10^{14})	

6. X - RAYS AND RADIOACTIVITY

X - rays were accidentally discovered by W.C Roentgen in 1895. He named this radiation as X - rays because its nature and properties could not be known at that time. Almost one year after the discovery of X - rays, radioactivity was discovered by Henry Becquerel in 1896.

The discovery of natural radioactivity marked the beginning of one of the most fruitful developments in modern physics. A detailed study of it has been of utmost importance in atomic physics forming the basis of many highly suggestive discoveries about an atom, such as the nuclear atom model, isotopic constitution, artificial disintegration, induced radioactivity, etc. In this chapter, we shall discuss the principle, the discovery, properties and uses of X - rays and also the basic concepts on natural and artificial radioactivity.

6.1 X - RAYS

When W.C. Roentgen was experimenting with the discharge of electricity through gases, he covered the discharge tube with a thin black card board to facilitate better observation of fluorescence. He accidentally noticed a brilliant glow on a screen coated with barium platino cyanide lying in a corner of his laboratory. He concluded that the invisible radiations coming out from the discharge tube should have caused the fluorescence on the screen. Roentgen called these invisible penetrating rays which affected the screen as X - rays.

W.C. Roentgen

The discovery of these rays in 1895 has opened a new field of study in medicine, surgery and industry and many forms of X-ray tubes have been designed to suit their needs.

6.1.1 Production of X - rays

Principle X - rays are produced when fast moving electrons are suddenly stopped by a metal target of high atomic mass.

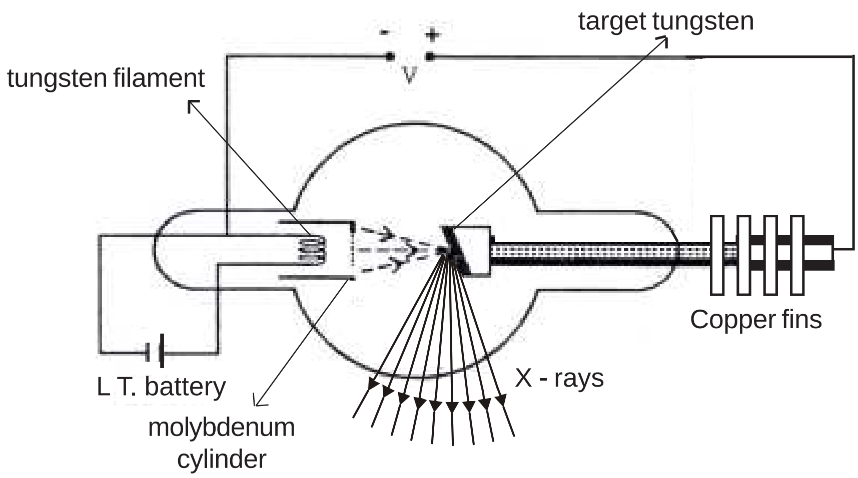


Fig 6.1 – Production of X - rays

The modern X-ray tube was designed by Dr.William Coolidge in 1912. It consists of a glass tube which is highly evacuated up to 10^{-7} m of mercury. A tungsten filament coated with barium oxide acts as a cathode. When heated by current from the low tension battery, it emits electrons. It is surrounded by a molybdenum cylinder to focus the electrons. Tungsten which has a high melting point acts as an anode and is inclined at an angle of 45^0. It is embedded in a copper block. Copper fins are provided at the end of the copper block and water is circulated through pipes to cool the anode.

A very high potential of about 100,000V from the secondary of an induction coil is applied between the anode and the cathode This high potential accelerates the electrons. When these electrons strike the tungsten target, X - rays are produced.

6.1.2. Properties of X - rays

1. X-rays are electromagnetic radiations of very short wavelength of the order of 10^{-10}m.
2. As they are not charged particles, they are not deflected by electric and magnetic fields.
3. They produce fluorescence in materials coated with barium platino-cyanide and zinc sulphide.
4. They travel in straight lines with the velocity of light.
5. They affect photographic plates.
6. They ionise the gases through which they pass.
7. They are photons of high energy.
8. They are diffracted by crystals.
9. They cause chemical and biological changes.
10. They have high penetrating power, but are stopped by lead and bones.

6.1.3. Applications of X - rays

MEDICAL	1. X-rays can pnetrate through flesh and not through bones. Hence they are used to detect (a) fractures and dislocation of bones (b) diseased organs and unwanted growth of bones and stones in the body (c) the presence of foreign bodies like bullets, pins and coins in the human body. 2. X - rays of very high penetrating power are used to destroy malignant tumours and cure skin diseases.
INDUSTRY	X - rays are used to detect 1. crack in metal structures - the body of aeroplanes and automobiles. 2. the quality of welding in moulds and metal castings. 3. the presence of pearls in oysters.

DETECTION They are used to detect the smuggling of precious metals, explosives and contraband goods.

RESEARCH X - rays are used to study the structure of crystals, which is called X - ray crystallography.

Know it yourself

The harmful effects of X-rays were known almost as soon as they were discovered. An X-ray photograph is taken when we cannot physically see or check an organ. When X-rays pass through the human body a part of it is absorbed and some part goes right through.

In the human body there are three parts which are affected by X-rays. First, is the genitalia, which, when affected may have a negative effect on the progeny. The is the skin. X - rays can cause rashes, hair loss and can lead to cancer. The third is the red blood cells which, when affected can cause anaemia. If the white blood cells are affected they can attack the immune system and lead to various diseases.

The International Commission on Radiological protection has recommended that the effective dose for a member of the public shall not exceed 1mSv per year averaged over a period of 5 years with not more than 5 mSv in any given year during the five year period.

We express radiation dosage in a unit called the “sievert (Sv)”. Smaller quantities are expressed in millisievert. (mSv)

Average dose for dental X - ray is 0.1 mSv and chest X - ray is 0.08 mSv

6.2. Radioactivity

In 1896, a French physicist Prof. Henri Becquerel, discovered that a photographic plate, lying near a uranium compound was affected. This prompted him to carry out the experiment with other salts of uranium and he concluded that uranium and its salts emit invisible radiations which can pass through paper, wood, glass etc. and affect photographic plates.

Henry Becquerel

Natural radioactivity is the spontaneous emission of alpha, beta, and gamma rays by the nuclei of heavy elements whose atomic number is greater than 82. These elements are called 'radioactive elements'.

6.2.1 Rutherford's experiment - Natural radioactivity

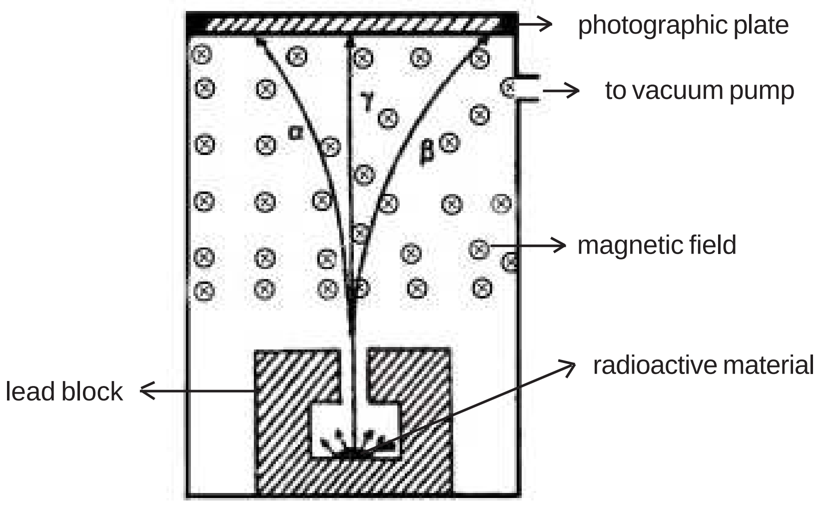
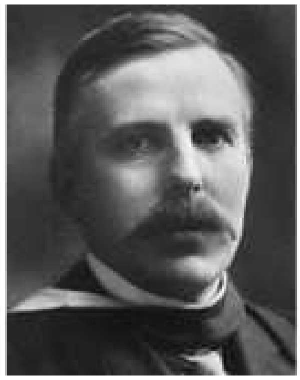


Fig 6.2 Rutherford's experiment

The nature of the radioactive radiations were studied experimentally by Dr. Ernest Rutherford.



Dr. Ernest Rutherford

A small quantity of a radioactive element is placed in the cavity of a lead block. A photographic plate is placed close to it. A strong magnetic field is set up perpendicular to the plane of the paper directed inwards and the whole arrangement is placed in an evacuated chamber.

On examining the photographic plate, three traces are observed indicating that there are three types of radiations. They are alpha particles, beta rays and gamma rays.

According to Fleming's left hand rule, the particles which get deflected towards the left are positively charged and are called alpha particles. The rays which get deflected towards the right are negatively charged and are called beta rays. The rays which are undeviated are gamma rays.

6.2.2. Properties of radioactive radiations

ALPHA RAYS	BETA RAYS	GAMMA RAYS
1.Alpha particles are helium nuclei	Beta rays are electrons	Gamma rays are electromagnetic radiations
2.They are positively charged particles	They are negatively charged particles	They do not have any charge.

3.They are deflected only by strong electric and magnetic fields.	They are deflected by electric and magnetic fields.	They are not deflected by electric or magnetic field.
4.Their velocity is much less than the velocity of light and is between 1.4 x 10^7 m s^{-1} and 2.15 x 10^7 m s^{-1}.	Being light particles their velocity is nearly equal to the velocity of light.	Their velocity is the same as the velocity of light.
5.Their ionising power is very high.	Their ionising power is less.	They have a very low ionising power.
6.They affect photographic plates.	They affect photographic plates.	They affect photographic plates.
7.When they are incident on materials coated with zinc sulphide they cause fluorescence.	When they are incident on materials coated with zinc sulphide, they cause fluorescence	When they are incident on materials coated with zinc sulphide, they cause fluorescence
8.Their penetrating power is very low. They can be stopped by cardboard or aluminium of 0.01 cm thickness.	They have a higher penetrating power. They can be stopped by aluminium of 0.5 cm or lead of 1mm thickness.	They have a very high penetrating power. They can be stopped only by lead of 30 cm thickness.
9.When an alpha particle is emitted by the nucleus, the mass number decreases by 4, and the atomic number decreases by 2.	When a beta particle is emitted, the mass number remains the same, but the atomic number increases by one.	When a gamma ray is emitted there is no change in the mass number or atomic number.

6.3. Forces of nature

Physicists have classified the basic forces of nature into four types such as gravitational, electromagnetic, strong and weak nuclear forces.

a) Gravitational force

(i). It is that force which keeps the earth orbiting the sun and holds the galaxies together.

(ii). It is the weakest of all the known forces, yet it dominates the universe.

(iii). It is a long range force

(iv). It is an attractive force.

b) Electromagnetic force

(i). It is the force between any two electric charges or two current carrying conductors.

(ii). It is stronger than gravitational force.

(iii). It is either attractive or repulsive.

c) Strong nuclear force

(i). It is the force that holds nucleons together. It is the force between two nucleons i.e. the force between two protons (p-p), two neutrons (n-n) or between a neutron and a proton (n-p).

(ii). It is the strongest of all forces.

(iii). It acts over short distances.

(iv). It is attractive and charge independent.

d) Weak nuclear force

(i). It is the force that arises in nuclear processes such as beta decay.

(ii). It is a very weak force

(iii). The range of the force is shorter than the size of the protons or neutrons.

6.4. Artificial radioactivity

Irene Curie

In 1934, Irene Curie and her husband Joliot found that even lighter nuclei elements which are stable could be made radioactive by artificial means when they were bombarded by high energy particles such as alpha particles.

When aluminium is bombarded by alpha particles an isotope of radio active phosphorous is produced, with the release of a neutron.

$${}_{13}A\ell^{27} + {}_{2}He^{4} \longrightarrow {}_{15}P^{30} + {}_{0}n^{1}$$

When boron is bombarded by alpha particles radioactive nitrogen is produced with the release of a neutron.

$${}_{5}B^{10} + {}_{2}He^{4} \longrightarrow {}_{7}N^{13} + {}_{0}n^{1}$$

Artificial or induced radioactivity is the transmutation of a nonradioactive element into a radioactive element by artificial means. These artificially produced radioactive elements are called radio-isotopes.

This discovery led to the production of more than 800 radio-isotopes which do not occur in nature.

6.4.1. Differences between natural and artifical radioactivity.

Natural radioactivity	Artificial radioactivity
1. Natural radioactive elements are found in nature.	Radioactive isotopes are not found in nature but are produced by artificial means.
2. Only heavy elements whose atomic number is greater than 82 exhibit natural radioactivity.	Artificial radioactivity is exhibited by both light and heavy elements.
3. Positrons are not emitted.	Positrons are emitted. Positrons are positively charged particles whose mass is equal to the mass of an electron.

6.4.2. Uses of Radio-isotopes

Radio-isotopes have provided a powerful tool for the solution of numerous problems in biology, physiology, chemistry and other sciences in addition to industry. Some of the problems particularly those connected with life processes could not have been solved without the use of isotopes. A few applications of radio-isotopes are discussed below.

1. In medicine

(a) **In diagnosis -** Radio iodine ${}_{53}I^{131}$ is used in determining the condition of the thyroid gland. Radio sodium ${}_{11}Na^{24}$ and Radio potassium ${}_{19}K^{42}$ are used to detect disorders in blood circulation. Radio chromium ${}_{24}Cr^{51}$ is used to locate the exact position of haemorrhage in the blood circulatory system.

(b) **In therapy** - Radio cobalt ${}_{27}Co^{60}$ is used in the treatment of cancer. Radio iron ${}_{26}Fe^{59}$ is used to treat anaemia. Radio Gallium ${}_{31}Ga^{67}$ is used to treat soft tissue tumours. Radio Strontium ${}_{38}Sr^{90}$ is used to treat skin cancer.

2. **In industry** - Special paints mixed with isotopes of Promethium ${}_{61}Pm^{147}$ are used for illuminating watches, aircraft instrument dials, safety signs, self - luminous paints and post markers.

3. **In agriculture** - Radio isotopes are used in the production and preservation of agricultural products. The shelf - life of edible items can be increased by irradiation. Sprouting in onion, garlic, potatoes and ginger can be reduced by exposing the containers to gamma rays from ${}_{27}Co^{60}$ for a certain duration. It also slows down the ripening of fruits like bananas, mangoes and papayas. Radio phosphorus ${}_{15}P^{32}$ is used in the soil as a fertilizer and the absorption of phosphorus by the plant from the soil is studied.

Radio-carbon dating

It is a technique of estimating the ages of mummies, wooden implements, etc, using radioactive carbon ($_6C^{14}$) present in them. Radio carbon is produced in the atmosphere by the bombardment of $_7N^{14}$ nuclei by neutrons present in cosmic rays. The half life period of $_6C^{14}$ is 5600 years. **Half life period of a radioactive element is defined as the time taken for half the number of its atoms to disintegrate.** Living organisms take in $_6C^{14}$ with their food they eat and the air they breathe in. Intake of $_6C^{14}$ stops at their death. Thereafter the radiocarbon present in them decreases due to its decay. By measuring the percentage of $_6C^{14}$ present in relics, their ages are calculated.

Let us muse upon

- ☞ X - rays are produced when fast moving electrons are suddenly stopped by a metal target of high mass number.
- ☞ X - rays can pass through human body but not through bones.
- ☞ X - rays are used to study the structure of crystals.
- ☞ The spontaneous emission of alpha, beta and gamma rays by the nucleus of heavy elements whose atomic number is greater than 82 is called radioactivity.
- ☞ The ionising power of alpha particles is very high.
- ☞ The penetrating power of gamma rays is very high.
- ☞ When a radioactive nucleus emits an alpha particle the atomic number of the nucleus decreases by 2 and its mass number decreases by 4.
- ☞ When a radioactive nucleus emits a beta ray, the atomic number increases by one and there is no change in the mass number.
- ☞ When a radioactive nucleus emits gamma rays, there is no change in the atomic number and mass number of the nucleus.

☞ There are four types of basic forces namely gravitational force, electro magnetic force, strong and weak nuclear forces.

☞ The gravitational force is the weakest of all the known forces.

☞ Artificial or induced radioactivity is the transmutation of a non-radioactive element into a radioactive element.

☞ The age of relics is estimated by a technique called radiocarbon dating.

Self evaluation

6.1. Natural radio activity was first observed by

a) Henri Becquerel b) Rutherford c) Joliot d) Irene Curie.

6.2. The transmutation of a non-radioactive element into a radioactive element is called

a) natural radioactivity b) artificial radioactivity
c) chain reaction d) nuclear fusion

6.3. X - rays were discovered by

a) Rutherford b) Coolidge
c) W.C. Roentgen d) Madam Curie

6.4. The production of X - rays requires

a) high voltage and low pressure b) high voltage and high pressure
c) low voltage high pressure d) low voltage and low pressure

6.5. The slowest among the following are

a) alpha particles b) beta rays c) gamma rays d) X - rays

6.6. The radiations of the maximum ionising power are

a) X - rays b) beta rays c) gamma rays d) alpha particles

6.7. The weakest among the basic forces of nature is

a) electro magnetic force b) gravitational force
c) weak nuclear force d) strong nuclear force

6.8. Natural radioactivity occurs in elements of atomic number greater than

a) 28 b) 82 c) 52 d) 40

6.9. Among the following the force that is charge independent is
a) electrostatic force b) electromagnetic force
c) nuclear force d) all the above forces

6.10. The radio isotope used to treat anaemia in the human body is
a) Ga^{67} b) Fe^{59} c) Sr^{90} d) Co^{60}

6.11. What are the basic forces of nature?

6.12. Define natural radioactivity.

6.13. What is artificial radioactivity?

6.14. What is the principle involved in producing X-rays?

6.15. Compare the penetrating and ionising properties of alpha, beta and gamma rays.

6.16. Distinguish between natural and artificial radioactivity.

6.17. Explain induced radioactivity with examples.

6.18. Mention the appliciations of radioisotopes in the field of medicines.

6.19. How are radio isotopes used in agriculture?

6.20. How are radio isotopes used for industrial purposes?

6.21. Write the uses of X-rays.

6.22. Mention the properties of X-rays.

6.23. With the help of a neat diagram explain the production of X-rays.

6.24. Describe Rutherford's experiment on radioactivity.

Answers

6.1. (a) **6.2.** (b) **6.3.** (c) **6.4.** (a) **6.5.** (a)

6.6. (d) **6.7.** (b) **6.8.**(b) **6.9.**(c) **6.10.**(b)

7. UNIVERSE

The science which deals with the study of heavenly bodies with respect to their motion, position and composition is known as astronomy. Astrophysics deals with the physical properties and interaction of celestial bodies, the application of the principles of physics to celestial bodies and their phenomena. Traditionally astronomy has been more observational in scope while Astrophysics is more analytical. Thus, astronomers look through telescopes while astrophysicists analyse the collected data.

7.1 Planetary motion

Long before the rise of civilization, primitive man who was mainly nomadic in culture was using the sun and stars for finding the direction during his journeys. The earliest evidence of planetary observations appeared around 1600 B.C.

Ptolemy, a Greek astronomer studied the motion of the planets in detail and proposed a theory known as Geocentric theory. According to this theory, the earth is at the centre of the universe and all other heavenly bodies move around it in various orbits. Aryabhatta, the Indian astronomer was the first to describe the rotation of the earth on its own axis. He also ascertained the fact that the earth rotates west - east by citing various illustrations.

The 16^{th} century A.D marked the transition from mediaeval to modern astronomy by two great advances: the suggestion of a heliocentric system by Copernicus and the systematic recording of accurate observations of Tycho Brahe. According to Heliocentric theory the sun is at the centre and all the planets revolve around it in circular orbits. Based on the observations made by Tycho Brahe, a German astronomer, Johannes Kepler proposed the three famous empirical laws of planetary motion.

7.2 Kepler's Laws of Planetary Motion

First Law (Law of orbits)

Each planet moves around the sun in an elliptical orbit with the sun at one of its foci.

P is a planet revolving round the sun as shown in fig. 7.1. The closest position A of the planet from the sun is called perigee and the farthest position B of the planet from the sun is called apogee.

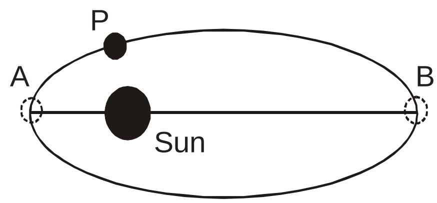


Fig. 7.1

Second Law (Law of areas)

The line joining the sun and the planet sweeps out equal areas in equal intervals of time.

The orbit of the planet around the sun is as shown in the fig. 7.2. In a given interval of time, the planet covers longer distance A to B near the perigee and short distance C to D near the apogee. Hence, the speed of the planet is maximum at the perigee position and minimum at the apogee position.

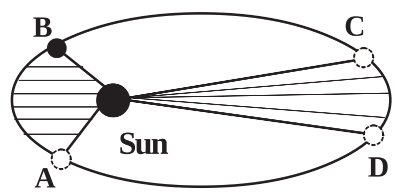


Fig. 7.2

Third law (Law of periods)

The square of the period of revolution of a planet (T) around the sun is directly proportional to the cube of the mean distance between the planet and the sun (r).

(i.e.) $T^2 \propto r^3$

$$\frac{T^2}{r^3} = \text{constant}$$

Planetary data applied to Kepler's third law are tabulated below. It can be seen that the ratio $\frac{T^2}{r^3}$ is constant for all the planets.

TABLE 7.1

Name of the Planet	Time period T (years)	Mean distance from the sun r (x 10^9m)	$\frac{T^2}{r^3}$ (x10^{-25}) $\frac{years^2}{km^3}$
Mercury	0.241	57.90	2.991
Venus	0.615	108.21	2.985
Earth	1.000	149.60	2.987
Mars	1.881	227.94	2.988
Jupiter	11.862	778.30	2.985
Saturn	29.458	1427.00	2.986
Uranus	84.015	2869.00	2.990
Neptune	164.788	4498.00	2.984
Pluto	248.400	5900.00	3.004

7.3 Newton's universal law of gravitation

Every body in the universe attracts every other body with a force which is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them.

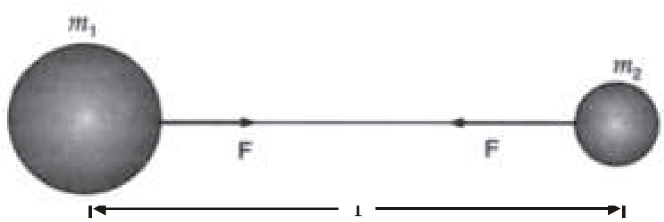


Fig. 7.3

If m_1 and m_2 are the masses of two bodies separated by a distance r, the force of attraction F between them is given by

$$F \,\alpha\, m_1 m_2$$

$$F \,\alpha\, \frac{1}{r^2}$$

$$F \propto \frac{m_1 m_2}{r^2} \qquad F = \frac{G m_1 m_2}{r^2}$$

where, G is a constant known as the universal gravitational constant.

The value of $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

If $m_1 = m_2 = 1$ kg and r = 1 m, then F = G.

Thus, **the gravitational constant is numerically equal to the force of attraction between two bodies each of mass 1 kg separated by a distance of 1 metre.**

7.4 The solar system

Solar system is the part of the universe in which the sun occupies the central position of the system holding together all the heavenly bodies such as planets, moons, minor planets or asteroids, comets and meteors. The sun holds all other heavenly bodies under the influence of the gravitational force. You might have studied about the nine planets in your earlier classes viz. Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto.

Asteroids

These are huge lumps of rocks orbiting round the sun mainly between Mars and Jupiter. They are also called minor planets and are considered to be the remains of a planet which broke up long ago. Ceres is the largest known asteroid.

Comets

Comets are insignificant tiny rock like objects with frozen gases moving around the sun in elliptical orbits having the sun at one of its foci.

During its motion, the comets pass quite close to the sun and then recede far away into the inter-planetary space. When comets travel quite far away from the sun, gaseous materials accumulate and freeze on the icy bodies. When they approach the sun, the solar heat vaporizes the condensed matter and are pushed away from the sun by the solar wind. Thus comets develop a tail pointing away from the sun. Some comets are seen at fixed regular intervals of time. Halley's Comet is a periodic comet which makes its appearance once in seventy six years. Its last appearance was in 1986 and it would appear again in 2062.

Meteors and meteorites

Meteors also called as shooting stars are rocky and metallic particles or fragments revolving round the sun. These may be the fragments of the asteroids or comets. When these pieces enter the earth's atmosphere they are burnt up by the heat generated due to friction in the earth's atmosphere. As a result we see a streak of light. The streak vanishes within a few seconds because the rocky pieces melt and vaporize completely in a short time.

Some bigger pieces may survive the heat produced by friction and they manage to reach the earth and they are called as meteorites.

7.5 Galaxy

A cluster of stars, gas and dust particles held together by gravitational force is called a galaxy. Millions of galaxies have been photographed by the modern telescopes and they constitute the universe. Galaxies consist of millions of stars. Our Galaxy - the Milky way is spiral in shape. The nearest galaxy to us is Andromeda galaxy which is at a distance of 2×10^6 light year. (The distance travelled by light in one year is called a light year. One light year = 9.467×10^{12} km.)

Expansion of universe

An American astronomer Edwin Hubble observed that all galaxies are rushing away from each other. He established the relationship between the speed (V) and the distance(R) of the galaxies. **The velocity with which galaxies are receding away is proportional to the distance between them.**

i.e. $V \propto R$

$V = HR$ where, H is Hubble's constant

This is known as Hubble's law

7.6 Origin of the universe

The Big bang theory

According to this theory all matter in the universe was concentrated to a small core which was dense and hot in the beginning. Some cosmic explosion occurred around 15 billion years ago. As a result the matter was thrown out in all directions in the form of galaxies and they were receding away from each other. The presence of cosmic radiation and observation of Edwin Hubble that the galaxies are moving away from each other supports this theory. As the galaxies move further and further all the matter in the galaxy will get used up and the universe will be empty at one point of time.

There are also two other theories namely - Pulsating theory and Steady State theory that explain the origin of the universe.

7.7 Artificial satellites

A body moving in an orbit around a planet is called a satellite. The moon is the natural satellite of the earth. **Artificial satellites are man-made objects, which revolve around the earth.** These satellites are used for communication purpose, weather monitoring etc.

Satellites used for communication purpose have a time period of 24 hours (i.e) the same as that of our earth. These satellites are called geo - stationary satellites. Everything that happens in the world comes to our door - step only with the help of communication satellites.

Remote sensing

Collection of information about an object without physical contact with the object is known as remote sensing. The remote sensing satellites can be used in agriculture, forestry, drought assessment, estimation of crop fields, detection of fishing zones, mapping and surveying.

Indian space mission

The Indian Government established the Department Of Space (DOS) in 1972 to promote development and application of space science and technology for socio - economic benefits. Indian Space Research Organisation (ISRO), is the primary agency under Department of Space, for executing space programmes. During the seventies, India undertook demonstration of space applications for communication, broadcasting and remote sensing; designing and building experimental satellites - Aryabhatta, Bhaskara, APPLE and Rohini, and experimental Satellite Launch Vehicles - SLV - 3 and ASLV. India has established space systems that form an important element of the national infrastructure.

Today, it is clear that the resolution has paid rich dividends, since, India has emerged as a front-ranking nation, not only in the development of space technology, but also in taking its benefits to the people. The Indian National Satellite (INSAT) and Indian Remote Sensing (IRS) satellite systems form the important components for the development of the infrastructure for telecommunication, television and broadcasting, meteorology, disaster warning and resource management for our country.

Early experiments

Aryabhatta The first Indian Satellite was launched into a near earth orbit on April 19, 1975 by an Intercosmos rocket of the erstwhile Russia, for conducting scientific experiments in space and to gain experience in the design, fabrication and operation of a complete system.

Bhaskara - I & II They carried two TV cameras, one in visible and the other in near - infrared band, and a 3 - frequency passive microwave radiometer.

APPLE (Ariane Passenger Payload Experiment) It was used to conduct several communication experiments.

Rohini series While the first Rohini satellite was used to measure the performance parameters of SLV 3, the second and third carried landmark sensor payloads viz. Stretched Rohini Series Satellites, SROSS C and SROSS C2.

Satellite telecommunication experiment project (STEP) provided experience in the operation of geostationary satellite system for domestic telecommunication in designing and building ground infrastructure.

Space science The research under the Indian space programme encompasses a wide spectrum of activities including a study of cosmic rays, astronomical investigation using space and ground - based systems, study of meteorites, lunar samples and physical observations of the sun. Another major branch of activity relates to the study of earth's atmospheric system through rockets, balloons and orbiting space systems.

Know it yourself

Some of the space centres in India are listed below:

Vikram Sarabhai Space Centre (VSSC), Thiruvanathapuram, pioneers in rocket research and in planning and execution of launch vehicle development projects of ISRO.

SRO Satellite Centre (ISAC), Bangalore is responsible for the design, fabrication, testing and management of satellite systems for scientific, technological and application missions.

Space Applications Centre (SAC), Ahmedabad. The major fields of activity cover satellite communications, remote sensing and meteorology.

SHAR Centre, Sriharikota. This centre also undertakes large scale production of solid rocket propellant and ground testing of solid fuelled rocket stages of launch vehicle.

National Remote Sensing Agency (NRSA), Hyderabad, under DOS, has facilities for surveying, identifying, classifying and monitoring earth resources using aerial and satellite data.

Know it yourself **TABLE 7.2**

NAME OF THE SATELLITE	DATE OF LAUNCH	LAUNCH VEHICLE	LAUNCHED AT
ARYABHATA	19.04.1975	INTER COSMOS	RUSSIA
BHASKARA – 1	07.06.1979	INTER COSMOS	RUSSIA
RS – 1	18.07.1980	SLV – 3	INDIA
RS – D1	31.05.1981	SLV – 3	INDIA
APPLE	19.06.1981	ARIANE	FRANCE
BHASKARA – 2	20.11.1981	INTER COSMOS	RUSSIA
INSAT – 1A	10.04.1982	US DELTA	USA
RS – D2	17.04.1983	SLV – 3	INDIA
INSAT – 1B	30.08.1983	SPACE SHUTTLE	USA
SROSS – 1	24.03.1987	ASLV	INDIA
IRS – 1A	17.03.1988	VOSTOK	RUSSIA
SROSS – 2	13.07.1988	ASLV	INDIA
INSAT – 1C	22.07.1988	ARIANE	FRANCE
INSAT – 1D	12.06.1990	US DELTA	USA
IRS – IB	29.08.1991	VOSTOK	RUSSIA
SROSS – C	20.05.1992	ASLV	INDIA
INSAT – 2A	10.07.1992	ARIANE	FRANCE
INSAT – 2B	23.07.1993	ARIANE	FRANCE
IRS – 1E	20.09.1993	PSLV	INDIA
SROSS – C2	04.05.1994	ASLV	INDIA
IRS – P2	15.10.1994	PSLV	INDIA
INSAT – 2C	07.12.1995	ARIANE	FRANCE
IRS – 1C	28.11.1995	MOLNIA	RUSSIA
IRS – P3	21.03.1996	PSLV	INDIA
INSAT – 2D	04.06.1997	ARIANE	FRANCE
IRS – 1D	29.09.1997	PSLV – C1	INDIA

INSAT – 2E	03.04.1999	ARIANE	FRANCE
IRS – P4	26.05.1999	PSLV – C2	INDIA
INSAT – 3B	22.03.2000	ARIANE	FRANCE
GSAT – 1	18.04.2001	GSLV – D1	INDIA
INSAT – 3C	24.01.2002	ARIANE	FRANCE
KALPANA – 1	12.09.2002	PSLV – C4	INDIA
INSAT – 3A	10.04.2003	ARIANE	FRANCE
GSAT – 2	08.05.2003	GSLV – D2	INDIA
IRS – P6	17.10.2003	PSLV – C5	INDIA
EDUSAT	20.09.2004	GSLV – F01	INDIA
CARTOSAT – 1 & HAMSAT	05.05.2005	PSLV – C6	INDIA

Let us muse upon

- The branch of science which deals with the study of heavenly bodies is known as Astronomy.
- According to the geocentric theory, the earth is at the centre of the universe.
- According to the heliocentric theory, the sun is at the centre and the earth rotates on its axis around the sun.
- Kepler's laws

  (i) Each planet moves around the sun in an elliptical orbit with the sun at one of its foci.

  (ii) The line joining the sun and the planet sweeps out equal areas in equal intervals of time.

  (iii) The square of the period of the revolution of a planet around the sun is directly proportional to the cube of the mean distance between the planet and the sun.
- The value of universal gravitational constant $G = 6.67 \times 10^{-11}\ Nm^2\ kg^{-2}$

- Asteroids are found between the orbit of Mars and Jupiter.
- A cluster of stars is called a galaxy.
- The nearest galaxy is Andromeda galaxy.
- The shape of our Milky Way galaxy is spiral.
- The distance travelled by light in one year is called a light year.
- Man made objects that revolve around the earth are called artificial satellites.
- Collection of information about an object without physical contact with it is known as remote sensing.
- The first satellite launched by India was Aryabhatta.
- The time period of geostationary satellites is 24 hours which is same as that of our earth.
- Comets develop a tail as they approach the sun.

Self evaluation

7.1 The geo-centric theory was proposed by
(a) Ptolemy (b) Copernicus
(c) Johannes Kepler (d) Newton

7.2 According to the law of periods
(a) $V \alpha r$ (b) $T \alpha r$ (c) $T^3 \alpha r^2$ (d) $T^2 \alpha r^3$

7.3 The value of universal gravitational constant G is
(a) $6.76 \times 10^{-11} Nm^2 kg^{-2}$ (b) $6.67 \times 10^{-11} Nm^{-2} kg^{-2}$
(c) $6.67 \times 10^{-11} Nm^2 kg^{-2}$ (d) $6.67 \times 10^{11} Nm^2 kg^{-2}$

7.4 The unit of G is ____________
(a) ms^{-2} (b) Nm^2 (c) $Nm^2 kg^{-2}$ (d) $Nm^{-2} kg^{-2}$

7.5 The objects which are found between orbits of Mars and Jupiter are
(a) meteors (b) meteorites (c) comets (d) asteroids

7.6 The shape of our galaxy is

(a) elliptical (b) spiral (c) irregular (d) none of the above

7.7 What is helio-centric theory?

7.8 What is geo-centric theory?

7.9 State Kepler's laws of planetary motion.

7.10 State the Universal law of gravitation.

7.11 Two students seated on a bench do not feel the gravitational force of attraction. Why?

7.12 What are asteroids?

7.13 Why is the moon not used for communication purpose?

7.14 Write a note on : a. Comet b. Meteor c. Meteorite

7.15 State Hubble's law.

7.16 What is a galaxy?

7.17 What are the uses of artificial satellites?

7.18 What is remote sensing?

7.19 What are called geostationary satellites?

7.20 Explain Big-bang theory.

7.21 Define light year.

7.22 Calculate the gravitational force of attraction between two bodies of masses 400 kg and 50 kg separated by a distance of 2 m.

Answers

7.1 **(a)** 7.2 **(d)** 7.3 **(c)** 7.4 **(c)** 7.5 **(d)**

7.6 **(b)** 7.22 **3.335×10^{-7} N**

LOGARITHMS

											Mean Differences								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	8	9	10
41	6128	6138	6419	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	8
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

LOGARITHMS

											Mean Differences								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	3	4	4	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	4	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	4	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	0	1	1	2	2	3	3	4	4
83	9191	9196	9201	9026	9212	9217	9222	9227	9232	9238	0	1	1	2	2	3	3	4	4
84	9243	9248	9253	9258	9263	9269	9274	9279	3284	9289	0	1	1	2	2	3	3	4	4
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	0	1	1	2	2	3	3	4	4
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	0	1	1	2	2	3	3	4	4
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9653	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	3	4

ANTILOGARITHMS

											Mean Differences								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	1	2	2	2
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	1	2	2	2
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	1	2	2	2
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	1	2	2	2
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	2	2	2	2
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	2	2	2	2
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	2	2	2	2
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	2	2	2	2
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	2	2	2	3
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	2	2	2	3
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	2	2	2	3
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	2	2	2	3
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	2	2	2	3
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	2	2	3	3
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	2	2	3	3
.15	1418	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	2	2	3	3
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	2	2	3	3
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	2	2	3	3
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	2	2	3	3
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	2	3	3	3
.20	1585	1589	1592	1596	1600	1603	1607	1611	1514	1618	0	1	1	1	2	2	3	3	3
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2	2	3	3	3
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	2	2	3	3	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	2	2	2	3	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	2	2	2	3	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	2	2	2	3	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	2	2	2	3	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	2	2	2	3	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	2	2	2	3	4	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1896	1991	0	1	1	2	2	2	3	4	4
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	2	2	2	3	4	4
.31	2042	2046	2051	2056	2061	2065	2075	2075	2080	2084	0	1	1	2	2	3	3	4	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	2	3	3	4	4
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	2	3	3	4	4
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3	3	4	4	5
.35	2239	2244	2249	2254	2259	2265	2265	2275	2280	2286	1	1	2	2	3	3	4	4	5
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3	3	4	4	5
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3	3	4	4	5
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3	3	4	4	5
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3	3	4	5	5
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3	3	4	5	5
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3	4	4	5	5
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	3	3	3	4	4	5	6
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3	4	4	5	6
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3	4	4	5	6
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3	4	5	5	6
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3	4	5	5	6
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3	4	5	5	6
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4	4	5	6	6
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4	4	5	6	6

ANTILOGARITHMS

											Mean Differences								
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4	4	5	6	7
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4	5	5	6	7
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4	5	5	6	7
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4	5	6	6	7
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4	5	6	6	7
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4	5	6	7	7
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4	5	6	7	8
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4	5	6	7	8
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4	5	6	7	8
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5	5	6	7	8
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5	6	6	7	8
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5	6	7	8	9
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5	6	7	8	9
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5	6	7	8	9
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5	6	7	8	9
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5	6	7	8	9
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5	6	7	9	10
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5	7	8	9	10
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6	7	8	9	10
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	4	6	7	8	9	10
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	3	4	6	7	8	9	11
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6	7	8	10	11
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6	7	9	10	11
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6	8	9	10	11
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6	8	9	10	12
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7	8	9	10	12
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7	8	9	11	12
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7	8	10	11	12
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	6	7	8	10	11	13
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7	9	10	11	13
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7	9	10	12	13
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8	9	11	12	14
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8	9	11	12	14
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8	9	11	13	14
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8	10	11	13	15
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	6	8	10	11	13	15
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8	10	12	13	15
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9	10	12	14	16
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9	11	12	14	16
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	6	7	9	11	13	14	16
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9	11	13	15	17
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9	11	13	15	17
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10	12	14	15	17
.93	8511	8531	8551	8570	8595	8610	8630	8650	8670	8690	2	4	6	8	10	12	14	16	18
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10	12	14	16	18
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10	12	15	17	19
.96	9120	9141	9162	9183	9204	9226	9247	9265	9290	9311	2	4	6	8	11	13	15	17	19
.97	9333	9354	9376	9394	9419	9441	9462	9484	9506	9528	2	4	7	9	11	13	15	17	20
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11	13	16	18	20
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11	14	16	18	20

NATURAL SINES

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	Mean Differences				
	0.0°	0.1°	0.2°	0.3°	0.4°	0.5°	0.6°	0.7°	0.8°	0.9°	1′	2′	3′	4′	5′
0°	0.0000	0017	0035	0052	0070	0087	0105	0122	0140	0157	3	6	9	12	15
1	0.0175	0192	0209	0227	0244	0262	0279	0297	0314	0332	3	6	9	12	15
2	0.0349	0366	0384	401	0419	0436	0454	0471	0488	0506	3	6	9	12	15
3	0.0523	0541	0558	0576	0593	0610	0628	0645	0663	0680	3	6	9	12	15
4	0.0698	0715	0732	0750	0767	0785	0802	0819	0837	0854	3	6	9	12	15
5	0.0872	0889	0906	0924	0941	0958	0976	0993	1011	1028	3	6	9	12	14
6	0.1045	1063	1080	1097	1115	1132	1149	1167	1184	1201	3	6	9	12	14
7	0.1219	1236	1253	1271	1288	1305	1323	1340	1357	1374	3	6	9	12	14
8	0.1392	1409	1426	1444	1461	1478	1495	1513	1530	1547	3	6	9	12	14
9	0.1564	1582	1599	1616	1633	1650	1668	1685	1702	1719	3	6	9	12	14
10°	0.1736	1754	1771	1788	1805	1822	1840	1857	1874	1891	3	6	9	11	14
11	0.1908	1925	1942	1959	1977	1994	2011	2028	2045	2062	3	6	9	11	14
12	0.2079	2096	2113	2130	2147	2164	2181	2198	2215	2233	3	6	9	11	14
13	0.2250	2267	2284	2300	2317	2334	2351	2368	2385	2402	3	6	8	11	14
14	0.2419	2436	2453	2470	2487	2504	2521	2538	2554	2571	3	6	8	11	14
15	0.2588	265	2622	2639	2656	2672	2689	276	2723	2740	3	6	8	11	14
16	0.2756	2773	2790	2807	2823	2840	2857	2874	2890	2907	3	6	8	11	14
17	0.2924	2940	2957	2974	2990	3007	3024	3040	3057	3074	3	6	8	11	14
18	0.3090	3107	3123	3140	3156	3173	3190	3206	3223	3239	3	6	8	11	14
19	0.3256	3272	3289	3305	3322	3338	3355	3371	3387	3404	3	5	8	11	14
20°	0.3420	3473	3453	3469	3486	3502	3518	3535	3551	3567	3	5	8	11	14
21	0.3584	3600	3616	3633	3649	3665	3681	3697	3714	3730	3	5	8	11	14
22	0.3746	3762	3778	3795	3811	3827	3843	3859	3875	3891	3	5	8	11	14
23	0.3907	3923	3939	3955	3971	3987	4003	4019	4035	4051	3	5	8	11	14
24	0.4067	4083	4099	4115	4131	4147	4163	4179	4195	4210	3	5	8	11	13
25	0.4226	4242	4258	4274	4289	4305	4321	4337	4352	4368	3	5	8	11	13
26	0.4384	4399	4415	4431	4446	4462	4478	4493	4509	4524	3	5	8	11	13
27	0.4540	4555	4571	4586	4602	4617	4633	4648	4664	4679	3	5	8	11	13
28	0.4695	4710	4726	4741	4756	4772	4787	4802	4818	4833	3	5	8	11	13
29	0.4848	4863	4879	4897	4909	4924	4939	4955	4970	4985	3	5	8	11	13
30°	0.5000	5015	5030	5045	5060	5075	5090	5105	5120	5135	3	5	8	11	13
31	0.5150	5165	5180	5195	5210	5225	5241	5255	5270	5284	2	5	7	10	12
32	0.5299	5314	5329	5344	5358	5373	5388	5402	5417	8432	2	5	7	10	12
33	0.5446	5461	5476	5490	5505	5519	5534	5548	5563	5577	2	5	7	10	12
34	0.5592	5606	5621	5635	5650	5664	5678	5693	5707	5271	2	5	7	10	12
35	0.5736	5750	5764	5779	5793	5807	5821	5835	5850	5864	2	5	7	9	12
36	0.5878	5892	5906	5920	5934	5948	5962	5976	5990	6004	2	5	7	9	12
37	0.6018	6032	6046	6060	6074	6088	6101	6115	6129	6143	2	5	7	9	12
38	0.6157	6170	6184	6198	6211	6225	6239	6252	6266	6280	2	5	7	9	11
39	0.6293	6307	6320	6334	6347	6361	6374	6388	6401	6414	2	5	7	9	11
40°	0.6428	6441	6455	6468	6481	6494	6508	6521	6534	6547	2	5	7	9	11
41	0.6561	6574	6587	6600	6613	6626	6639	6652	6665	6678	2	4	7	9	11
42	0.6691	6704	6717	6730	6743	6756	6769	6782	6794	6807	2	4	6	9	11
43	0.6820	6833	6845	6858	6871	6884	6896	6909	6921	6934	2	4	6	8	11
44	0.6947	6959	6972	6984	6997	7009	7022	7034	7046	7059	2	4	6	8	10

NATURAL SINES

	0′	6′	12′	18′	24′	30′	36′	42′	48′	54′	Mean Differences				
	0.0^0	0.1^0	0.2^0	0.3^0	0.4^0	0.5^0	0.6^0	0.7^0	0.8^0	0.9^0	1′	2′	3′	4′	5′
45^0	0.7071	7083	7096	7108	7120	7133	7145	7157	7169	7181	2	4	6	8	10
46	0.7193	7206	7218	7230	7242	7254	7266	7278	7290	7302	2	4	6	8	10
47	0.7314	7325	7337	7249	7361	7373	7385	7396	7408	7420	2	4	6	8	10
48	0.743	7443	7455	7466	7478	7490	7501	7513	7524	7536	2	4	6	8	10
49	1.7547	7559	7570	7581	7593	7604	7615	7627	7638	7649	2	4	6	8	9
50^0	0.7660	7672	7683	7694	7705	7716	7727	7738	7749	7760	2	4	6	7	9
51	0.7771	7782	7793	7804	7815	7826	7837	7848	7859	7869	2	4	5	7	9
52	0.7880	7891	9702	7912	7923	7934	7944	7955	7965	7976	2	4	5	7	9
53	0.7986	7997	8007	8018	8028	8039	8049	8059	8070	8080	2	3	5	7	9
54	0.8090	8100	8111	8121	8131	8141	8151	8161	8171	8181	2	3	5	7	8
55	0.8192	8202	8211	8221	8231	8241	8251	8261	8271	8281	2	3	5	7	8
56	0.8290	8300	8310	8320	8329	8339	8348	8358	8368	8377	2	3	5	6	8
57	0.8387	8396	846	8415	8425	8434	8443	8453	8462	8471	2	3	5	6	8
58	0.8480	8490	8499	8508	8517	8526	8536	8545	8554	8563	2	3	5	6	8
59	0.8572	8581	8590	8599	8607	8616	8625	8634	8643	8652	1	3	4	6	7
60^0	0.8660	8669	8678	8686	8695	8704	8712	8721	8729	8738	1	3	4	6	7
61	0.8746	8755	8763	8771	8780	8788	8796	8805	8813	8821	1	3	4	6	7
62	0.8829	8838	8846	8854	8862	8870	8878	8886	8894	8902	1	3	4	5	7
63	0.8910	8918	8926	8934	8942	8949	8957	8965	8973	8980	1	3	4	5	6
64	0.8988	8996	9003	9011	9018	9026	9033	9041	9048	9056	1	3	4	5	6
65	0.9063	9070	9078	9085	9092	9100	9107	9114	9121	9128	1	2	4	5	6
66	0.9135	9143	9150	9157	9164	9171	9178	9184	9191	9198	1	2	3	5	6
67	0.9205	9212	8219	9225	9232	9239	9245	9252	9259	9265	1	2	3	4	6
68	0.9272	9278	9285	9291	9298	9304	9311	9317	9323	9330	1	2	3	4	5
69	0.9336	9342	9348	9354	9361	9367	9373	9379	9385	9391	1	2	3	4	5
70^0	0.9397	9403	9409	9415	9421	9426	9432	9438	9444	9449	1	2	3	4	5
71	0.9455	9461	9466	9472	9478	9483	9489	9494	9500	9505	1	2	3	4	5
72	0.9511	9516	9521	9527	9532	9537	9542	9548	9553	9558	1	2	3	3	4
73	0.9563	9568	9573	9578	9583	9588	9593	9598	9603	9608	1	2	2	3	4
74	0.9613	9617	9622	9627	9632	9636	9641	9646	9650	9655	1	2	2	3	4
75	0.9659	9664	9668	9673	9677	9681	9686	9690	9694	9699	1	1	2	3	4
76	0.9703	9707	9711	9715	9720	9724	9728	9732	9736	9740	1	1	2	3	3
77	0.9744	9748	9751	9755	9759	9763	9767	9770	9774	9778	1	1	2	3	3
78	0.9781	9785	9789	9792	9796	9799	9803	9806	9810	9813	1	1	2	2	3
79	0.9816	9820	9823	9826	9829	9833	9836	9839	9842	9845	1	1	2	2	3
80^0	0.9848	9851	9854	9857	9860	9863	9866	9869	9871	9874	0	1	1	2	2
81	0.9877	9880	9882	9885	9888	9890	9893	9895	9898	9900	0	1	1	2	2
82	0.9903	9905	9907	9910	9912	9914	9917	9919	9921	9923	0	1	1	2	2
83	0.9925	9928	9930	9932	9934	9936	9938	9940	9942	9943	0	1	1	1	2
84	0.9945	9947	9949	9951	9952	9954	9956	9957	9959	9960	0	1	1	1	2
85	0.9962	9963	9965	9966	9968	9969	9971	9972	9973	9974	0	0	1	1	1
86	0.9976	9977	9978	9979	9980	9981	9982	9983	9984	9985	0	0	1	1	1
87	0.9986	9987	9988	9989	9990	9990	9991	9992	9993	9993	0	0	0	1	1
88	0.9994	9995	9995	9996	9996	9997	9997	9997	9998	9998	0	0	0	0	0
89	0.9998	9999	9999	9999	9999	1.000	1.000	1.000	1.000	1.000	0	0	0	0	0

"Seek knowledge like a sinking star beyond the utmost bound of human thought." Strive ceaselessly success shall crown you gloriously.

Subrahmanyan Chandrasekhar

Success and achievement were not only in the genes of Subrahmanyan Chandrasekar, the Nobel Prize winner, for Physics in 1983, but also in the undeterred spirit of determination. Born on 19th October 1910, in Lahore, he was inspired by his Paternal uncle Sir C. V. Raman. He graduated from Presidency college and did his higher studies at the Trinity College, England in 1930. In 1936, he joined the staff at the University of Chicago and was honoured as Morton D Hull distinguished service professor of the university in 1952. In 1930, he proved that a star of a mass greater than 1.4 times that of the sun, ends its life by collapsing into an object of enormous density. This limit is known as Chandrasekhar's limit. He had published 400 papers. Theory of radioactive transfer, quantum theory of the negative ion of hydrogen (1943 - 1950), Mathematical black holes (1971 -1983) and Theory of Colliding gravitational waves are a few important research work carried out by him.

Subrahmanyan Chandrasekhar

He remained active until the evening of his life and published, "Newtons Principia for the common Reader (1995)". He died on 21st August 1995 in Chicago, Illinois, USA. He has left behind his paths, to be treaded upon by the young challenging minds.

Chandrasekhara Venkataraman

The life and achievements of the illustrious Indian Physicist and Nobel Prize Awardee, C.V. Raman are an orifice for today's generation to explore greater depths, in the field of science, at large and Physics in particular. C.V. Raman was bron on November 7, 1888 in Tiruchirapalli. He graduated himself in Physics and English in the highest distinctions. He won the Nobel Prize for his work on the scattering of light and for the discovery of the Raman effect. He was the first Indian scholar to receive the Nobel Prize with an Indian Education. In 1934, he was the Director of the Indian Institute of Science, Bangalore and became the first National Professor of Independent India. He had published journals and delivered lectures about Dynamical Theory of the motion of Bowed strings (1914) Aspects of Science (1948) and Physical Optics (1959). In 1949 he established the Raman Research Institute in Banglore. He was knighted in 1929 and received the Bharat Ratna in 1954. India celebrates National Science Day on the 28th February to commemorate the discovery of the Raman effect. Raman died at the age of 82 on November 21, 1970.

Sir C.V. Raman

A perusal of the lives of these Indian Scientists will certainly remind you that your progenitors have paved your way to scale greater scientific heights.

STD : X **Model question paper**

Science Paper – I

Physics

Max. marks : 50

Time : $1\frac{1}{4}$ hrs

I. Choose the correct answer and write it against the question number in your answer book. (10 x 1 = 10)

1. A man carrying a cement bag on his back up a slope will

   (a) lean backward (b) lean forward

   (c) walk straight (d) lean towards his left.

2. The wavelength of Chennai A broadcasting station is 60 m. At what frequency does Chennai A broadcast?

   (a) 3000 kHz (b) 4000 kHz

   (c) 5000 kHz (d) 6000 kHz

3. The input voltage of a transformer whose turns ratio 40 is 6 volt. The output voltage is

   (a) 6 V (b) 40 V

   (c) 120 V (d) 240 V

4. Which of the following is based on electromagnetic induction ?

   (a) transformer (b) galvanometer

   (c) loudspeaker (d) motor

5. The unit of stress is

   (a) N m (b) N m^{-1}

   (c) N m^{-2} (d) N s^{-1}

6. A chain reaction is possible when the mass of the fuel is greater than

   (a) proton mass (b) neutron mass

   (c) electron mass (d) critical mass

7. In a Nuclear reactor the fissionable material is

(a) ${}_{92}U^{232}$ (b) ${}_{92}U^{235}$ (c) ${}_{90}Th^{234}$ (d) ${}_{94}Pu^{235}$

8. Natural radioactivity occurs in elements of atomic number greater than

(a) 28 (b) 82
(c) 52 (d) 40

9. The objects which are found between orbits of Mars and Jupiter are

(a) meteorites (b) asteroids
(c) comets (d) meteors

10. The ratio of the velocities with which two galaxies move away from the earth is 2:3. The ratio of their distances is

(a) 3 : 2 (b) 2 : 3
(c) 4 : 9 (d) 9 : 4

II. Answer any five of the following questions in one or two sentences:
(5 x 2 = 10)

11. Define angular momentum.

12. What is the energy of a photon of frequency 7.5×10^{14} Hz ?

13. The magnetic flux linked with a coil changes from 0.3 Wb to zero in 1.2 second. Calculate the induced emf.

14. State Fleming's left hand rule.

15. Why does a person standing in a railway platform tend to fall towards the moving train?

16. How does the surface tension vary with temperature?

17. Find the nuclear radius of ${}_{13}A\ell^{27}$.

18. What is the principle involved in the production of X-rays?

19. State Newton's universal law of gravitation.

III. Answer any five of the following questions (5 x 3 = 15)

20. Compare the motion of a freely falling body with that of a projectile.

21. Derive the relation between linear velocity and angular velocity.

22. Caluculate the momentum of a particle associated with de Broglie wave of wavelength 2 $\mathring{A}$.

23. What is photoelectric effect? On what factors does the photoelectric current depend?

24. Find the cost of using a 1500 W immersion heater and a 700 W electric iron for 30 minutes per day for 30 days, at the cost of Rs. 2 per unit.

25. Distinguish between streamline flow and turbulent flow.

26. Define reproduction factor. Give its significance.

27. Write any three properties of X-rays.

28. What are meteors and meteorites?

IV. Answer any three of the following questions (3 x 5 = 15)

29. A force of 150 N is required to break a 3m long nylon cord. An object of mass 1.2 kg is fixed to one end of the cord and whirled around. Determine the maximum speed with which it can be whirled around without breaking the cord.

30. Explain Raman effect and write its applications.

31. List the parts of a D C generator and describe its working with a neat diagram.

32. Explain the various energies possessed by a liquid that flows through a pipe.

33. Describe Rutherford's α - particle scattering experiment and write the inferences.

34. Write the uses of Radio - isotopes.

PRACTICAL

List of experiments

1. Using simple pendulum determine the acceleration due to gravity in the laboratory.

2. Determine the melting point of wax by plotting cooling curve.

3. Determine the focal length of the given convex lens.

4. Determine the weight of the given solid using the principle of moments.

5. Determine the relative density (specific gravity) of a liquid using a test-tube float as a constant immersion hydrometer.

6. Verify the first law of transverse vibration of a stretched string using sonometer.

7. Determine the refractive index of the material of the given glass prism.

8. Determine the specific resistance of the material of a given wire.

1. SIMPLE PENDULUM

Aim

To determine the acceleration due to gravity using a simple pendulum.

Apparatus required

A vertical stand with clamps, a metal bob with a hook, an inelastic thread, split halves of a rubber cork, a metre scale, a stop-clock and two wooden blocks.

Formula

Acceleration due to gravity $g = 4\pi^2 \frac{\ell}{T^2}$

where $\pi = 3.14$

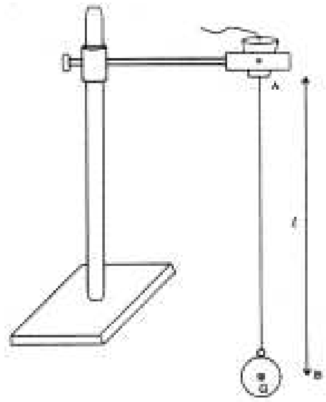
ℓ = length of the pendulum

T = time period of oscillation

Procedure

A metal bob is tied to one end of a light inextensible thread. Its other end passes between two halves of a split cork held tightly in a clamp of vertical stand. The length of the simple pendulum is measured from the lower end of split cork to the centre of the bob. It is noted as 'ℓ'. The equilibrium position of the pendulum is noted as the mean position. The bob is drawn to one side and it is released so that the pendulum oscillates to and fro in a vertical plane. When the bob crosses the mean position towards one side, the stop clock is started and it is counted as zero. Next time when the bob crosses the mean position towards the same side it is counted as one oscillation. Thus the time taken for 10 oscillations is noted, from which the time period of oscillation is calculated as T. The experiment is repeated for various lengths and in each case the time period is found.

The value of ℓ and the corresponding time period T are tabulated. $\frac{\ell}{T^2}$ is calculated for each trial. The mean value of $\frac{\ell}{T^2}$ is calculated. The value of acceleration due to gravity is calculated using the formula $g = 4\pi^2 \frac{\ell}{T^2}$ by substituting the mean value of $\frac{\ell}{T^2}$



simple pendulum

Tabulation - to determine $\frac{\ell}{T^2}$

Trial No	Length of the pendulum ℓ cm	Time for 10 oscillations second			Time for one oscillation T sec	T^2 sec^2	$\frac{\ell}{T^2}$ cm s^{-2}
		trial 1	trial 2	mean			
1							
2							
3							
4							
5							

Mean $\frac{\ell}{T^2}$ =

Result

The value of acceleration due to gravity g = ms^{-2}

2. MELTING POINT OF WAX

Aim

To determine the melting point of wax by the cooling curve method.

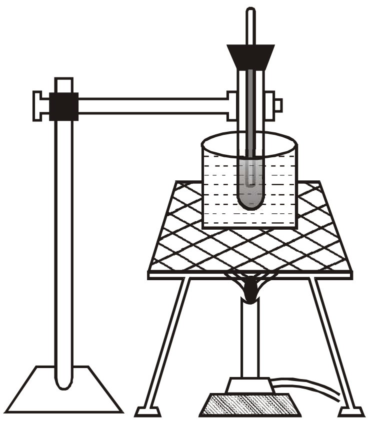
Apparatus required

A hard glass tube or a boiling tube, a thermometer, vessel containing water (water-bath), a bunsen burner, tripod stand, wire gauze, stop clock and wax pieces.

Procedure

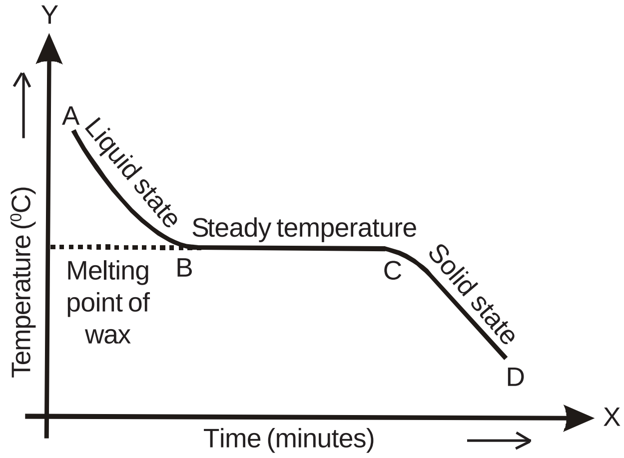
A boiling tube with scraped pieces of wax is taken. A sensitive thermometer is introduced in it. Now the boiling tube is clamped to a retort stand, so that the tube is immersed into a trough containing boiling water. The solid wax gradually starts melting into a liquid. When the solid wax is completely melted boiling tube is removed from the trough along with the stand. Now the wax is allowed to cool. The temperature of the molten wax is noted down for every 30 second till the temperature reaches 50°C.

A graph is drawn with time along the x-axis and temperature along the y-axis. The temperature corresponding to the horizontal portion (BC) of the graph gives the melting point of wax.



melting point of wax

Graph



Tabulation

Time (minutes)	Temperature (^0C)
0	
$\frac{1}{2}$	
1	50°C

Result

The melting point of wax by the cooling curve method = °C

3. FOCAL LENGTH OF CONVEX LENS

Aim

To determine the focal length of convex lens by

(i) distant object method

(ii) plane mirror method

(iii) u-v method and

(iv) graphical method

Apparatus required

The given convex lens, lens stand, white screen, metre scale, an illuminated wire gauze and a plane mirror.

Formula

Focal length of the convex lens by u - v method $f = \frac{uv}{u+v}$

where u = distance between the lens and the object.

v = distance between the lens and the image.

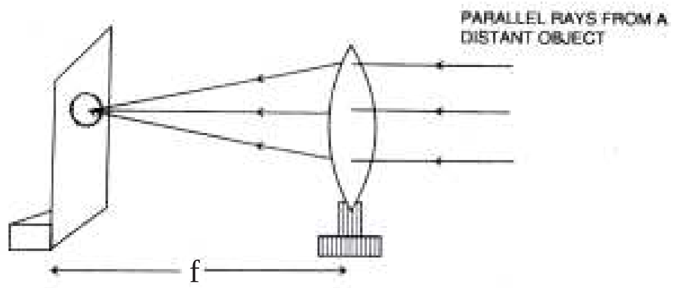
Procedure

(i) Distant object method

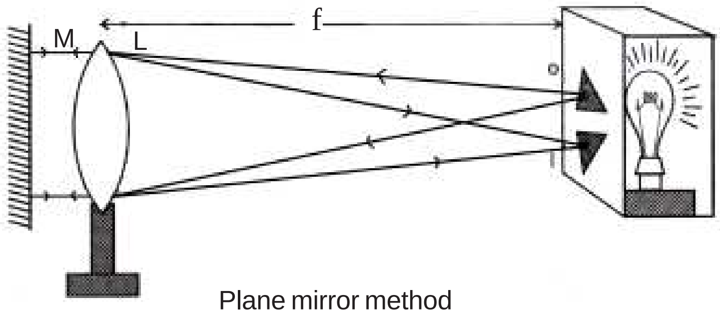
The convex lens is mounted on the stand and is kept facing a distant object (may be a tree or a building). The white screen is placed behind the convex lens and its position is adjusted to get a clear, diminished and inverted image of the object. The distance between the convex lens and the screen is measured. This gives an approximate value of the focal length of the convex lens.

(ii) Plane mirror method

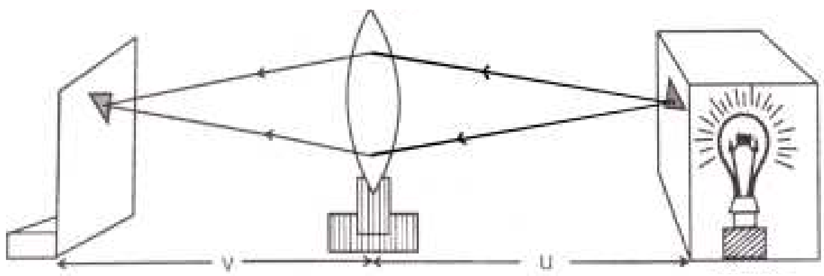
The given convex lens is mounted on the lens stand and placed in front of the illuminated wire gauze at the same level. A plane mirror is held close behind the lens and its reflecting side faces the lens. The plane mirror and convex lens are moved close to the wire gauze, till a clear image is obtained on the box by the side of the wire gauze. The distance between the lens and illuminated wire gauze gives the focal length of the convex lens



Distant object method



Plane mirror method



Focal length of the Convex lens - u-v method

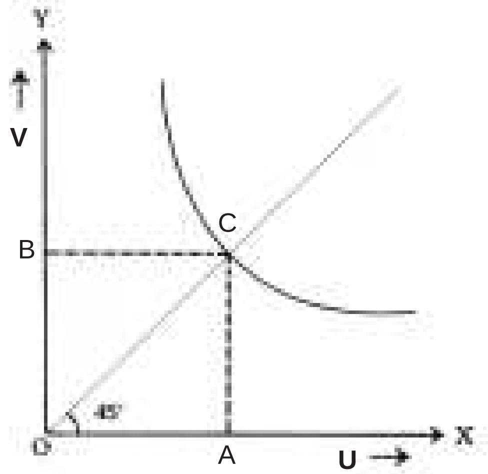
(iii) U-V method

The convex lens is mounted on the stand and placed in front of the illuminated wire gauze at a certain distance 'u' from the wire gauze. Two values of 'u' are chosen between f and 2f of the lens and the other two values of u are chosen above 2f. A screen is placed on the other side of lens and its distance from the lens is adjusted to get a clear image. The value of 'u' less than 2f will produce an enlarged image and that greater than 2f will produce a diminished image. The distance between the lens and the screen is taken as 'v' and it is measured for each experimental value of 'u'.

The focal length of the convex lens is calculated using the formula,

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

(iv) Graphical method



u-v graph

A graph is drawn taking the same origin and the same scale with 'v' along the y-axis and u along the x-axis. The bisector drawn to the angle at origin cut the u – v graph at C. From C perpendiculars are drawn to both the axes.

The intercepts OA along x – axis and OB along y – axis are noted. The focal length of the lens is calculated as

$$f = \frac{OA}{2} = \frac{OB}{2}$$

Observation

The focal length of the convex lens by

(i) Distant object method $f =$ ________ $\times 10^{-2}$ m

(ii) Plane mirror method $f =$ ________ $\times 10^{-2}$ m

Tabulation

U-V method

Trial No	Nature of image	Object distance u cm	Image distance v cm	focal length $f = \frac{uv}{u+v}$ cm
1 2	Real, inverted and magnified $u < 2f$			
3 4	Real, inverted and diminished $u > 2f$			

Result mean f =

The focal length of the convex lens by

(i) distant object method $f =$ ________ $\times 10^{-2}$ m

(ii) plane mirror method $f =$ ________ $\times 10^{-2}$ m

(iii) u – v method $f =$ ________ $\times 10^{-2}$ m

(iv) graphical method $f =$ ________ $\times 10^{-2}$ m

4. PRINCIPLE OF MOMENTS

Aim

To determine the weight of a given solid using principle of moments.

Apparatus required

Metre scale, slotted weights, the given solid of unknown weight and a knife-edge fixed on a vertical stand.

Principle

When a rigid body is in equilibrium under the action of number of parallel forces, then the sum of the clockwise moments is equal to the sum of the anticlockwise moments.

Formula

$$w_1 = \frac{w_2\, d_2}{d_1}$$

w_1 = unknown weight.
w_2 = weight suspended (slotted weight).
d_1 = distance between the centre of gravity and the unknown weight.
d_2 = distance between the centre of gravity and the slotted weights.

Procedure

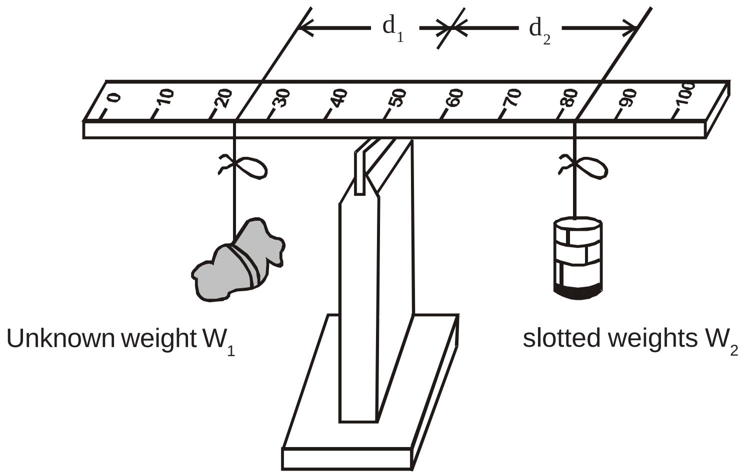
The metre scale is balanced on the knife-edge of the vertical stand so that it is horizontal. The balancing point is its centre of gravity. The solid whose weight is to be found is suspended at a fixed distance, say 25 cm from the centre of gravity by means of a twine. The slotted weights (w_2) are suspended on the other side of the knife-edge with the help of a twine. This position is adjusted till the scale attains horizontal position. The distance between the point of suspension of the known weights (slotted weights) and the centre of gravity is measured as d_2.

If w_1 is the unknown weight of the solid, then by the principle of moments

$$w_1\, d_1 = w_2\, d_2$$

$$w_1 = \frac{w_2\, d_2}{d_1}$$

Thus the unknown weight of the solid w_1, is calculated. The experiment is repeated for different values of the known weight w_2. The calculations are done for every trial. The average value of w_1 is found. This gives the weight of the given solid.



Principle of moments

Tabulation

Trial No	Known weight w_2 g wt	Distance of the unknown weight d_1 cm	Distance of the slotted weights d_2 cm	Weight of the solid $w_1 = \frac{w_2 d_2}{d_1}$ g wt
1				
2				
3				
4				
5				

mean w_1 =

Result

The weight of the given solid using principle of moments w_1= x 10^{-3} kg wt

5. CONSTANT IMMERSION HYDROMETER

Aim

To determine the specific gravity or relative densityof a liquid using a test tube float as a constant immersion hydrometer.

Apparatus required

A test tube float, lead shots or sand, two tall jars containing water and the given liquid and a spring balance.

Formula

$$\text{Specific gravity or relative density of the liquid} = \frac{\text{weight of the float in liquid}}{\text{weight of the float in water}}$$

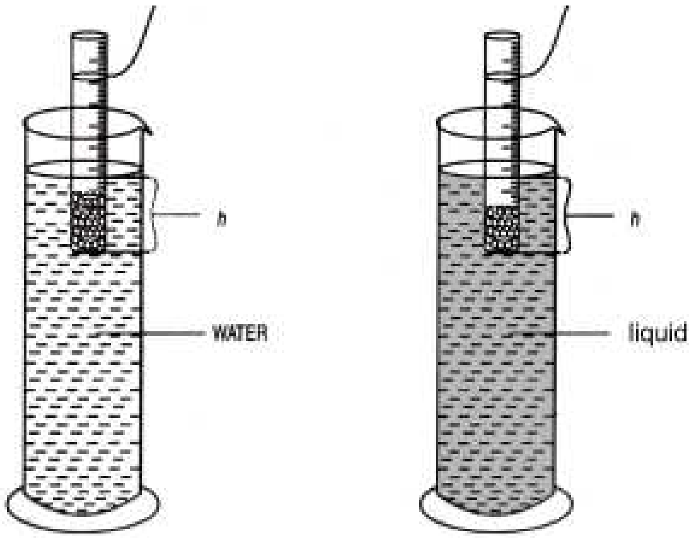
$$= \frac{w_2}{w_1}$$

Procedure

The test tube is made to float in water vertically to a certain depth by adding sand or lead shots. The depth of immersion of the float in water is noted as 'h'. The float should not touch the bottom or sides of the jar and there should be no air bubbles sticking to its sides. The test tube is taken out and its outer surface is wiped off. Then it is suspended from the hook of a spring balance and its weight in water is noted as w_1 g wt. Then it is allowed to float to the same depth 'h' in the given liquid by adding or removing lead shots. Its outside is wiped dry and again its weight in the liquid is found using a spring balance as w_2 g wt.

The experiment is repeated by varying the depth of immersion 'h'. The readings are tabulated. The specific gravity of the liquid using the test tube float as a constant immersion hydrometer is calculated using the formula,

$$\text{Specific gravity or relative density of the liquid} = \frac{w_2}{w_1}$$



test tube float

Tabulation

Trial No	Depth of the immersion of float h cm	Weight of the float		Specific gravity of the liquid $\frac{w_2}{w_1}$
		in water w_1 g wt	in liquid w_2 g wt	
1				
2				
3				
4				
5				

mean $\frac{w_2}{w_1}$ =

Result

The specific gravity of the liquid using the test tube float as a constant immersion hydrometer = ________ (no unit)

6. SONOMETER

Aim

To verify the first law of transverse vibrations in stretched string using sonometer.

Apparatus required

Sonometer, tuning fork, rubber hammer, slotted weights and paper rider.

Law

The frequency of the vibration is inversely proportional to length of the vibrating segment.

Formula

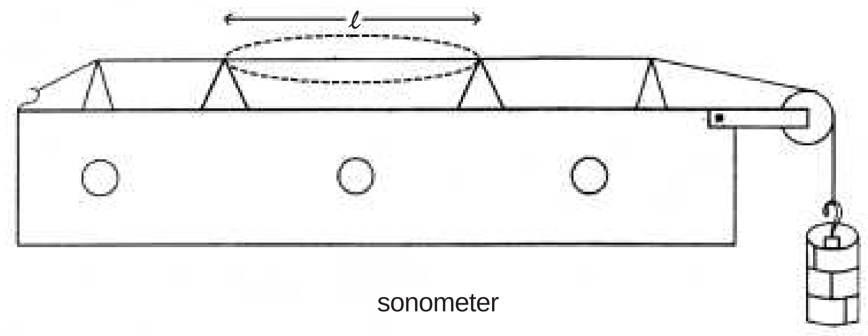
$$n\ell = \text{constant (tension of the wire is kept constant).}$$

where n = frequency of the resonating wire.
(i.e. the frequency of the tuning fork)
ℓ = length of the resonating wire.

Procedure

The sonometer wire is kept under tension by a suitable load, say 3 kg. A small paper rider is placed on the wire between the movable bridges. A tuning fork of known frequency 'n' is excited by striking it gently with a rubber hammer. It is then placed with the stem on the sonometer box. Now the wire segment between the movable bridges will vibrate. By moving one movable bridge gently, the length of the vibrating segment is adjusted till the paper rider flutters violently and is thrown off. (If the tuning fork stops vibrating, it is again excited and placed on the sonometer box). At this stage resonance is said to occur (i.e.) the frequency of the tuning fork is equal to the frequency of the vibrating segment.

The length of the wire between the two movable bridges gives the resonating length 'ℓ'. Keeping the tension constant, the experiment is repeated with tuning forks of different frequencies and the corresponding resonating lengths of the wire are found out as before. The values are tabulated and '$n\ell$' is found to be a constant



sonometer

Tabulation

S. No.	Frequency of the tuning fork n Hz	Resonating length ℓ cm	$n\ell$ x 10^{-2} Hz m
1			
2			
3			

Result

$n\ell$ = constant

Thus it is proved that the frequency is inversely proportional to the vibrating length.

7. REFRACTION THROUGH GLASS PRISM

Aim

To determine the refractive index of the material of the given glass prism.

Apparatus required

Glass prism, drawing board, sheets of white papers, instrument box, pins and board pins.

Formula

$$\mu = \frac{\text{Sin}\,\frac{A+D}{2}}{\text{Sin}\,\frac{A}{2}} \quad \text{(no unit)}$$

where

μ = refractive index of the glass prism

A = angle of the prism.

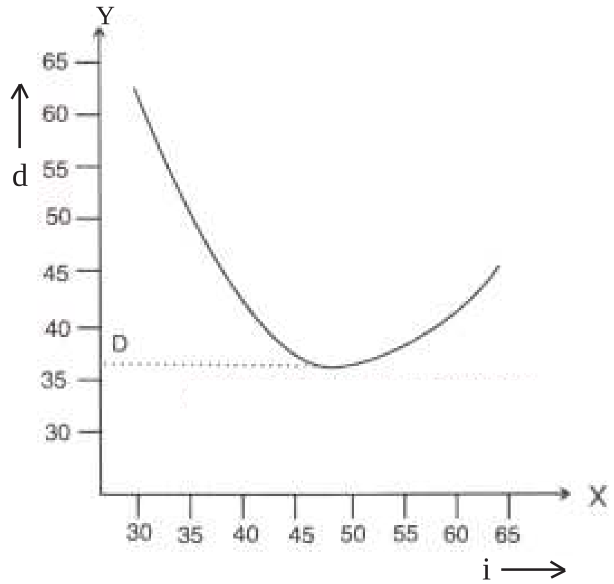
D = angle of minimum deviation.

Procedure

A sheet of white paper is fixed on a drawing board. The glass prism is placed on the paper and its outline ABC is drawn. The prism is removed. The point D is marked on the side AB (near its midpoint). A normal ED is drawn at D using a protractor. A line RD is drawn at an angle say 30^o to ED. This $\angle RDE=30^o$ is the angle of incidence and RD is the incident ray. Two pins P and Q are placed vertically on the line RD. Now the prism is placed on its outline. On looking through the face AC of the prism, the images of P and Q are seen. Two pins F and G are fixed vertically at two different positions, so that they lie in line with the images of P and Q. Now MN is the emergent ray. Produce the incident ray and the emergent ray backward into the outline of the prism. The two rays meet at a point O. The external angle formed at O is the angle of deviation 'd'. The experiment is repeated for different angle of incidence.

i-d graph

A graph is plotted taking 'i' along x - axis and 'd' along 'y' - axis. It is shown below:

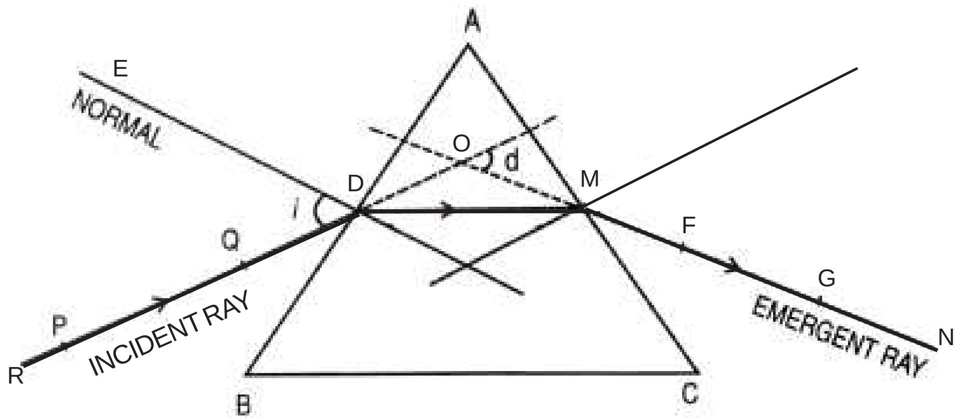


i-d curve

From the graph, it is seen that as the angle of incidence increases the angle of deviation decreases, reaches a minimum and then increases. This minimum value is called angle of minimum deviation, D.

Substituting the values of angle of the prism (A = 60^o) and the angle of minimum deviation (D), the refractive index of the material of the prism can be calculated using the formula,

$$\mu = \frac{\text{Sin}\,\frac{A+D}{2}}{\text{Sin}\,\frac{A}{2}}$$



Refraction through a glass prism

Tabulation

S. No.	Angle of incidence i	Angle of deviation d degree
1	30^o	
2	35^o	
3	40^o	
4	45^o	
5	50^o	

Result

The refractive index of the material of the prism μ = __________ (no unit)

8. SPECIFIC RESISTANCE OF A WIRE

Aim

To determine the specific resistance of the material of the wire (given the radius of the wire and the length of the wire).

Apparatus required

A battery eliminator, ammeter, voltmeter, key, rheostat, experimental wire and connecting wires.

Formula

Resistance of the wire $R = \frac{V}{I}$

Specific resistance of the wire $S = \frac{\pi r^2 R}{\ell}$

S = specific resistance of the wire

R = resistance of the given wire

r = radius of the given wire

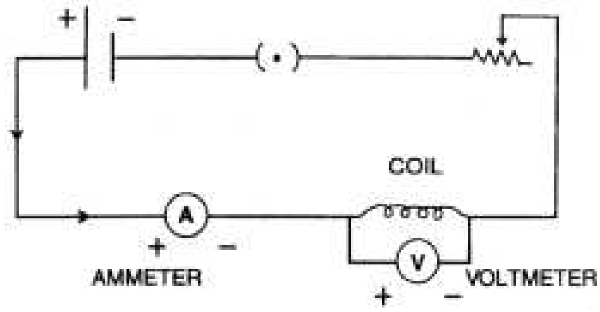
ℓ = length of the given wire

Procedure

Connect the battery eliminitor, ammeter the given wire, rheostat and key in series. The voltmeter is connected in parallel connection across the given wire. The circuit is closed and the rheostat is adjusted such that a constant current flows through the given coil of wire. The current is noted as 'I' from the ammeter and the potential difference across the wire V is noted from the voltmeter. The value $\frac{V}{I}$ gives the resistance of the wire. The experiment is repeated for different values of the current.

The average value of $\frac{V}{I}$ gives the resistance of the wire R.

The radius of the wire is given as 'r' metre. The length of the wire is given as 'ℓ' metre.



Specific resistance of the material of the wire is calculated using the formula

$$S = \frac{\pi r^2 R}{\ell}$$

Tabulation

To determine the resistance of the wire

Trial No	Ammeter reading I ampere	Voltmeter reading V volt	Resistance R = V/I ohm
1			
2			
3			
4			
5			

mean R =

Observations

length of the wire ℓ = x 10^{-2} m

radius of the wire r = x 10^{-2} m

resistance of the wire R = ohm

Specific resistance $S = \dfrac{\pi r^2 R}{\ell}$ ohm m

Result

Specific resistance of the material of the wire S = _______ ohm m.

Important Constants

Name	Symbol	Value
Speed of light	c	3×10^{8} m s^{-1}
Gravitational constant	G	6.67×10^{-11} Nm^{2} kg^{-2}
Acceleration due to gravity	g	9.8 ms^{-2}
Permittivity of free space	ε_o	8.854×10^{-12} C^{2} N^{-1} m^{-2}
Permeability of free space	μ_o	$4\pi \times 10^{-7}$ henry / metre
Charge of an electron	e	1.602×10^{-19} C
Mass of an electron	m_e	9.1×10^{-31} kg
Mass of a proton	m_p	1.67×10^{-27} kg
Mass of a neutron	m_n	1.675×10^{-27} kg
Planck's constant	h	6.625×10^{-34} Js

STD : X **SCIENCE PAPER – I** **Marks : 25**

Time : $1\frac{1}{2}$ hrs

SECTION A : PHYSICS PRACTICAL

MODEL QUESTION PAPER

1. Using simple pendulum determine the acceleration due to gravity in the laboratory. (atleast 4 readings)

   (or)

   Verify the first law of transverse vibration of a stretched string using sonometer. (atleast 3 readings)

2. Determine the melting point of wax by plotting cooling curve.

   (or)

   Determine the refractive index of the material of the given glass prism. (atleast 5 readings)

3. Determine the focal length of the given convex lens by u-v method. Verify by plane mirror method. (atleast 5 readings)

   (or)

   Determine the relative density (specific gravity) of a liquid using a test-tube float as a constant immersion hydrometer. (atleast 4 readings)

4. Determine the weight of the given solid using the principle of moments. (atleast 4 readings)

   (or)

   Determine the specific resistance of the material of a given wire. (atleast 4 readings)

5. Determine the relative density (specific gravity) of a liquid using a test-tube float as a constant immersion hydrometer. (atleast 4 readings)

   (or)

   Verify the first law of transverse vibration of a stretched string using sonometer. (atleast 3 readings)

6. Determine the specific resistance of the material of a given wire. (atleast 4 readings)

   (or)

   Determine the refractive index of the material of the given glass prism. (atleast 5 readings)

7. Verify the first law of transverse vibration of a stretched string using sonometer. (atleast 3 readings)

(or)

Determine the melting point of wax by plotting cooling curve.

8. Determine the weight of the given solid using the principle of moments. (atleast 4 readings)

(or)

Determine the melting point of wax by plotting cooling curve.

9. Determine the focal length of the given convex lens by u-v method. Verify by u-v graph method. (atleast 5 readings)

(or)

Determine the specific resistance of the material of a given wire. (atleast 4 readings)

10. Determine the focal length of the given convex lens by u-v method. Verify by u-v graph method. (atleast 5 readings)

(or)

Using simple pendulum determine the acceleration due to gravity in the laboratory. (atleast 4 readings)

Scheme for Evaluation

Record	–	5 marks
Formula	–	3 marks
Procedure	–	3 marks
Tabulation	–	2 marks
Observation	–	5 marks
Calculation	–	5 marks
Result	–	2 marks
Total	**–**	**25 marks**

BLUE PRINT

Science Theory Paper - Physics   Maximum Marks - 50   Time : 1¼ Hours

OBJECTIVES	KNOWLEDGE				UNDERSTANDING				APPLICATION				SKILL				TOTAL
	MCQ	VSA	SA	LA	MCQ	VSA	SA	LA	MCQ	VSA	SA	LA	MCQ	VSA	SA	LA	
Mechanics	1(1)	1(2)	1(3)				1(3)									1(5)	14
Light			1(3)									1(5)	1(1)	1(2)	1(3)		14
Electricity		1(2)			1(1)			1(5)					1(1)	1(2)	1(3)		14
Properties of Matter	1(1)		1(3)			1(2)		1(5)		1(2)							13
Modern physics				1(5)	2(1)						1(3)			1(2)			12
X - rays & radioactivity	1(1)	1(2)									1(3)	1(5)					11
Universe	1(1)	1(2)	1(3)										1(1)				7
	4	8	12	5	3	2	3	10		2	6	10	3	6	6	5	85

MCQ - Multiple Choice Question; VSA - Very Short Answer; SA - Short Answer; LA - Long Answer.

Note: Figures within brackets indicate marks & figures outside the brackets indicate the number of question.

Scheme of sections : MCQ VSA SA LA

Scheme of options : 10/10 5/9 5/9 3/6