A COMPREHENSIVE TEXTBOOK OF APPLIED PHYSICS

Prof. Manoj Kumar

A COMPREHENSIVE TEXT BOOK OF APPLIED PHYSICS

Prof. Manoj Kumar

ABHISHEK PUBLICATIONS
CHANDIGARH (INDIA)

ISBN : 978-81-8247-226-6
Copyright : Author
First Edition : 2009

Published by :
Abhishek Publications
SCO 57-59, Sector 17-C, Chandiharh.
Phone : 0172-5003768 Telefax : 0172-2707562
e-mail : abhpub@ yahoo.com, www.abhishekpublications.com

Printed at : Shiva Offset, Naveen Shahadra, Delhi

---**Syllabus**---

APPLIED PHYSICS-II

1. Waves and vibrations (8 hrs)

1.1 Waves, Generation of waves by vibrating particles.

1.2 Types of wave motion, transverse and longitudinal wave motion with examples

1.3 Relation between velocity of wave, frequency and wave length of a wave ($v = \eta\lambda$)

1.4 Simple harmonic motion: definition, expression for displacement, velocity, acceleration, time period, frequency in S.H.M.

1.5 Vibration of spring mass system, cantilever and determination of their time period.

1.6 Free, forced and resonant vibrations with examples

2. Applications of sound waves (8 hrs)

2.1 Acoustics of buildings-reverberation, reverberation time, echo, noise, coefficient of absorption of sound, methods to control reverberation time

2.2 Ultrasonics-Methods of production (magnetostriction and piezoelectric) and their engineering applications to cold welding, drilling, cleaning, flaw detection and SONAR

3. Principles of optics (8 hrs)

3.1 Review of concept of mirrors, lenses, reflection & refraction of light, refractive index, lens formula (no derivation), real and virtual image, magnification.

3.2 Power of lens

3.3 Simple and compound microscope, astronomical telescope, magnifying power and its calculation (in each case)

3.4 Total internal reflection, critical angle and conditions for total internal reflection.

4. Electrostatics (10 hrs)

4.1 Coulomb's law, unit charge

4.2 Gauss's Law

4.3 Electric field intensity and electric potential

4.4 Electric field of point charge, charged sphere, straight charged conductor, plane charged sheet

4.5 Capacitance, types of capacitors, capacitance of parallel plate capacitor, series and parallel combination of capacitors

4.6 Dielectric and its effect on capacitors, dielectric constant and dielectric

5. Current Electricity (8 hrs)

5.1 Ohm's law

5.2 Resistance of a conductor, specific resistance, series and parallel Combination of resistors, effect of temperature on resistance

5.3 Kirchhoff's laws, Wheatstone bridge principle and its applications
5.4 Heating effect of current and concept of electric power

6. Semi conductor physics (8 hrs)
6.1 Energy bands, intrinsic and extrinsic semi conductor, p-n junction diode and its characteristics
6.2 Diode as rectifier-half wave and full wave rectifier, semi conductor transistor pnp and npn (concept only)

7. Modern Physics (9 hrs)
7.1 Lasers: concept of energy levels, ionizations and excitation potentials; spontaneous and stimulated emission; lasers and its characteristics, population inversion, types of lasers, ruby laser and applications
7.3 Fiber optics: Introduction and applications

7.4 Super conductivity: Phenomenon of super conductivity, Type I and Type II super conductor and its applications

LIST OF PRACTICALS

1. To determine and verify the time period of cantilever by drawing graph between load and depression
2. To determine the magnifying power of a compound microscope
3. To determine the magnifying power of an astronomical telescope
4. To verify Ohm's law
5. To verify law of resistances in series
6. To verify law of resistances in parallel
7. To convert a galvanometer into an ammeter of given range
8. To convert a galvanometer into a voltmeter of a given range

CONTENTS

"This page is Intentionally Left Blank"

UNIT - 1

WAVES AND VIBRATIONS

INTRODUCTION :-

Sound waves, electromagnetic waves, mechanical waves etc are the waves which are used by us in our daily life. When we are watching Television or enjoying Radio programmes, every thing we see and hear is transmitted to us from the station through Radio or Electromagnetic waves produced by the stations.

The telephones are also based on the concept of waves. In a telephone we can hear the sound, as the energy moves from one point to another point, but there is no movement of the object and the message is transfered in the from of sound waves.

Another example of waves is, When we drop a stone in a pond of water, the water ripples, means the waves spread out on water surface around the point where the stone hits the water surface.

GENERATION OF WAVES BY VIBRATING PARTICLES :-

The particles of every medium have some elastic forces. When a particle of the medium is disturbed by giving him some energy, it gets displaced from its mean position. The disturbed particle begins to vibrate about its mean position and this is called simple harmonic motion (S.H.M.)

Let us consider, that a stone is dropped in a pond of still water. The water ripples or wave spreads out on the water surface around the point where the stone hits the water surface. As shown in fig. (1.1), the water ripples, spread away in the form of crests as shown by full circles, and troughs as shown with dotted circles. If bits of paper are thrown over the surface of water, it will be seen that they do not travel along with the waves from the point where the stone hits the water surface. The bits of paper only excute an up and down motions.This indicates that, whereas the waves are formed due to repeated periodic motion of water molecules, the water molecules do not move along with the waves.

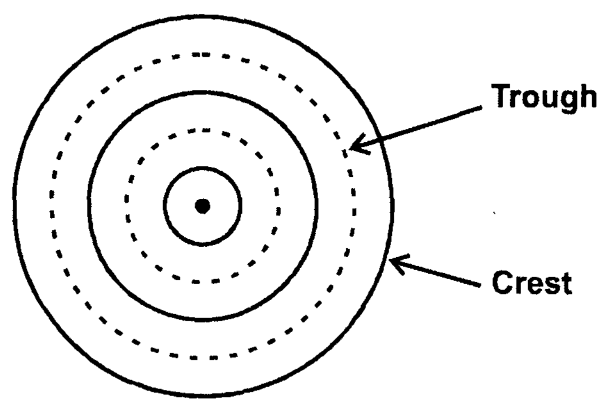


Fig (1.1)

Thus the disturbed water particles moves up and down again and again about their mean position and excute, this is known as S.H.M. This means that the particles transfer their energy to the next particle, thus resulting in generation of waves.

WAVE MOTION :-

"Wave motion is a form of disturbance, which travels through a medium due to the repeated periodic motion of the particles of the medium about their mean position.The motion being handed over from one particle to another is known as wave motion."

The waves which can be propagated only in a meterial medium are called Mechanical waves. e.g waves on water surface, sound waves etc.

The waves which require no material medium are called Non-mechanical wave e.g. light wave, X-rays, γ-rays, Radio waves, Microwaves & electromagnetic waves.

All the electromagnetic waves traveling through vaccum with the speed C is given by C = 3×10^8 m/sec.

Sometimes the wave motions are also knwon as progressive waves.

EXPLANATION OF WAVE MOTION :-

When we throw a stone in a pond of still water, it presses the particles of water underneath. As water possesses volume elasticity, the pressed particles tends to come back to the surface. The particles of the water acquire some velocity and over shoot the mark due to momentum and rise above the level of the rest of the water forming a crest, due to the gravitational pull of the earth the water in the rear positions and causing a depression forming a trough. These particles starts moving up and down and so on. Thus the disturbed water surface moves up and down again and again about their mean position and this excute is known as S.H.M. Thus the particles transfer their energy to next particle. If we place cork near the centre of disturbance at certain distance, we find that when the ripple reaches the cork, it will simply move the cork up and down and no movement of the cork takes places in the direction of propagation of the disturbance. This shows that it is only the distrubance which travels outwords,while the water particles keep on moving up and down and continue to transfer the motion to the neighbouring particles. Such a disturbance is called wave motion.

CHARACTERSTICS OF WAVE MOTION :-

The Characterstics of wave motion are given below :-

1. Wave motion is a disturbance travelling through a medium.
2. There is no bodily motion of the particles of the medium from one part to another. The particles of the medium execute vibrating about their mean positions.
3. The displacement of a vibrating particle of the medium is zero over one complete vibration.
4. For the propagation of wave motion, a material medium having properties of elastiity and inertia is essential.
5. There is a regular phase differance between the various particles of the medium.

6. The energy is propagated form one part of the medium to another, without any net transport of the meterial medium.
7. The distrubance from one particle reaches its next neighbouring particle a little later and as the disturbance reaches the neighbouring particle, it also starts executing vibration about its mean position.

TYPE OF MOTION :-

The wave motion is of two types namely transverse waves and longitudnal waves.

(1) LONGITUDNAL WAVES :-

"When the particles of a medium vibrate about their mean position in the directions of propagations of disturbance, the wave motion is called the longitudnal wave motion." as shown in fig. (1.2) (a)

Example, when a tuning fork is set to vibrate, its prong compresses the air medium in front of it. As a result a wave of compression progresses in the air horizontally, the particles of the air medium also execute periodic motion horizantally. Sound waves are longitudnal wave in nature.

A longitudnal wave travels in the form of Compressions and Rarefactions.

COMPRESSION :-

A compression is a region of the medium in which particles come closer to eachother than the normal distance between them as shown in fig. (1.2) (b).

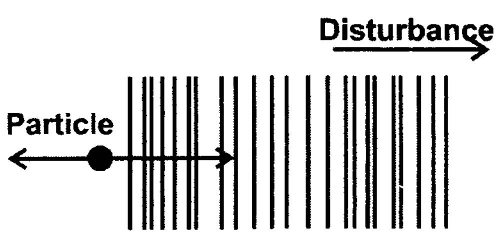


Fig (1.2) (a)

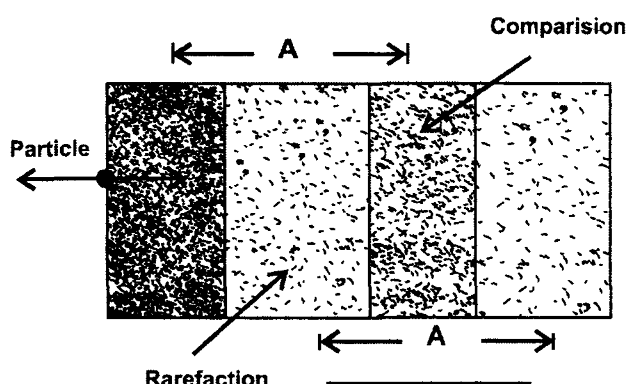


Fig (1.2) (b)

RAREFACTION :-

A rarefaction is a region of the medium, in which particles of the medium move apart from eachother than the normal distance between them as shown in fig. (1.2) (b)

PROPAGATION OF LONGITUDNAL WAVES :-

It has been already expalained that the particles of a medium in a longitudnal wave vibrate about their mean positions in the direction of the propagation of the disturbance and there are regions of compressions and rorefaction in it. Sound travels in the form of a longitudnal wave through air.

To explain the propagation of a longitudnal wave in a medium, we considered five particles of the medium placed at equal distance to each other, as shown by dotted lines in fig. (1.3). Let the wave travel from left to right .The particles are vibrating about their mean position in same direction of the waves. Let us suppose that the time period is T, so that the disturbance will take T/4 second to travel from one particle to the next.

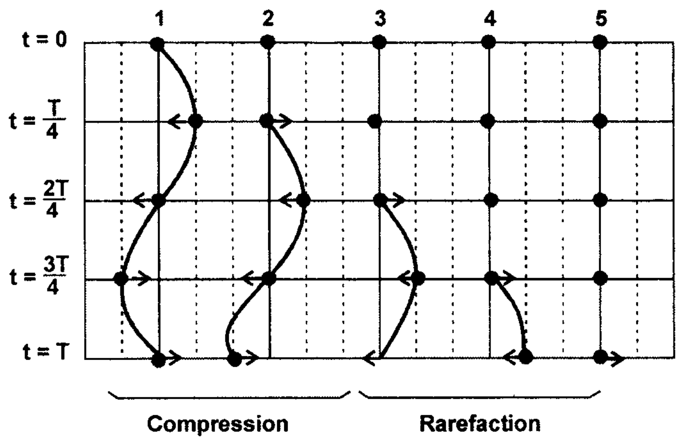


Fig (1.3)

As each particle vibrates about their mean position, its velocity goes on decreasing, as the displacement increases the velocity decreases and finally goes to zero at extreme positions.

Let the first particle be disturbed by a wave coming from its left side. So the first particle starts vibrating, going first to its right side and then coming back to the left. Let the time period of its motion be T sec. As the motion of the particle is S.H.M. so in T/4 sec, it must travel a distance more than half of its amplitude. It reaches its extreme position in T/2 sec and then it start moving towards its mean position but as the time passes by T/4 sec. from its start of the extreme posotion, it covers a distance less than half of its amplitude.

(i) At $t = 0$, all the particles are at rest and particle 1 is disturbed and it starts vibrating and moves towards right.

(ii) At $t = T/4$, Particle 1 completes T/4 of its vibration towards right and reaches its extreme position and disturbance reaches particle 2, but particles 3, 4 and 5 still in rest.

(iii) At $t = 2T/4$, Particle 3 will be disturbed but particle 4 and 5 still in rest.

(iv) At $t = 3T/4$, Particle 1 reaches its left extreme position and particle 2 reaches the mean position, particle 3 reaches its extreme position and hence particle 4 is just disturbed but particle 5 remains at rest.

(v) When t= T sec. At this time particles 1 completes its one vibration and reaches back to its mean position. Particles 2 reaches its left extreme position, in this way we can say that particles 3 come back to mean position.

Particle 4 goes to its right extreme position and causes a disturbence for particle 5. It vibrates towards right extreme position as shown in fig. (1.3)

Join all the relative points of all the particles at different times. As one cycle of vibration is complete, we find that the distance between the particles 1, 2 and 3 is less than their normal distance. This region between the particles 1, 2 and 3 are called compressions. The distance between particles 3, 4 and 5 is more than their normal distance then the region between the particles 3, 4 and 5 are called rarefaction.

PROPERTIES OF LONGITUDNAL WAVE :-

The following are the characterstic properties of longitudnal wave motion :-

(i) In a longitudnal wave motion the particles of the medium vibrate about their mean positions in the directions of the propagation of the waves.

(ii) The waves travel in the form of compressions and rarefactions.

(iii) There is a phase change from one particle to the next.

(iv) Particles move forward in a compression and backword in a rarefaction.

(v) There is a transfer of energy by the longitudnal waves.

(vi) Each particle starts vibrating a little later than it predecessor.

(ii) TRANSVERSE WAVE :-

"When the particles of the medium vibrate about their mean position in a direction perpendicular to the direction of propagation of disturbance, the wave motion is called transverse wave motion."

e.g if we fix a string at one end, a disturbance in the form of the pulse travels along the length of the string, it means that particles of the string vibrate along a direction perpendicular to the direction of the disturbance. The stretched string of Violin, Sitar, Sonometer etc. are execute transverse wave.

All electromagnetic waves are transverse in nature. In a transverse wave motion if the particles of the medium vibrate up and down then the disturbance travels horizontally as shown in fig. (1.4)

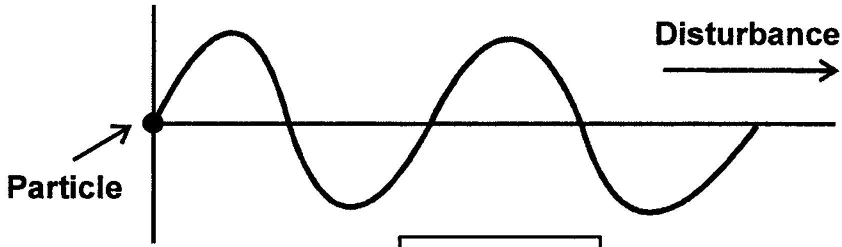


Fig (1.4)

Transverse waves travel in the form of crests and troughs. A crest is a position of the medium, which is highly raised above the normal position of rest of the particles of the medium when a transverse wave passes through it.

A trough is a portion of the medium, which is highly depressed below the normal positions of rest of the particles of the medium when a transverse wave passes through it.

PROPAGATION OF TRANSVERSE WAVE :-

To explain the propagation of a transverse wave, let us considered five particles of the medium placed at same distance as shown in fig. (1.5). Let us transfer a transverse wave travelling from left to right reaches the first S.H.M. at right angle to the direction of wave propagation.

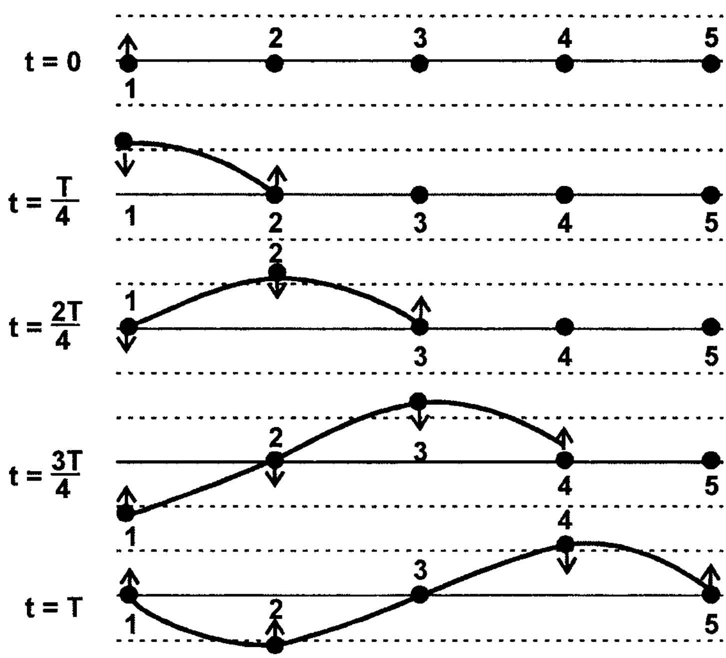


Fig (1.5)

Let us suppose that T be the time period of vibrating particle and disturbance travels from one to next particle in a time interval of T/4 sec.

(i) At $t = 0$, the disturbance has just reached the 1st particle and it is ready to move upwards as shown by the arrow. Whereas all the particle are in rest and at mean positions.

Thus in time T/4 sec. the first particle will reach the position of particle 2 covering a distance more than half of its amplitude. Because the particle is moving in S.H.M. and thus has maximum velocity, as the distance increase its velocity will be decrease and as it goes to extreme positon, its velocity fall to zero at that position.

(ii) At $t = T/4$, the disturbance from the particle 1 reaches to particle 2 and it is ready just ot move up. The particles 1 reaches at extreme position. Whereas particle 3, 4 and 5 are at rest.

(iii) At $t = 2T/4$, The particle1 complete its first half vibration and reach back its mean position. At the same time particle 2 will reach its extreme position and gives a disturbance to particle 3 which reaches its upper extreme position and gives a disturbance to particle 4, but particle 5 is still at rest.

(v) At $t = T$, 1st particle complete its one vibration and reaches back to mean position, particle 2 reaches at its lower extreme position, particle 3 reaches its mean position and particle 4 goes to upper extreme position and disturbance reaches particle 5 and it move towards upper extreme position.

Joining all the relative positions of the particles 1, 2, 3, 4 and 5 at different time. After complete time T, the particle 1, 3 and 5 are lying at their mean position. When the wave reaches particle 5, then particle 1 and 5 are in the same phase, means the position and direciton of the wave at particle 1 and 5 are the same. So particle 1 completes one vibration from 1 to 5 particle. Hence the highly raised portion or maximum diatance above the mean position is called crest and highly below portion or maximum distance below the mean position is called trough as shown in fig. (1.6)

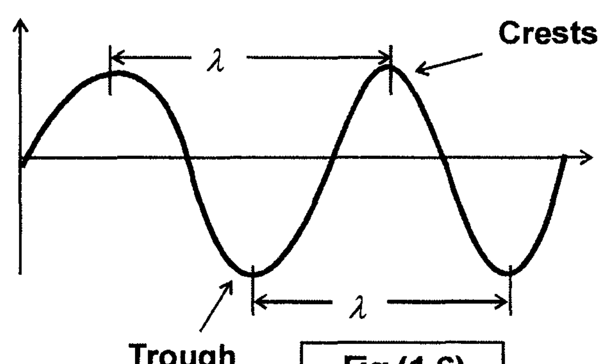


Fig (1.6)

PROPERTIES OF TRANSVERSE WAVE :-

The following are the characterstic properties of transverse wave :-

(i) In transvers waves, the particles vibrate about their mean position at right angles to the directions of propagation of the disturbance.

(ii) The amplitude and time period of the wave motion remains the same.

(iii) Every particles begins to vibrate a little later than its proceeding particles.

(iv) The transverse waves are in the form of crest and trough.

DIFFERENCE BETWEEN LONGITUDNAL AND TRANSVERSE WAVE :-

LONGITUDNAL WAVE	TRANSVERSE WAVE
1. In a longitudnal wave, the particles of the medium vibrate about their mean position in the same direction to the direction of the propagation.	1. In a transverse wave, the particles of the medium vibrate about their mean position at right angle to the direction of propagation.
2. longitudnal waves travel in the form of compressions and Rarefaction.	2. Transverse wave travel in the form of crests and troughs.
3. One copression and one rarefaction constitute one wave.	3. One crest and one trough constitute one wave.
4. longitudnal waves cannot be polarised.	4. Transveıse waves can be polarised.
5. There is a change of density of the medium which is higher in compression as compared to rarefaction.	5. There is no change of density of the waves.
6. Sound waves are longitudnal waves in nature.	6. Light waves or all electromagnetic waves are transverse in nature.

TERMS USED IN WAVE MOTION :-

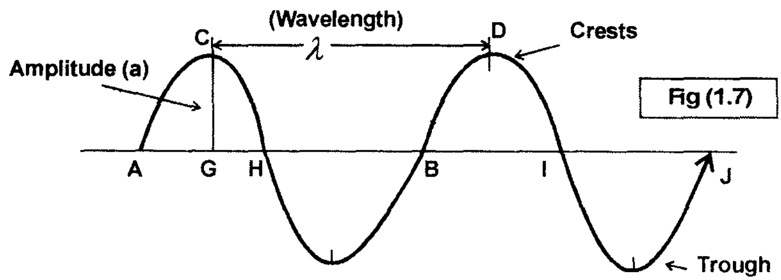
(i) WAVELENGTH :-

The distance between the two crests or two troughs is known as the wavelength.

(or)

It can also be defined as the distance travelled by the waves during a time when the vibrating particle of medium completes one rotation.

It is denoted by λ. So the distance AB = λ or CD = λ or EF = λ as shown in fig. (1.7) are the wavelength.



(ii) AMPLITUDE :-

The maximum displacement of the particle from its mean position is called amplitude. It is denotted by 'a'. In fig. (1.7) the amplitude is CG.

(iii) TIME PERIOD :-

It may be defined as the time taken by a wave or a particle to complete one cycle or one vibration.

It is represented by 'T'.

Thus in fig. (1.7), time taken by wave to complete one cycle from A to B.

(iv) FREQUENCY :-

It may be defined as the number of vibrations or cycles completed by a wave in one second.

It is denoted by 'n'.

$$\therefore\ n = \frac{1}{T} \text{ per sec.}$$

(v) PHASE :-

The phase of a vibrating particles at any given time is defined as, its state with regard to its position and direction of the motion at that time from fig. (1.5) we can say that particles 1 and 5 are in same phase, means they have a phase difference of 2T or T between them.

RELATION BETWEEN TIME PERIOD AND FREQUENCY :-

Let us take a particle having time period T sec, completes n vibrations in one second. So frequency is n vibrations in 1 sec.

So time taken by the particle to complete n vibrations = 1 second.

Time taken by the particle to complete 1 vibration is called time period T.

So,	$T = \frac{1}{n}$

or,	$n\,T = 1$

(vi) WAVE VELOCITY :-

It may be defined as the distance travelled by the wave per unit time. It is represented by 'v'.

RELATION BETWEEN WAVE VELOCITY, WAVELENGTH AND FREQUENCY :-

Let us suppose, ~~wave~~ wave velocity = v

frequency of the wave = n

wavelength = λ

By defination of wave velocity, the distance travelled by the wave per unit time is given by.

$$\text{wave velocity } v = \frac{\text{distance travelled}}{\text{time taken}} \text{---------(1)}$$

Now distance travelled by the wave is called wavelength (λ)

Time taken by the particle = T

$$\text{So equation becomes, } v = \frac{\lambda}{T} \text{--------(2)}$$

By using $T = \frac{1}{n}$ or $\frac{1}{T} = n$, putting in equation (2) we have.

$$v = n\lambda$$

i.e. Wave velocity = Frequency × Wavelength

DIFFERENCE BETWEEN SOUND WAVE & LIGHT WAVES :-

SOUND WAVE	LIGHT WAVE
1. Sound waves are Mechanical waves.	1. Light waves are Non-Mechanical.
2. The velocity of sound in air is 332m/sec.	2. Velocity of light in air is 3x(10)8 m/sec.
3. Sound wave cannot be polarised.	3. It can be polarised.
4. Sound waves are longitudnal in nature.	4. Light wave are transverse in nature.
5. Sound waves follow the relation between wavevelocity, wavelength and frequency $\nu = n\lambda$	5. Light waves follow the relation $C = n\lambda$, where c = velocity of light..
6. Sound waves require a material medium for propagation.	6. It doesnot requires any material medium.

EXAMPLE (1.1)

A tuning fork having a frequency of 512 produced a wave of 6.1 cm wavelength to air. Calculate velocity of sound in air.

SOLUTION :-

Given, frequency n = 512

wavelength (λ) = 67 cm

We know that, $\nu = n\lambda$

$\nu = 512 \times 67$

$\nu = 33404$ cm/sec. Ans.

EXAMPLE (1.2)

A tuning fork produced a sound wave of wavelength 68 cm. If the velocity of sound is 340 m/sec. What is the frequency of tuning fork ?

SOLUTION :-

Given, wavelength $\lambda = 68$ cm $\Rightarrow$ 0.68 m

Velocity of sound $\nu = 340$ m/sec

frequency (n) = ?

We know that, $\nu = n\lambda$

$$\therefore n = \frac{\nu}{\lambda}$$

$$\therefore n = \frac{340}{0.68} = 500 \text{ Hz} \quad \text{Ans.}$$

EXAMPLE (1.3)

The velocity of radio waves is 3×10^8 m/sec. find the wavelength of the wave having frequency of 500 kilo hertz.

SOLUTION :-

Given, velocity of radio waves $v = 3\times10^8$ m/sec.

frequency (n) = 500 KHz $\Rightarrow$ 500.00 Hz.

Wavelength (λ) = ?

We know that $v = n\lambda$

$$\therefore \lambda = \frac{v}{n}$$

$$\therefore \lambda = \frac{3\times10^8}{500\times1000} \Rightarrow 600 \text{ m} \quad \text{Ans.}$$

EXAMPLE (1.4)

How far does the sound in air Travel when a tuning fork of frequency 560 make 30 vibrations ? Given velocity of sound v = 330 m/sec.

SOLUTION :-

Given, velocity of sound V = 330 m/sec.

frequency (n) = 560 Hz.

By using, $v = n\lambda$

$$\therefore \lambda = \frac{\upsilon}{n} = \frac{330}{500} \Rightarrow .589 \text{ m}$$

So distance travelled in 30 vibration = 30 × wavelength

= 30 × .589

= 17.67 m Ans.

EXAMPLE (1.5)

A stone is dropped into a well 90 m deep. If the impact of sound is heard 4.56 second later. find the velocity of sound.

SOLUTION :- Given, distance S = 90 m

time t = ?

intial velocity u = 0

We know that, $S = ut + 1/2\ g t^2$

$$\therefore\ 90 = 0 + \frac{1}{2} \times 9.8 \times t^2$$

$$90 = 4.9\ t^2$$

$$\therefore\ t = 4.29 \text{ sec.}$$

Now time taken by sound to travel 90 m = 4.56-4.29 $\Rightarrow$ 0.27 Ans.

$$\text{velocity of sound} = \frac{\text{distance}}{\text{time}}$$

$$= \frac{90}{0.27} \Rightarrow 333.33 \text{ m} \qquad \text{Ans.}$$

EXAMPLE (1.6)

A body vibrating with a certain frequency sends wave 1.5 m long through a medium a and 2 m long through a medium B. The velocity of wave in a is 120 m/sec. fing the velocity in b.

SOLUTION :-

Given, Let us frequency of the body be = n

Wavelength in medium A = λ_1 = 1.5 m

Wavelength in medium B = λ_2 = 2 m

Velocity of medium A = v_1 = 120 m/sec.

Let velocity of medium in B = v_2

So we know that, $v = n\lambda$

for medium A, $v_1 = n\lambda_1$

$$\therefore n = \frac{v_1}{\lambda_1} \Rightarrow \frac{120}{1.5} \Rightarrow 80 \text{ Hz.}$$

So velocity of medium B, $v_2 = n\lambda_2$

$$\therefore v_2 = 80 \times 2, \quad v_2 = 160 \text{ m/sec.} \qquad \text{Ans.}$$

EXAMPLE (1.7)

The wavelength of hg green light is 5461 Å in vaccum. Find out the frequency if $C = 3 \times 10^8 m/sec$. Also find out the wave length of glass given μ for glass = 1.58

SOLUTION :-

Given, Wavelength of Hg light $\lambda = 5461$ Å $\Rightarrow 5641 \times 10^{-10} m$

Velocity of light in vaccum, $C = 3 \times 10^8 m/sec$

frequency (n) = ?

We know that $C = n\lambda$

$$\therefore n = \frac{C}{\lambda}$$

$$\therefore n = \frac{3 \times 10^8}{5641 \times 10^{-10}} = 5.494 \times 10^{14} \text{ Hz} \qquad \text{Ans.}$$

Now Given, refractive index of glass $\mu = 1.58$

Wavelength in glass = ?

Let velocity of light in glass = Cg

We know that, $\mu = \frac{v}{C}$

$$\text{So, } \mu = \frac{3 \times 10^8}{Cg}$$

$$\therefore Cg = \frac{3 \times 10^8}{Cg} \Rightarrow 1.9 \times 10^8 m/sec$$

So wavelength of glass, $\therefore \lambda = \frac{Cg}{n}$ $[\therefore v = n\lambda \text{ or } C = n\lambda]$

$$\therefore \lambda = \frac{1.9 \times 10^8}{5.494 \times 10^{-14}}$$

$\lambda = 3458$ Å Ans.

EXAMPLE (1.8)

A radio station broadcasts at a frequency of 12×10^6 Hz. **find out wavelength.**

SOLUTION :- Given, frequency (n) $= 12 \times 10^6$ Hz

Velocity of radio wave $v = 3 \times 10^8$ m/sec

Wavelength of radio wave $\lambda = ?$

We know that, $v = n\lambda$

$$\therefore \lambda = \frac{v}{n}$$

or $$\lambda = \frac{3 \times 10^8}{12 \times 10^6} \Rightarrow 25 \text{ m Ans.}$$

EXAMPLE (1.9)

A tuning fork is vibrating with a frequency of 400 hz. Find out wavelength of sound if velocity of sound in air is 300 m/sec.

SOLUTION :-

Given, frequency (n) = 400 Hz.

velocity of sound (n) = 300 m/sec.

We know that, $v = n\lambda$

$$\lambda = \frac{v}{n}$$

$$\therefore \lambda = \frac{300}{400} \Rightarrow 0.75 \text{ m} \quad \text{Ans.}$$

PERIODIC MOTION :-

A motion that repeats itself over and over again after a regular interval of time is called a periodic motion.

e.g. earth goes around the sun in the elliptical orbit ever and over again repeating the motion after every one year, motion of the bob of a simple pendulom, motion of hands of a clock etc.

OSCILLATORY MOTION :-

A motion in which a body moves back and forth repeatedly about a mean position is called oscillatory motion.

e.g motion of pendulom, the vibrations produced in the strings of a drum of tabla are also oscillatory. If the motion is periodic then it is called harmonic motion. Thus harmonic motion is periodic but periodic motion is not necessaraly harmonic.

SIMPLE HARMONIC MOTION :- (S.H.M.)

"A body is said to be in simple harmonic motion (S.H.M.) when its acceleration is directed towards a certain fixed point and is proportional to its desplacement from its mean position."

e.g the motion of bob of a simple pendulom, motion of liquid osicillating in u-tube, vibration of the prongs of a tuning fork are some example of simple harmour motion.

UNIFORM CIRCULAR MOTION :-

Let us consider a point P moving in a circle of radius r with constant angular velocity ω. The point P is called refrence point and the circle is called the circle of refrence. Let us draw a perpendicular PN on YOY′. as shown in fig. (1.8)

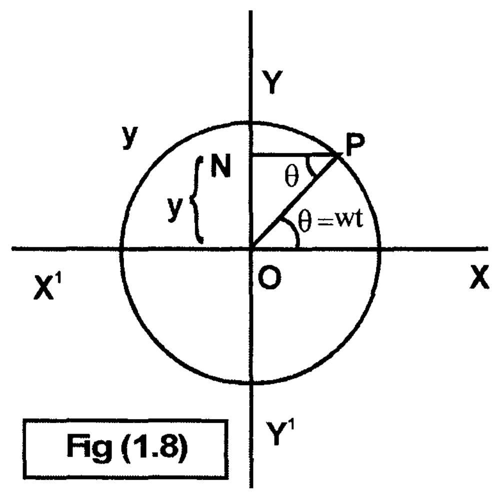


Fig (1.8)

As we move the point P from X to Y, the projection N also move from O to Y, when the particle moves from Y to X', the projection moves from Y to O and when we move from Y' to O. After completing one circle the projection point N moves also from Y to O, Y to Y' and then Y to O. Thus N always moves on Y-axis round the circle of reference.

"Hence simple harmonic motion is the projection of uniform circular motion on a diameter of the circle of reference."

A FEW DEFINATIONS :-

(i) DISPLACEMENT :-

The displacement of a particle at any instance is the distance of the oscillating particle from its mean position at that instance. In fig. (1.8) ON = Y, the displacement of the particle at any time t.

(ii) AMPLITUDE :-

The maximum displacement of the particle from the mean position to one extreme position is called amplitude. from fig. (1.8) OY = amplitude (a).

(iii) FINAL PERIOD :-

The time taken to complete one vibration is called time period. It is represented by T. from fig. (1.8), Let us consider a particle P moving in the circle with angluar velocity ω at an angle $\theta = \omega t$ and time period is T. then,

We know that, angular velocity $\omega = \dfrac{\text{angle covered in one rotation}}{\text{Time taken to complete one rotation}}$

$$\therefore \omega = \frac{2\pi}{T}$$

$$\text{or} \qquad T = \frac{2\pi}{\omega}$$

(iv) FREQUENCY :-

The number of vibrations compeleted in one second is called frequency. It is represented by 'n'.

Hence, $n = \dfrac{1}{T}$

We know that, $\omega = \dfrac{2\pi}{T}$

$\therefore \omega = 2\pi\ n$

CHARACTERSTICS OF SIMPLE HARMONIC MOTION :-

Now we shall discuss and derive the expression for displacement, velocity, acceleration, time period and frequency of S.H.M.

(i) EXPRESSION FOR DISPLACEMENT:

Considered a particle P is moving in an anticlockwise direction with uniform angular velocity ω along a circle whose centre is O and radius is r. Draw perpendicular PN on YOU' diameter. So that ON=y is called displacement of S.H.M. at any time t.

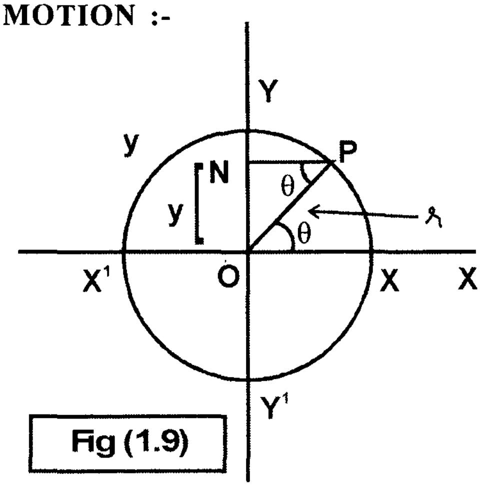


Fig (1.9)

Let us suppose that particle P move with on angle θ at O.

So that, $\angle POX = \theta = \angle NPO$

Now in ΔOPN, $\text{Sin}\,\theta = \frac{ON}{OP}$

$\therefore$ ON = OP Sin θ

y = r Sin θ [as ON =y, OP = r]

But $\theta = \omega t$, so $y = r\,\text{Sin}\,\omega t$ ------------(1)

If we drawn perpendiculor PN on diameter XOX' then we get,

$y = r\,\text{Cos}\,\theta$

$y = r\,\text{Cos}\,\omega t$ -----------(2)

Equation (1) and (2) are called equation of simple harmonic motion.

(ii) EXPRESSION FOR VELOCITY OF A PARTICLE EXECUTING SHM :-

Let us consider a particle P, moving in a circle with the radius r with uniform speed ν. The velocity of the particle at point P is given by the tangent drawn on it as shown in fig. (1.10). Now draw PN on YOY' Diameter.

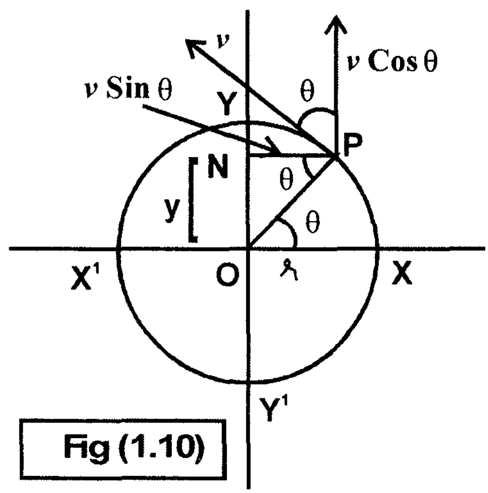


Fig (1.10)

The velocity of the particle resolved in to two components :-

(a) v Sin θ along Y axis or diameter YOY'

(b) v Sin θ along X-axis or diameter XOX'

Since vSin θ is perpendicular to the diameter YOU' and hence produces no effect on the motion of N. In other word we say that we take only those component who are in the same moving direction of the projection point N. Hence in both components only v Sin θ are Parallel or along in the direction of YOY or in some direction of moving of projection point N.

So velocity of N, V = v Cos θ

or $V = v\,\text{Cos}\,\omega t$ $(\therefore \theta = \omega t)$

Now $V = v\sqrt{1-\text{Sin}^2\omega t}$ ------(1) $[\because \text{Cos}\,\theta = \sqrt{1-\text{Sin}^2\theta}\,]$

Now by using $Y = r\ \text{Sin}\,\omega t$

$$\therefore \text{Sin}\ \omega t = \frac{y}{r}$$

Squaring both sides we get,

$$\text{Sin}^2\ \omega t = \left(\frac{y}{r}\right)^2$$

Now putting the value of $\text{Sin}^2\ \theta$ in equation (1) we get,

$$v = v\sqrt{1-\left(\frac{y}{r}\right)^2}$$

$$v = v\sqrt{\frac{r^2 - y^2}{r^2}}$$

$$\text{or } v = r\omega\sqrt{\frac{r^2 - y^2}{r}} \qquad (\therefore v = r\omega)$$

$$\text{or } v = \omega\ \sqrt{r^2 - y^2} \qquad \text{---------------(2)}$$

SPECIAL CASES :-

(a) WHEN PARTICLES ARE AT MEAN POSITION :-

If the particle P is at mean position means when it is lying at point O then Y=O so put Y= O in equation (2) weget,

$$v = \omega\sqrt{r^2 - 0}$$

$$v = \omega\sqrt{r^2}$$

$$v = \omega r$$

It is the maximum velocity at which the particle executes S.H.M.

$$\therefore\ V\max = r\omega$$

$$V\max = \frac{2\pi}{T}\ r \qquad \left[\therefore \omega = \frac{2\pi}{T}\right]$$

(b) WHEN PARTICLES ARE AT EXTREME POSITIONS :-

If the particle P lies at extreme position means at Y' then OY' = y or it is equal to radius hence y = r putting y = r in eq^n (2) we get,

$$v = \omega \sqrt{r^2 - r^2}$$

$$V = O$$

It takes clear that when particle is at extreme position the velocity of the S.H.M. is zero.

EXPRESSION FOR ACCELAERATION OF A PARTICLE EXECUTING S.H.M :-

The acceleration A (say) of the revoloving particle has a constant magnitude $\frac{u^2}{a}$ (centripetal accelaration) and is always directed towards the centre of the circle. So at time t when the revolving particle is at a point P the accelaeration (A) of the revolving particle acts as shown in fig. (1.11)

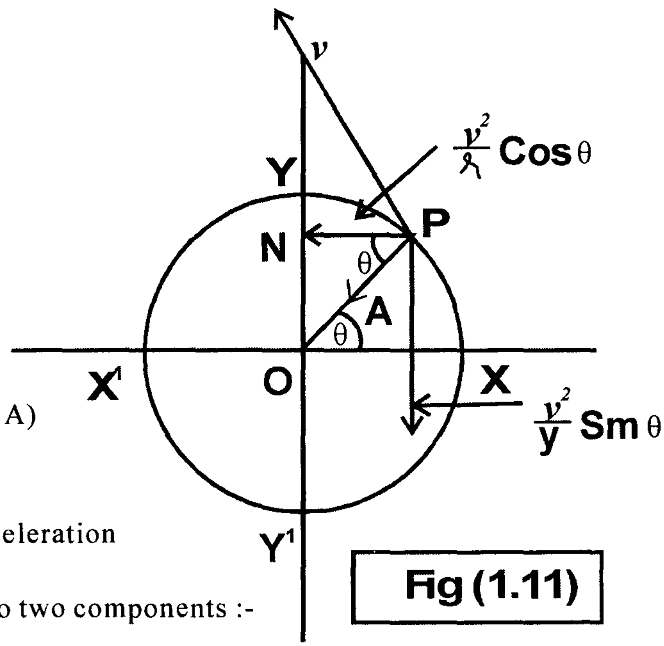


Fig (1.11)

By the defination of force

$$F = ma \text{ ----------(1)}$$

According to centripetal force

$$F = \frac{mv^2}{r} \text{ --------(2)}$$

from equation (1) and (2) we get

$$ma = \frac{v^2}{r} \text{ (here we suppose a = A)}$$

$$\therefore a = \frac{v^2}{r} \text{ called centripetal acceleration}$$

This acceleration A can be resolved into two components :-

(a) $\frac{v^2}{r} \cos\theta$ along X-axis or along XOX'

(b) $\frac{v^2}{r} \text{Sin}\,\theta$ along Y-axis or along diameter YOY'

But $\frac{v^2}{r} \cos\theta$ being perpendicular to YOY' produced no effect on the motion of N.

So only component $\frac{v^2}{r} \text{Sin}\,\theta$ acts along YOY' and give acceleration of N.

So acceleration of N, $a = \frac{v^2}{r} \text{ Sin } \theta$

$$a = \frac{(r\omega)^2}{r} \text{ Sin } \theta \qquad (\because \; v = r\omega)$$

$$a = \frac{r^2\omega^2 \text{ Sin } \theta}{r}$$

or $a = \omega^2 \text{ r Sin } \theta \qquad [\because \text{r Sin } \theta = y]$

or $a = \omega^2 y$ -----------(1)

But actual expression for aceleration is given by

$a = -\omega^2 y$ -----------(1)

Where -ve sign shows that acceleration is directed in a direction opposite to the one in which displacement increases. Since displacement increase in directions away from the the mean position the acceleration of S.H.M. is always directed towards the mean position.

SPECIAL CASE :-

(i) WHEN PARTICLE IS AT THE MEAN POSITION :-

When particle P lies at point O then y = O put y = O in equation (2) weget,

$a = 0$

So the acceleration of S.H.M. is zero.

(ii) WHEN PARTICLE IS AT EXTREME POSITION :-

Then y = r putting in equation (2) weget,

$a = \omega^2 r$

This is the maximum acceleraion when particles is at extreme position.

EXPRESSION FOR TIME PERIOD AND FREQUENCY OF A PARTICLE EXECUTING S.H.M.

Thus time taken to complete one rotation is called time period. By using equation,

$a = \omega^2 y$

or $\omega^2 = \frac{a}{y}$

$$\text{or } \omega = \sqrt{\frac{a}{y}} \Rightarrow \sqrt{\frac{\text{acceleration}}{\text{displacement}}}$$

We know that $\omega = \frac{2\pi}{T}$

$$\therefore \frac{2\pi}{T} = \sqrt{\frac{\text{acceleration}}{\text{displacement}}}$$

$$\text{or } T = 2\pi\sqrt{\frac{\text{acceleration}}{\text{displacement}}} \qquad \text{------(1)}$$

EXPRESSION FOR FREQUENCY :-

Total number of cycles per second is called frequency.

We know that, $n = \frac{1}{T}$

By using equation (1) we have,

$$n = \frac{1}{2\pi\sqrt{\frac{\text{acceleration}}{\text{displacement}}}}$$

$$\text{or } n = \frac{1}{2\pi}\sqrt{\frac{\text{acceleration}}{\text{displacement}}}$$

EXAMPLE (1.10)

A body is executing simple harmonic motion with an amplitude of 20 cm and frequency 6 per second. Find the equation of the vibrating body.

SOLUTION :-

Given, a = 20 cm

n = 6

We know that $\omega = 2\pi$ n

$\omega = 2 \times \pi \times n$ radians/sec.

$\omega = 12\pi$ radians/sec.

$\omega = 12 \times \frac{22}{7}$ radians/sec.

ω = 37.70 radians/sec.

So equation of motion of vibrating body is given by.

y = a Sin θ

or y = a Sin ωt

hence y = 20 Sin 37.70 t Ans.

Example (1.11)

A body is executing S.H.M with an amplitude of 6 cm and frequency 9 Hz.

Find (a) Velocity at mean position

(b) Velocity at extreme position

(c) Acceleration at mean position

(d) Acceleration at extreme position

SOLUTION :-

(a) maximum velocity is given by Vmax = a ω

(Given a = 6, ω = g cps)

We know that, $\omega = 2\pi$ n

$\omega = 2\pi \times 9$

$\omega = 18\pi$ radian/sec.

$\because$ Vmax = $6 \times 18\pi$

= 339.12 cm/sec. Ans.

(b) Velocity at the extreme position is zero, V = O Ans.

(c) Acceleration at the mean position is zero, a = O Ans.

(d) Acceleration at the extreme position,

Given, a = y = 6 cm

We know that, $a = -\omega^2 y$

$\therefore a = -(18\pi)^2 \times 6$

$a = -324 \times 9.87 \times 6$

a = -191872.8 cm/sec^2

or a = -1918.728 m/sec^2 Ans.

VIBRATION OF SPRING MASS SYSTEM :-

Let us consider a spring AB of negligible mass of length L suspended from a rigid support as shown in fig. (1.12) (a) When a mass m is attached to the free end of the spring, it elongates to point C, such that BC = ℓ. On being loaded a restoring force F comes into the play and spring tries to regain its original length as shown in fig. (1.12) (b).

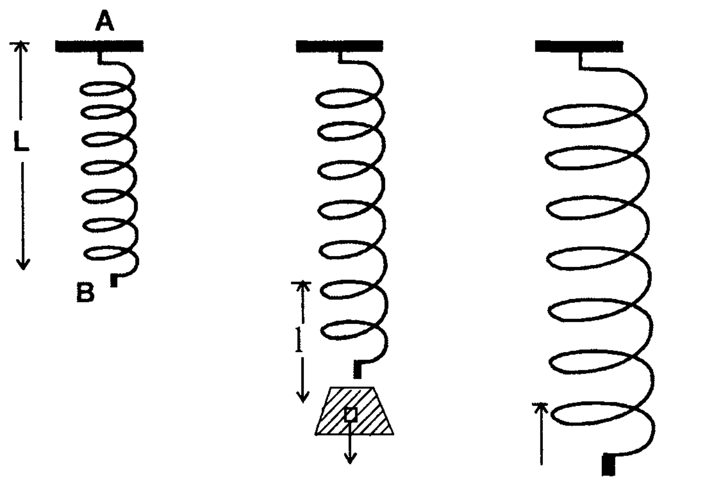


Fig (1.12) (a) Fig (1.12) (b) Fig (1.12) (c)

According to Hook's Law, the restoring force F is given by

$$F = -K\ell \qquad \text{----------(1)}$$

Where K is called force constant or spring constant.

Let us suppose ℓ = 1, then eg^n (1) becomes

$$K = F$$

Hence spring constant may be defined as the restoring force set up per unit extension in the spring.

Negative sign indicates that restoring force acting in opposite direction of the extension of spring.

In position C, the system of spring and the mass attached is in equilibrium therefore the upward restoring force must be exactly equal and opposite to weight mg i.e

$$F = -mg - \qquad \text{------(2)}$$

From equation (1) and (2) we get,

$$mg = K\ell \qquad \text{-------(3)}$$

Now displace the attached mass to the point D through a distance y below the equilibrium position marked by the point C. Then the total extension will become (ℓ +y) and restoring force will be increase by F', Then according to Hook's Law,

$$F' = - K\,(\ell + y)$$

$$\text{or } F' = - K\ell - Ky \qquad \text{--------(4)}$$

Now subtracting the equation (1) from (4) we get,

$$F' - F = - k\ell - ky - (-k\ell)$$

$$F' - F = - k\ell - ky + k\ell$$

$$\text{or } F' - F = - ky \qquad \text{--------(5)}$$

If the mass m is released then the force F' - F will make the mass attached to return to the equilibrium position C.

If a is acceleration produced in the motion of mass attached then,

F = ma (according to newton, 2nd law of motion)

$$\text{or } a = \frac{F}{m}$$

$$\text{or } a = \frac{F' - F}{m}$$

$$a = \frac{-ky}{m} \qquad \text{---------------(6) } [\because \text{ By using eq}^n \text{ (5)}]$$

Since k and m are constant the acceleration of the mass m at any instant is proportional to the displacement and it is directed towards equilibrium position.

The time period is given by.

$$T = 2\pi\sqrt{\frac{\text{displacement}}{\text{acceleration}}}$$

$$T = 2\pi\sqrt{\frac{y}{a}}$$

$$\text{or } T = 2\pi\sqrt{\frac{y}{ky/m}} \qquad \text{[By using equation (6) By neglecting - vc sign]}$$

$$T = 2\pi\sqrt{\frac{ym}{ky}}$$

$$T = 2\pi\sqrt{\frac{m}{k}} \qquad \text{------------(7)}$$

from equation (3) we have $mg = k\ell$

$$\frac{m}{k} = \frac{\ell}{g}$$

Putting value of m/k in equation (7) weget,

$$T = 2\pi\sqrt{\frac{\ell}{g}} \qquad \text{------------(8)}$$

from the equation (8) we say that

(i) Spring is mass less.

(ii) The motion of the spring through air is not effected by the drag.

(iii) It vibrates within elastic limits so that Hook's law is always applicable.

Now frequency of the vibration is given by $n = \frac{1}{T}$

Putting the value of T from equation (8) we have,

$$n = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}} \qquad \text{-----------(9)}$$

EXAMPLE (1.12)

A spring balance has a scale that reads from 0 to 50 kg. the length of the scale is 20 cm. A body suspended from this spring, When displaced and released, oscillates with a period of 0.60 sec. What is the weight of the body ?

SOLUTION :- If $m = 50$ kg.

$\ell = 20$ cm $\Rightarrow 0.2$ m

Now $mg = k\ell$

or $k = \frac{mg}{\ell}$

$$k = \frac{50 \times 9.8}{0.2}$$

$k = 2450$ N/m

The time period is given by. $T = 2\pi \sqrt{\frac{m}{k}}$

given T = 0.60 sec.

$\therefore\ 0.60 = 2\times\pi \sqrt{\frac{m}{2450}}$

or M = 22.34 kg.

Weight of the suspended body, Mg = $22.34\times9.8 \Rightarrow 218.93$ N Ans.

CANTILEVER :-

"A beam fixed horizentally at one end and free to vibrate at the other end is called contilever."

Let us take a weightless rod AB, fixed at point A with the help of a clamp and the other end B is free. Now we placed the weight m on the free end B which bends the beam to position B' as shown in fig. (1.13). As the weight increase the cantilever starts to vibrate.

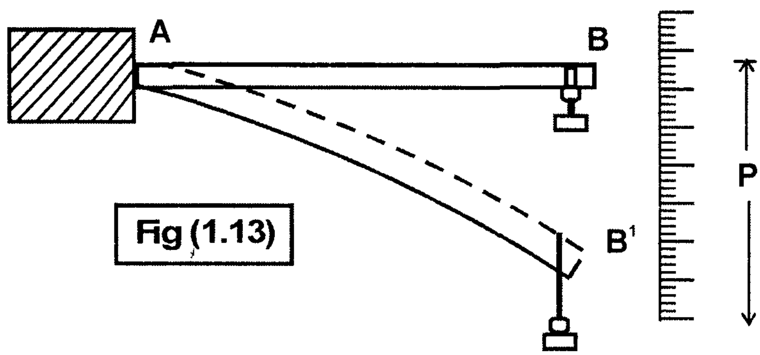


Fig (1.13)

When the rod is depressed through a discharge P, a restoring force comes into the play which tries to bring the cantilever at its original positions.

Now we determine the time period of vibration,

then according to Hook's Law. we get,

$F = -kP$ ---------(1)

Where k is spring constant,

According to Newton's 2nd Law of motion,

$F = ma$ ---------(2)

From equation (1) and (2) weget,

$ma = -kP$

$a = \frac{-kP}{m}$

$$a = \frac{-k}{m} P$$

$$\text{or } \frac{a}{P} = \frac{-k}{m}$$

$$\text{or } \frac{\text{Displacement}}{\text{Acceleration}} = \frac{-k}{m} \qquad \text{---------(4)}$$

from equatin (3) and (4) weget,

$$T = 2\pi \sqrt{\frac{-m}{k}} \qquad \text{---------(5)}$$

Now $F = ma,$

or $F = mg$ ---------(6) [$\therefore$ have particles moves in downwords]

from equation (1) and (6) we get,

$$mg = -kP$$

$$\text{or } -\frac{m}{k} = \frac{P}{g}$$

Now putting value of $(-\frac{m}{k})$ in equation (5) we get,

$$T = 2\pi \sqrt{\frac{P}{g}}$$

$$\text{or } T = 2\pi \sqrt{\frac{\text{depression}}{\text{Acc. due to gravity}}}$$

FREE, FORCE AND RESONANT VIBRATION :-

Any object executing simple harmonic motion may be called as harmonic oscillator.

(a) FREE VIBRATION :-

A body is said to be executing free vibration if it vibrates with its natural frequency. The natural frequency of oscillations of an ascillator depends upon its mass, dimensions and the restoring force. Further natural frequency is independent of the initial displacement or amplitude. A few examples of free vibrations are :-

(i) A tuning fork, when set into vibration executes free vibration.

(ii) The spring of a Sonometer or a Sitar when plucked and released, execute free vibration.

(b) FORCED VIBRATION :-

"The oscillation produced by an oscillator under the effect of an external periodic force of frequency other than the natural frequency of the oscillator are called forced vibration."

Considered an oscillator A is executing free vibration of natural frequency ν_0. Lets suppose that an oscillator A is driven by another oscillator B.

Then the oscillator B is called driver oscillator and A called driven oscillator whose natural frequency is ν. As the time passes the oscillator A is found to be lose its vibration B has its own frequency on the oscillatorA. The oscillator is called forced vibration. A few examples of forced vibrations are : -

(i) The sound box of a Voilin execute force vibrations.

(ii) When the stem of a vibrating tuning fork is passed against the table top, it starts vibrating with the frequency of vibration of tuning fork.

(c) RESONANCE :-

"The Phenomenon of setting a body of large apmlitude into oscillations by the influence of another vibrating body moving with the same natural frequency is called resonance."

The vibrations so produced are called resonant.

Resonance is sometimes undesirable and harmfull as explained below :-

(i) While soldiers cross a bridge they are ordered to go out of steps. If they do not do so, the bridge may starts oscillating and hence may get damaged, if by chance the frequency of the steps of the marching soldiers happens to be equal to that of the bridge.

(ii) The Periodic vibrations of earth may prove fatal to tall building, whose structure by chance are of the same frequency as that of vibrations inside the earth.

MULTIPLE CHOICE QUESTIONS

1. Sound waves are examples of :-
   (a) Longitudnal wave (b) Transverse wave
   (c) Velocity (d) None of these.

2. Which of the following is a transverse wave :-
   (a) Sound wave (b) Electromagnetic wave
   (c) Medium (d) None of these.

3. The unit of frequency is
   (a) Newton (b) Watt
   (c) Hz (d) Jaule.

4. Relation between wavelength λ, frequency n, and wave velocity ν is
   (a) $n\nu = \lambda$ (b) $n\lambda = \nu$
   (c) $\nu\lambda = 1$ (d) $\nu\lambda = n$

5. What types of waves required material medium ?
   (a) Sound wave (b) Light wave
   (c) Current (d) None of these.

6. Velocity of a light wave is
   (a) 332 m/sec. (b) 3×10^{8} m/sec.
   (c) 3×10^{-8} m/sec. (d) -332 m/sec.

7. Velocity of a sound wave is
   (a) 3×10^{8} m/sec. (b) 3×10^{-8} m/sec.
   (c) 332 m/sec. (d) -332 m/sec.

8. Elastic waves in a solids are
   (a) Transverse (b) Longitudnal
   (c) Neither transverse nor longitudnal
   (d) None of these.

9. The velocity of sound in air is independent on the change in
   (a) Pressure (b) Density
   (c) Temperature (d) Humidity

10. The speed of sound will be greatest in
    (a) Air (b) Vaccum
    (c) Water (d) Metal

11. A particle is moving in a circle at a uniform speed, its motion is
    (a) Periodic and simple harmonic
    (b) Periodic but not simple harmonic

(c) A periodic (d) None of these.

12. The distance travelled by a particle in S.H.M. in one time period is
(a) r (b) 2 r
(c) 4 r (d) Zero.

13. The displacement of a particle in S.H.M. in one time period is
(a) r (b) 2 r
(c) 4 r (d) Zero

14. In S.H.M. the acceleration of particle is Zero, when velocity is
(a) Zero (b) Half of its maximum value
(c) Maximum (d) Minimum

15. A spring of force constant k is cut into two pieces such that one piece is double the length of the other. Then the longer piece will have a force constant of
(a) 2/3 k (b) 3/2 k
(c) 3 k (d) 6 k

16. Resonance is a special case of
(a) Forced vibration (b) Damped vibration
(c) Free vibration (d) None of these.

17. The value of velocity at extreme position is
(a) Maximum (b) Minimum
(c) Zero (d) Infinity

18. The value of acceleration at extreme position is
(a) Maximum (b) Minimum
(c) Zero (d) Infinity

19. The relation between time period and frequency is
(a) n T = 0 (b) n T = 1
(c) $T = n \times \omega$ (d) None of these.

20. The time period of a centilever is
(a) $T = 2\pi\sqrt{\frac{g}{\ell}}$ (b) $n = \frac{1}{T}$
(c) $T = 2\pi\sqrt{\frac{\ell}{g}}$ (d) None of these.1

VERY SHORT ANSWER QUESTIONS

1. What is a wave motion ?
2. Define longitudnal and transverse waves.

3. Define compressions and rarefactions.
4. Define crest and trough.
5. Define wavelength.
6. Define time period.
7. Define frequency.
8. What is amplitude ?
9. What is wave velocity ?
10. What is the relation between period and frequency ?
11. What is periodic and oscillatory motion ?
12. Define S.H.M.
13. What is resonance ?
14. What is a free vibration?

SHORT TYPE QUESTIONS

1. Explain the Generation of wave motion by particles.
2. Differentiate between longitudnal and transverse waves.
3. Differentiate between light wave and sound wave.
4. Explain the proagation of a transverse waves.
5. What is S.H.M. ? Derive an expression for displacement.
6. Define S.H.M. and also derive an expression for velocity of a particle.
7. Derive an expression for acceleration for a particle.
8. Explain the vibration of spring mass system.
9. What is a contilever ? Derive an expression for time period of vibration.
10. Explain free, force and resonance vibrations.

LONG ANSWER QUESTIONS

1. What is a wave motion ? Explain Generation of wave motion by particles.
2. Explain Longitudnal and Transverse wave and its propagation.
3. What is S.H.M ? Derive an expression for velocity, displacement and acceleration of Particle.
4. Explain free, forced and Resonance vibration.
5. What is contilever ? Drive an expression for time period for its vibration.

NUMERICAL PROBLEMS

1. The speed of radio wave is 3×10^{8} m/s. A radio station broadcasts on 25 m. What is the freqeuncy of the wave.

   (a) 7500 MHz (b) 12 MHz

   (c) 12000 MHz (d) 0.3×10^{-3} per sec.

   [Ans. 12 MHz]

2. A body executing S.H.M has amplitude 1 cm. Its velocity at the mean position is 10 cm its displacement is 10 cm.

   [Ans. 1.4 sec.]

3. A body of S.H.M of amplitude 10^{-2} m. Its velocity while passes through equilibrium is 10 m/sec. Find its frequency.

   [Ans. 1.591 Hz]

4. Calculate the energy possessed by a stone of mass 0.02 kg executing S.H.M of amplitude 1 cm and time period 4 sec.

   [Ans. 24.66×10^{-7} J]

5. A particle describe an S.H.M. in a line 4 cm long. Its velocity when passes through the centre of the line is 12 cm/sec. Find the time period.

   [Ans. $\frac{\pi}{3}$ sec.]

ANSWER OF MULTIPLE CHOICE QUESTIONS

(1)	a	(2)	b	(3)	c	(4)	b	(5)	a
(6)	b	(7)	c	(8)	c	(9)	a	(10)	d
(11)	b	(12)	c	(13)	d	(14)	c	(15)	b
(16)	a	(17)	c	(18)	a	(19)	b	(20)	c

UNIT - 2

APPLICATION OF SOUND WAVES

INTRODUCTION :-

" Accoustics is a branch of Physics which deals with the gereration of sound waves, the propagation and reception of the obstacles in their way."

Upto 19th century there was no consideration of sound effects in the halls, auditorium etc. All the buildings such as cinema halls, theatres etc. were found to have unsatisfactory sound means, as there was huge dearth of knowledge on accoustics. In the 19th century a scientist named C. Sabine faced similar problems and suggested ways to get better sound quality and effects in the halls, cinema halls, auditorium.

SOUND ABSORPTION AND SOUND REFLECTION :-

When a sound is produced in a hall or auditorium, it spreads out in all the directions and strikes the walls, ceilling, floor, window etc. of the hall. Sound incident on any surface of a material splits into three parts. One part is reflected.

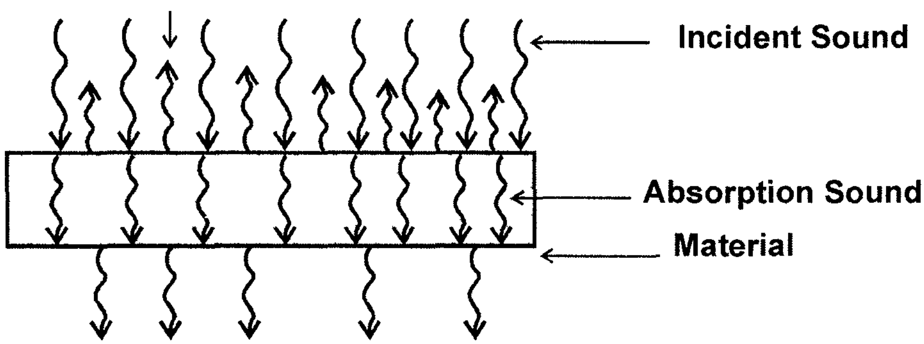


Fig (2.1)

from the surface with a reflection angle equal to the angle of incidence. Second part gets absorbed by the material and third part is transmitted through the material as shown in fig. (2.1)

COEFFICIENT OF ABSORPTION OF SOUND :-

"The Coefficient of absorption of sound is defined as the ratio of the sound energy absorbed by the surface to the total incidence sound energy on the surface."

It is denoted by Q.

Hence, $$a = \frac{\text{Sound energy absorbs by the surface}}{\text{Total sound energy incidence on the surface}}$$

The value of 'a' depends upon the nature of material as well as the frequency of the sound.

If the sound energy falls upon an open window, then all the sound energy passes out into the open, no sound energy will be reflected, this means that an open window completely absorbs the sound energy. By this we derive that an open window is a perfect obsorber of the sound energy.

The Coefficient of absorption of sound may be expressed in terms of O.W.U. (open window unit), and the value of 'a' for a open window is 100%.

MUSICAL SOUND :-

The sound which produces a pleasent effect on the ears of the listener is called musical sound. For example sound produced by Violin, Piano, Singing of songs and chirping of birds etc.

A musical sound consists of a series of harmonies, components, starting from fundamental to higher harmonies as shown in fig. (2.2)

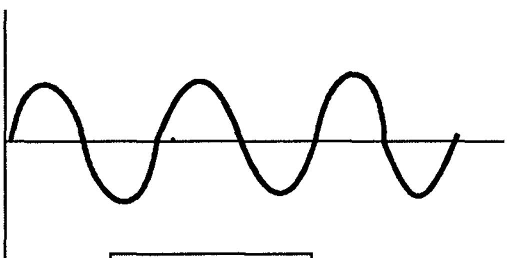


Fig (2.2)

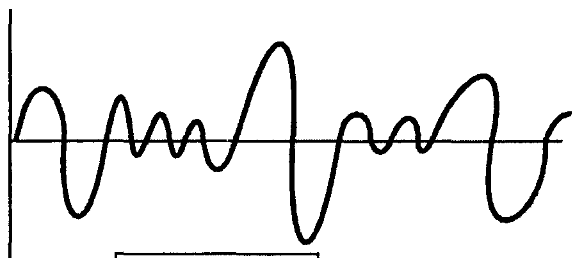


Fig (2.3)

NOISE :-

The sound which produces an unpleasent effect on the ears of the listener is called a Noise. For example, murmuring by students in a class room, sound of a gun shot etc. are the example of noise.

A noise consists of a series of waves following each other at irregular intervals of time, with sudden charges in their amplitude as shown in fig. (2.3)

CHARATERSTICS OF A MUSICAL SOUND :-

A musical sound has three mains characteristics namely loudness, pitch and quality.

1. **LOUDNESS :-**

It is related to the Intensity of sound ("intensity of sound is defined as the amount of sound energy passing per unit time per unit area around that point in a perpendicular direction.") It is a physical quantity and it is measured in Watt-metre^2 in S.I.

"Loudness is the sensation of hearing which enables to distinguish between a loud and a faint sound is called loudness."

The loudness of sound dep. ıds upon the intensity of the sound at a place and the sensativeness of the ear of the listener.

The unit of loudness is "BEL" (B)

The lowest intensity of sound that can be perceived by the human ear is called threshold of hearing. It is denoted by Io.

and its value is 10^{-12} watt /m^2

The loudness of a sound of intensity I is given by

$$L = \log_{10} \frac{I}{I_o} \text{ ---------------(1)}$$

Where Io is threshold of hearing.

If I = 10 Io then,

$$L = \log_{10} \frac{10\, I_o}{I_o} = 1 \text{ bel.}$$

Thus the loudness of a sound is said to be 1 bel if the intensity is 10 times that of the threshold of hearing.

The smallest unit of loudness is decibel (db)

so 1 decibel (db) = $\frac{1}{10}$ bel.

In decibelof the loudness of a sound of a specific Intensity is given by

$$L = 10 \quad \log_{10} \frac{I}{I_o}$$

FACTOR ON WHICH INTENSITY OF LOUDNESS DEPENDS :-

(i) AMPLITUDE :-

The intensity of sound I is directly proportional to the square of the amplitude (a)

so that $I \,\alpha\, a^2$

(ii) SURFACE AREA OF A VIBRATING BODY :-

The intensity of sound I is directly proportional to the area of the vibrating body.

$I \,\alpha\, A$

This means that greater the area , larger the energy transmitted and greater is the intensity of sound.

(iii) The intensity of sound also depends upon the density of the medium through which the sound travels from the source and the presence of the other surrounding bodies.

(iv) FREQUENCY OF SOURCE :-

The intensity of sound I is directly proportional to the square of the frequency of sound.

i.e $I \alpha n^2$

(v) DISTANCE FROM THE SOURCE :-

The intensity of sound I is inversly proportional to the square of the distance d from the source of sound.

i.e $I \alpha \frac{1}{d^2}$

This is also known as Inverse square las. If the distance from the source is higher, the intensity of sound will be decreased.

(2) PITCH :-

It is the characterstics of musical sound that differentiates a shrill sound from a flat or dull sound.

A shrill sound means higher pitch and found on greater frequency. On the other hand flat sound means low pitch and it has low frequency. Thus pitch depends upon the requency and does not depends upon the loudness.

The voice of a child is always shriller than that of a boy and much shriller than that of a man. In other words pitch of the voice of a child is higher than that of a boy and much higher than that of a man.

(3) QUALITY :-

It is the characterstics of the musical sound that differenttiates between the two sounds of same pitch and loudness from one another. Quality of a sound is determined by the number of harmonic components in it and their relative amplitudes and the phase relations.

ACOUSTING OF BUILDINGS :-

"The branch of Physics that deals with the production of best sound effect in public buildings such as cinema halls, auditorium, theatres etc. is called acousting of buildings."

REVERBERATION :-

When a sound is produced in an open space, it is heard only once by the listener when it travels across him. But when a sound is produced in a hall or in a room, it spreads out in all the directions and gets reflected from the walls, ceiling, floor of the room or hall. The reflected sound will travel back and meet other surface of hall, where it is partially reflected. Thus sound keeps on persisting in the hall for some time by reflecting from surface to surface and loosing a part of energy at every point till it becomes too weak to be heard.

"Thus reverberation may be defined as the persistance or prolongation of the osund in a hall or in auditorium after the source has stopped emitting sound."

REVERBERATION TIME :-

"The time for which the sound persists in a room or in a hall is called reverberation time."

For getting good sound effects the reverberation time should be minimum. The reverberation time depends upon the nature of the reflecting material, size of the room or hall and area of reflecting surfaces.

Let us assume that we produce a sound, In the begining the intensity of the sound will be low and it increasse when it is reflected by walls, ceiling, floor, window of the hall or room and a stage is reached where the intensity of the sound is maximum. Now when we stop producing the sound, even after that point the intensity of sound does not fall suddenly to zero, but falls exponentially along the path CB as shown in fig. (2.4) Then, AB represents the reverberation Time.

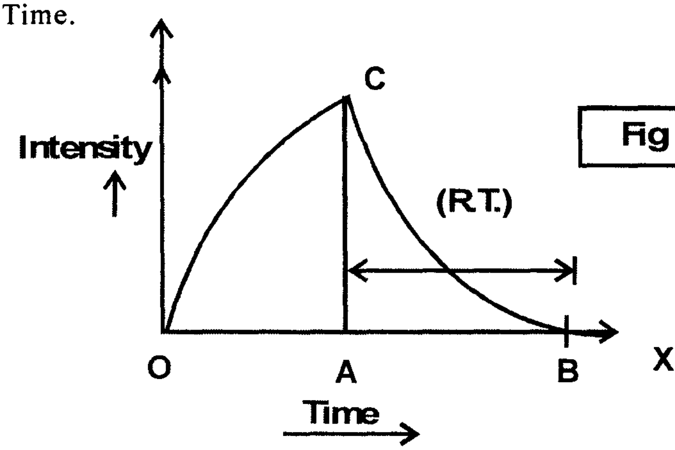


Fig (2.4)

STANDARD REVERBERATION TIME :-

"It may be defined as the time taken by the sound intensity fall to one millionth (10^{-6}th) of its original intensity after the source stop soundings."

The formula of a standard reverberation time is given by W.C Sabine and it is known as Sabine formula.

Thus $T = \dfrac{0.165\ V}{\sum as}$

Where, T = reverberation time in seconds.

V = volume of the room in cubic metres.

a = The coefficient of absorption.

s = The area of reflecting surface in square metre.

and $\sum as = a_1s_1 + a_2s_2 + a_3s_3 + \text{------} + a_ns_n$

ie $\sum as$ = The total absorptions of the surface of different materials.

where a_1, a_2, a_3------a_n are the absorption coeffiecient of different materials

ans s_1, s_2, s_3------s_n are their respective areas in square metres.

METHOD TO CONTROL REVERBERATION TIME :-

The following methods can be followed to control the reverberation time :-

(i) By using open windows, as open windows are the perfect absorbers of sound energy.

(ii) By using a sound absorbeing material like absorb sheets, card boards, on the walls of the room. Also floor is carpeted. This helps to decrease the reverberation time.

(iii) A large number of audience also contribute to decrease the reverberation time. Each member of the audience is equivalent to 4.7 square feet of an open window.

(iv) By using heavy curtains on the walls of the room or in a hall, it also controls the reverberation time.

(v) Maps and pictures hanging on the walls of hall.

(vi) The false ceiling of a suitable sound absorbing meterial also helps to control the reverberation time.

(vii) Setting upholding seats in the halls also control the reverberation time as these seats work as a good absorbing materials.

FACTORS AFFECTING THE ACOUSTING OF BUILDINGS :-

For making good sound effects in an auditorium, hall etc. The following factors must be consideration.

(i) REVERBERATION TIME :-

The reverberation time should be adjusted at a optimum value for music and speech.

(ii) FOCUSSING :-

If the walls of the room, or ceiling of the room is a curved surface then it produces undesirable concentration of energy. So focussing effect of sound can be avoided by ignoring curved surfaces, this is means that the walls of the room should be made of plain surface with poor reflecting.

(iii) LOUDNESS :-

There should be sufficient loudness through out the hall or in an auditorium. The loudness can be improved by making a large parabolic reflector near or arround the speaker, with the speaker at its focus for uniform sound intensity throughout the hall or in auditorium as shown in fig. (2.5)

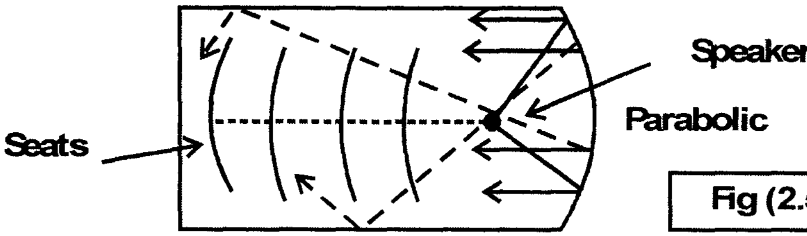


Fig (2.5)

(iv) ECHELON EFFECT :-

When a sharp sound is produced in front of the foot steps near a staircase, a musical sound is produced due to regular series of reflected sound, each consisting of a simple echo of the original sound. This is known as Echelon effect. This can be avoided by covering the stair case with carpets to avoid refection of sound.

(v) ABSORBING MATERIAL :-

For good quality of sound in a hall, it is necessary that all the walls of the hall are covered with a good absorbing materials.By using upholding chairs in the halls we can control the quality af sound as upholding chairs are good absorber and reduce reverberaion time.

(vi) ECHO :-

An echo is the repetition of the original sound from a source by reflection from some object. So during the construction a hall we differentiate or avoid the confusion between the original sound and its echo by using absorbing material.

(vii) QUALITY OF SOUND :-

The quality of sound in a hall means that the speaker phones, microphone, and amplifier used in the hall should work in a synchronised or coordinating manner. This is known as the fidelity.

(viii) EXTRANEOUS NOISE :-

It is the outside noise that enters a hall. It is of two types

(a) Structure borne and (b) Air borne.

(a) Structure borne noise is the noise made by fittings in the halls like water pipes etc.

(b) Air borne noise is the noise entering the hall from outside through an open window. This can minimised by using double windows or effective window closers.

ECHO :-

"An echo is the repetition of original sound from a source being reflected from some distance from the listener."

A normal person can differentiate between two sound separatelly as they are recieved by the ear with the time interval of $^1/_{10}$ sec. or later, he hears the repetition of the original sound called "Echo".

The velocity is given by $(v = {}^d/_t)$, hence, distance = $v \times t$. This mean that d = $332 \times \frac{1}{10} \Rightarrow 33.2$ m (where $v = 332$ m/s is velocity of sound.) for an echo to be heard. So that least distance of the large reflected surface is $\frac{33.2}{2} = 16.6$ m. as in that case reflected sound will take $^1/_{10}$ sec. or move covering the distance from the source to surface and came back.

Example (2.1)

What is the reverberation time of a room of $3000\ m^3$ volume and $1850\ m^3$ area. Given a = 0.2 0.w.u.

SOLUTION :-

Total absorption of surface = $\sum as$

Given, V = $3000\ m^3$, $\theta = 0.2$ owu, S = $1850\ m^3$

So Reverberation time T = ?

We know that $T = \frac{0.165\ V}{\sum as}$

$$T = \frac{0.165 \times 3000}{0.2 \times 1850} \Rightarrow 1.33 \text{ sec.} \qquad \text{Ans.}$$

Example (2.2)

An auditorium of volume 120000m³. has a reverberation time of 1.5 sec. Find out the average absorbing Power of the surface, if the total sound absorbing surface is 25000m³.

SOLUTION :-

Given, $v = 120000\ m^3$

$t = 1.5$ sec.

Area of absorbing surface, $S = 25000\ m^3$

$a = ?$

So total absorption $\sum as = as$

$= a \times 25000$ o.w.u.

Now, $t = \dfrac{0.16\ V}{\sum as}$

$$1.5 = \frac{0.165 \times 120000}{9 \times 25000}$$

or, $$a = \frac{0.165 \times 120000}{1.5 \times 25000}$$

$a = 0.512$ o w u Ans.

Example (2.3)

A cinema hall has a volume of 6000m³ and total surface absorption is 20 owu. Calculate reverberation time.

SOLUTION :-

Volume, $V = 6000\ m^3$

Surface absorption $\sum as = 20$ owu.

Reverberation time, $T = \dfrac{0.165\ V}{\sum as}$

$$T = \frac{0.165 \times 6000}{20}$$

$T = 11$ sec. Ans.

Example (2.4)

A cinema hall of 3500m³ volume having a seating capacity for 600 person having the following material in it .

Sr. no.	Materials	Surface Area	Cofficient of absorption
1.	Wooden doors	$60m^3$	0.04
2.	Plastered walls	$700m^3$	0.03
3.	Glass work	$50m^3$	0.06
4.	Seats (Spungy)	300	1.5 owu/seat
5.	Seats (Wooden)	300	2.0 owu/seat
6.	Audience	370	4.2 owu/head

Find out the reverberation time.

SOLUTION :-

Given Volume, $V = 3500\ m^3$

No. of audience accupying wooden seats = audience - wooden seats.

$= 370 - 300$

$= 70$

No. of empty wooden seats = 300 - 70 = 230

absorption due to each material and the audience is given by.

by Wooden doors, $a_1s_1 = 0.04 \times 60 = 2.40$

by Plastered walls, $a_2s_2 = 0.03 \times 700 = 21.00$

by Glass work, $a_3s_3 = 0.06 \times 50 = 3$

by audience occupying spungy and wooden seats :-

$$a_4s_4 = 4.2 \times 370 = 1554$$

by Empty seats, $a_5s_5 = 2 \times 230 = 460$

so total absorption of the cinema hall,

$$\sum as = a_1s_1 + a_2s_2 + a_3s_3 + a_4s_4 + a_5s_5$$

$$= 2.4+21+3+1554+460$$

$$= 2040.40$$

Reverberation time $T = \dfrac{0.165\ V}{\sum as}$

$$T = \frac{0.165 \times 3500}{2040.40}$$

$T = 0.27$ sec. Ans.

ULTRASONICS :-

(1) AUDIBLE SOUND :-

The sound with a frequency between 20 Hz to 20000 Hz (20 Hz – 20 KHz) which can be heared by a normal human being. It is called audible sound.

(2) INFRASONICS :-

The sound of frequency less than 20 Hz which is not heard by the normal human ear is called infrasonics. These sounds can be used to break the rocks and similar other object.

(3) ULTRASONICS :-

The sound wave of frequency more 20 KHz or 20000 Hz are known as ultrasonics. This sound can not be heard by the human beings. But some animals like Dogs, Bats, Mosquito etc. heard the unltrasonics.

PRODUCTION OF ULTRASONICS WAVES :-

The untrasonics waves can be produced mainly by the following two methods.

(i) Magnetostriction Method

(ii) Piezo-electric oscillator Method

(I) MAGNETOSTRICTION METHOD :-

Ultrasonic wave can be produced by using Magnetostriction effect

PRINCIPLE :-

The production of an ultrasonic wave by the magnetostriction method depends upon the magnetostriction effect. According to this effect, "When an ferromagnetic bar of Iron or Nickle, is subjected to the alternating magnetic field, the bar expands and slightly changes in length alternately." This effect is known as magnetostriction effect. The length of bar or rod increases or decreases with a frequency twice that of the frequency of the applied alternating magnetic field.

CONSTRUCTION AND WORKING :-

Let XY be a rod or ferromagnetic bar of Ni and iron (36% Ni and 64% Fe) is placed in two coils L_1 and L_2 Parallel to its axis. The rod is clamp at the middle as shown in fig. (2.6). Then a high frequency alternating current is passed through the coil L_1 from an oscillatory circuit.

As the alternating current is passed in the rod through the coil L_1, the bar or rod becomes magnetised or demagnetised depending upon the frequency of the current. The rod gets compressed and expands, (means that length of rod changes accordingly) Periodically and its free end starts vibrating and produces a high frequency vibration. This frequency vibration is ultrasonic.

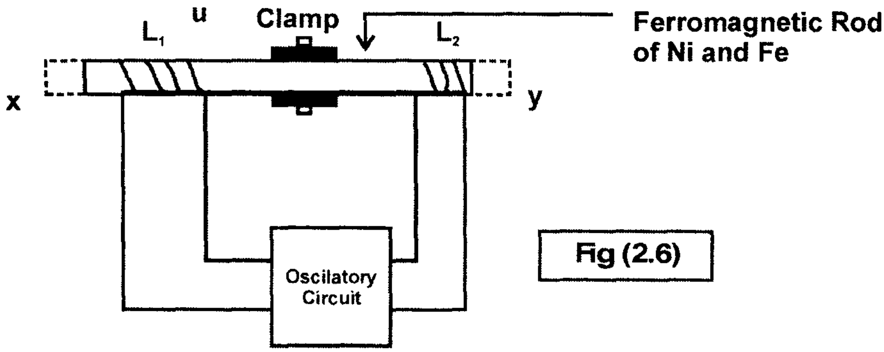


Fig (2.6)

The two coils L_1 and L_2 are produced in the plate circuit and in the grid circuit respectively of the oscillatory circuit as shown in fig. (2.6). The oscillations are maintained by the coupling effect between the two coils L_1 and L_2 and by the rod itself.

The length of the rod or bar is so adjusted that its natural frequency is the same as that of the applied. A. C. resonance takes place. At this stage the amplitude of the vibration becomes very high, ranging approximately 300 KHz . When the rod vibrates longitudinally.

Then its frequency (n) is given by :- $n=\frac{1}{2\ell}\sqrt{\frac{Y}{\rho}}$

Where n = frequency of vibration

ℓ = length of the rod or bar

Y = Young modulus of elasticity of the rod.

ρ = density of the material.

from this equation we can say that the frequency of ultrasonics produced by this method will depend upon the length of rod, Young modulus of elasticity and density of the materials.

To increase the frequency, the length of the rod should be decreased. But it is not possible to decrease the length of the rod within a certain limit. So a very high frequency ultrasonic cannot be produced by this method.

For getting a good frequency of vibration the rod is magnetised initially by passing direct current (d.c.).

(II) PIEZO-ELECTRIC OSCILATOR :-

The ultrasonic wave produed by Piezo-electric oscillator is based on the piezoelectric effect.

PRINCIPLE :-

According to this effect, when a mechanical pressure is applied to a pair of opposite faces of a quartz crystal another pair of faces of equal and opposite electrical charges develope on them. The sign of charges changes when the quartz crystal is subjected to mechanical pension. This effect is known as piezolelectric effect.

The converse of Piezoelectric effect is also true. If an alternating Potential difference is applied across the two faces of the crystal it contracts or expands periodically which is the cause of compression or rarefaction developed in the surrounding medium.

CONSTRUCTION AND WORKING :-

A thin slab of quartz crystal is placed between the two metallic plates A and B and cuts with its optical axis normal to the faces. As shown n fig. 2.7 (a) and (b). A high frequency A.C. voltage is applied to the crystal like quartz, Zinc Blende, Rochelle salt etc. Cell with their faces perpendicular to the optical axis.

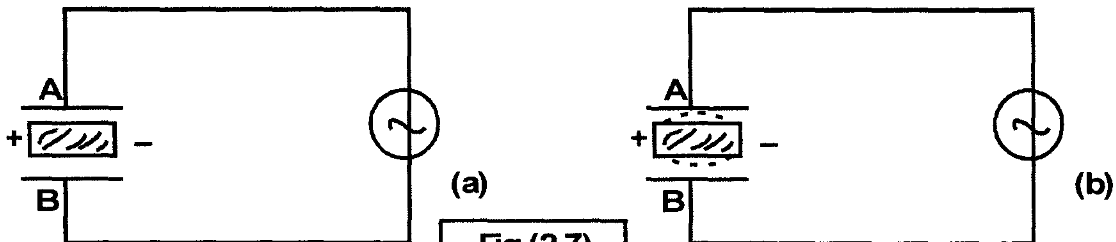


Fig (2.7)

Then due to Piezoelectric effect the crystal expands and contracts Periodically. This results in the methonical vibration of the crystal producing longitudinal vibration comprising of alternate compression and rarefactions in the surroundidng medium. Thus vibrations of high frequency which are ultrasonic, are produced.

If the size of the crystal is adjusted so that the natural frequency of the quartz crysal is equal to that of the applied A.C voltage then crystal is thrown into resonant vibrations and then ultrasonic with appreciable amplitude are produced in the surrounding medium. The frequency of vibration is given by

$$n = \frac{m}{2t}\sqrt{\frac{Y}{\rho}}$$

Where, n = frequency of vibration.

m = 1, 2, 3, 4, -------etc. modes of stationary weres produced by crystal.

t = twickness of the quartz crystal.

Y = Young modulus of elosticity.

ρ = density of the crystal

from this equation we say that smaller the twickness of plates, higher is the frequency of waves produced. A high frequency of 50,000 KHz can be produced by using quartz crystal and 150,000 KHz by Toumaline crystal.

PROPERTIES OF ULTRASONICS :-

The properties of ultrasonics are given below :-

(1) Ultrasonic waves follow the relation $V = n\lambda$

Where V = velocity of wave
n = frequency of wave
λ = wavelength.

(2) Ultrasonic waves travel in a medium with a constant velocity and reflected when they change their medium. This propertie is known as reflection and it is used in detecting the cracks and cavities in metal casting.

(3) Ultrasonic waves also show refraction, diffraction, polarisation and interference.

(4) The speed of longitudnal waves is given below :-

(a) Speed of longitudnal wave in the solid of the rod type is given by.

$$V = \sqrt{\frac{Y}{\rho}}$$

Where, Y = Young modulaus of the material
f = density of the material

(b) The speed of longitudnal wave in liquid is given by,

$$V = \sqrt{\frac{Y}{K}}$$

Where K = Bulk modulus of the liquid.

(c) In gas, the speed of longitudnal is given by.

$$V = \sqrt{\frac{\gamma \times P}{\rho}}$$

$\sum$as = 20 owu.

Where γ = Specific heat ratio
P = Pressure of gas,
ρ = density of gas.

(5) Ultrasonic wave comes back to a long distance without any spreading of waves, so it is used as SONAR means to calculate the depth of sea.

ENGINEERING APPLICATIONS OF ULTRASONICS :-

The following applications are the most popular engineering applicaiton of the ultrasonics waves :-

(1) DRILLING :-

Drilling use to be tough with the usual machine process but is now made convenientwith the help of ultrasonics. Ultrasonics are used to make bore holes on the hard material surfaces like diamond, ceramics, glass and alloys etc.The drill as shown in fig. (2.8) consists of a rod of some ferro-megnetic material through which a high frequency alternating current flows.

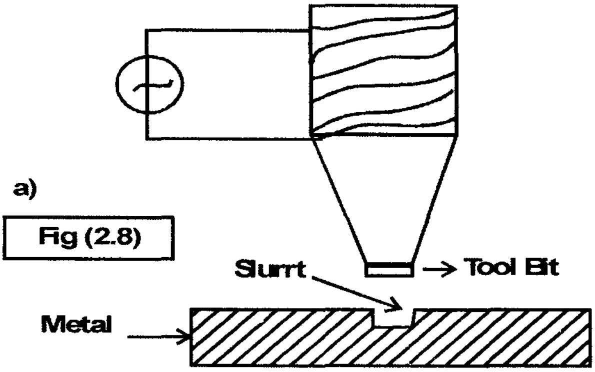


Fig (2.8)

At the lower end of the rod, a tool bit of some hard material is attached. When high frequency of A.C. is passed the rod vibrates with high frequency. The tool attached to the rod moves up and down quickly. This process continues and a hole of the desired shape and size is drilled in the plate.

(2) CLEANING :-

When an ultrasonic wave is applied to a vessel containing liquid, cavities are formed in the liquid that releases high atmospheric pressure and so the break and drift is cleaned without damaging any parts.

(3) COLD WELDING :-

It is a process of joining two different materials permanently without any involement of heat. In case of welding we use the tool bit at the lower end but in case of cold welding we used a Hammer (H) at the lower end as shown in fig. (2.9).

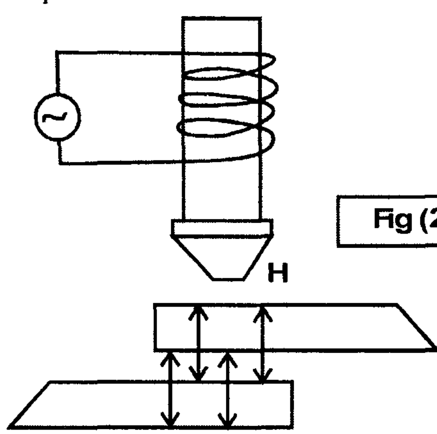


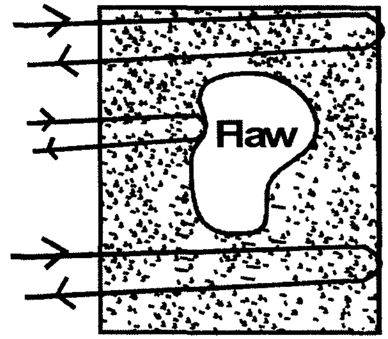
Fig (2.9)

The two different materials which are to be welded are placed together below the Hammer H. When the ultrasonic wave is produced, the Particles of the two pieces vibrate violently resulting in the diffusion and binding forces are developed so that welding is completed. This process is known as cold welding.

(4) FLAW DETECTION :-

Ultrasonic waves are used to detect cracks or cavities in metal casting because ultrasonics can pass through metals. As the ultrasonics passes through metals, the reflection takes place, both at the end of the plate and at the position of defect. By noting the time interval for reception the position of the defect can be located as shown in fig. (2.10)

Fig (2.10)



(Flaw Detection)

(5) SONAR :-

SONAR is an acronym that stands for "SOUND NAVIGATION AND RANGING". The principle of SONAR is similar to that of RADAR. In RADAR we use microwaves which are electromagnetic in nature whereas in SONAR we use the ultrasonic. SONAR are used to detecting submarines, depth of sea water and other obstacle on the sea water. A beam of ultrasonic waves is sent by the ultrasonic transmitter towards the bottom of sea water.

The total time for the ultrasonic wave to go to bottom and come back can be measured. As we know the velocity of the ultrasonics waves, and hence we find out the depth of the sea water.

EXAMPLE (2.5)

A 10 cm long ferromagnetic rod vibrate longitudingally. Find out the frequency of the ultrasonics produced if young modulus of elasticity of the material is 20×10" dynos/cm² and the density of the rod is 8 gm/cc.

SOLUTION :-

Given, $\ell = 10$ cm

$Y = 20 \times 10^{''}$ dyne/cm^2

$\rho = 8$ gm/cc

We know that,

$$n = \frac{1}{2\ell}\sqrt{\frac{Y}{\rho}}$$

$$\therefore\ n = \frac{1}{2 \times 10}\sqrt{\frac{20 \times 10^{11}}{8}}$$

$$n = \frac{10^6}{2\times10}\sqrt{\frac{2}{8}}$$

$$\therefore\ n = \frac{10^6}{2\times10}\times\frac{1}{2}$$

$$n = \frac{10^5}{4}$$

n = 25000 Hz. Ans.

EXAMPLE (2.6)

Determine the fundamental frequency of vibration of an x-cut crystal of thickness 0.1 cm.

Given γ = 8.75 × 10^{11} dyne/cm^2, ρ = 2.654 gm/cc.

SOLUTION :-

GIVEN T = 0.1 cm

γ = 8.75 × 10^{11} dyne/cm^2

ρ = 2.654 gm/cc.

We know that $$n = \frac{1}{2t}\sqrt{\frac{y}{\rho}}$$

$$n = \frac{1}{2\times0.1}\sqrt{\frac{8.75\times10^{11}}{2.654}}$$

N = 2871 × 10^3 Hz Ans.

EXAMPLE (2.7) :

Find out the speed of sound waves in water if bulk modulus of water is 2.026×10^9 n/m^2 and density of water is 10^3Kg/m^3.

SOLUTION : -

GIVEN K = 2.026 × 10^9 N/M^2

ρ = 10^3 Kg/M^3

We know that $$V = \sqrt{\frac{K}{\rho}}$$

$$V = \sqrt{\frac{2.026\times10^9}{10^3}}$$

V = 1423.38 m/sec. Ans.

EXAMPLE (2.7) :

Find out the speed of ultrasonic wave in air at n.t.p.
GIVEN γ = 1.41 & density of Air = 1.293×10^{-3} Kg/m^3.

SOLUTION :-

GIVEN $\gamma = 1.41$

$\rho = 1.293\times10^{-3}$ g/cm^3

P = 1 atmospheric pressure

$P = 76\times13.6\times980$ dyne/cm^2

We know that $V=\sqrt{\dfrac{\gamma P}{\rho}}$

$$V=\sqrt{\frac{1.41\times76\times13.6\times980}{1.293\times10^{-3}}}$$

V = 332.5 m/sec. Ans.

MULTIPLE CHOICE QUESTIONS

1. The unit of intensity of sound is
   (a) Volt (b) Hz
   (c) Decibel (d) Joule.

2. A Pitch depends upon :-
   (a) Loudness (b) Speed sound
   (c) Frequency (d) None of these.

3. Which of the following is a perfect absorber of energy :-
   (a) A closed window (b) An open window
   (c) Chairs (d) Floor

4. The absorption coefficient of an open window is
   (a) 10% (b) 50%
   (c) 90% (d) 100%

5. The unit of absorption coefficient is given by
   (a) Ohm (b) Decibel
   (c) open window unit (d) None of these.

6. Sabine formula will be written as :-

(a) $T = 2\pi \sqrt{\frac{\ell}{g}}$ (b) $T = \frac{1}{n}$

(c) $T = \frac{0.16v}{\sum as}$ (d) None of these.

7. Sound waves are ---------- in nature.
(a) Electromegnetic (b) Longitudnal
(c) Transverse (d) None of these.

8. Each person of the audience is equivalent to --------square feet of an open window.
(a) 4.6 (b) 4.7
(c) 4.8 (d) 4.9

9. The velocity of sound wave in air is
(a) 330 m/sec. (b) 331 m/sec.
(c) 332 m/sec. (d) 333 m/sec.

10. A human being can hear a sound of frequency ranging----------- .
(a) 20 Hz to 20 KHz (b) Below 20 Hz
(c) Above 20 Hz (d) None of these

11. The frequency of ultrasonic wave is
(a) More than 20 KHz (b) Less than 20 Hz
(c) 200 Hz (d) 20 Hz to 20 KHz.

12. The infrasonic wave have a frequency of.
(a) More than 20 KHz (b) Less than 20 Hz
(c) 20 Hz to 20 KHz. (d) None of these.

13. Velocity of sound in vaccum is given by
(a) 332 m/sec. (b) 0
(c) Infinity (d) None of these.

14. During rainy season, we see lightning first and hear thundering of clouds a little later becuase.
(a) Due to moisture (b) Velocity of sound is very large.
(c) Velocity of light is greater than the velocity of sound
(d) None of these.

15. SONAR stands for
(a) Sound not radiated (b) Sound obstackes and radiantions.
(c) Sound Navigation and radiation (d) None of these.

16. The sound wave of frequency more than 10^9 is known as

(a) Ultrasonic (b) Infrasonic
(c) Audible sound (d) Hypersonics

17. The time gap between the two sounds for an echo is

(a) 1 sec. (b) $\frac{1}{10}$ sec.
(c) 1 min. (d) None of these.

VERY SHORT ANSWER TYPE QUESTIONS :-

1. Define coefficient of absorption of sound. (IMP)
2. What is musical sound ? (IMP)
3. What is a noise ?
4. Name the characterstics of musical sound.
5. Define intensity of sound. Give its units.
6. What is pitch of musical sound.
7. Define quality of musical sound.
8. Define accousting of Building. (IMP)
9. Define reverberation.
10. Define standered reverberation time. (IMP)
11. Write down the Sabine formula. (IMP)
12. Define Echo. (IMP)
13. Define Echelon effect.
14. Define ultrasonic and infrasonic. (IMP)
15. What is supersonic wares.
16. What do you mean by audiable sound ?
17. Define magnetastriction effect.
18. Define Piezoelectric effect.
19. What do u mean by SONAR. (IMP)

SHORT ANSWER TYPE QUESTIONS :-

1. Explain absorption and reflection of sound.
2. What do you mean by musical sound and Noise ?
3. What is reverberation, reverberation time. Explain How it can be controlled ? (IMP)
4. Explain the reverberation time. (IMP)

5. Write a short note on accousting of building.
6. Write down the factor affecting to design a good accousting of building. (V.IMP)
7. What is echo ? Explain. (IMP)
8. What do you mean by Ultrasonic, Infrasonic, Supersonic and Audiable range of sound.
9. Explain the Phenomena magnetostriction effect.
10. Explain the Phenomenon Piezoelectric effect.
11. Explain the Engineering application of Ultrasonic. (IMP)
12. Explain the Property of Ultrasonics.
13. Explain the Phenomenon drilling and cold welding.
14. Explain the Flaw detection.
15. What do you mean by SONAR ? Explain. (IMP)

LONG ANSWER TYPE QUESTIONS :-

1. What do you mean by Musical Sound and Noise? Explain the charactersitcs of Musical Sound.
2. What is reverberation, reverberation time ? How it can be controlled ? (V. IMP)
3. What do you mean by accousting of Building. On which factors it can be depends. (V. IMP)
4. Sound in an empty halls seems to be louder than when it is full of audience. Explain. Why ?
5. What is Ultrasonic ? Explain magnetastriction method for producing ultrasonic. (V. IMP)
6. What is Ultrasonic ? Explain Piezpelectric method for producing ultrasonic. (V. IMP)
7. Explain Engineering applcations of Ultrasonic in details. (V. IMP)

NUMERICAL PROBLEMS

1. A hall of volume of $80,000 \text{ m}^3$. Its total absorption Power is $100\ o\omega u$. W hat will be the effect on reverberation time if audience fils and thereby increase the absorption by another $1000\ o\omega u$.

   [Ans. R.T. is reduced from 12.8 sec to 6.4 Sec.]

2. An auditorium has a volume of $9,000 \text{ m}^3$ and total surface absorption is $160\ o\omega u$. Find the reverberation time.

   [Ans. 9.3 Sec.]

3. A cinema hall a volume $7,500 \text{ m}^3$. It is required to have reverberation time 1.5 sec. What would be the total absorption in the hall ?

[Ans. $\sum as = 80$ units]

4. Find the reverberation time for (a) the empty hall, (b) with 60 Persons with date given below, $V = 2,900 \text{ m}^3$

Surface	Area	Absorption Coefficient
1. Plastered Walls	$4 \times 28 \text{ m}^2$	0.03 *oωu*
2. Wooden Walls	130 m^2	0.06 *oωu*
3. Plastered Ceiling	170 m^2	0.04 *oωu*
4. Wooden Doors	$2 \times 10 \text{ m}^2$	0.06 *oωu*
5. Audience	60 no's	4.7 *oωu*
6. Seats Cushioned	100	1.0 *oωu*

[Ans. $T_1 = 3.89$ sec. $T_2 = 1.36$ sec.]

5. Find the reverberation time for a hall of 2600m^3 with a seating capacity of 200 Persons (a) with empty (b) when ful with audience from the following data.

Surface	Area	Coefficient of Absorption
1. Plastered Ceiling	500 m^2	0.04
2. Plastered Walls	600 m^2	0.03
3. Wooden Floor	500 m^2	0.06
4. Wooden Doors	400 m^2	0.06
5. Seats Cushioned	100 no.	1.00 *oωu* / seat
6. Seats Cone.	100 no.	1.00 *oωu* / seat

[Ans. (a) 2.05 sec. (b) 0.4 sec.]

6. What is reverberation time of a hall of 3000m^3 volume and 1850m^2 area. The average absorption coefficient of the surface is 0.2 *oωu.*

[Ans. 1.33 sec.]

7. A man shouts into a mine. The echo is heared after 4.2 sec. If the velocity of sound is 340 m/s. Find the depthe of the mine.

[Ans. 714 m]

8. A tunning fork frequency 284 Hz is emitting sound waves of velocity 330 m/sec in air. Find the wavelength of waves emitted.

[Ans. 1.162 m]

9. Find out the wavelength of ultrasonics produced in quartz of velocity is 5.5×10^3 m/sec and thickness is 0.5 cm.

[Ans. 1×10^{-2}m]

10. Find the speed of longitudnal wave in a medium of density 2.7×10^{-3}Kg m^{-3} modulaus of rigidity is 2.1×10^{10} N/m^2 and bulk modulus is 7.5×10^{10} N/m^2.

[Ans. 6.2×10^{3} m/sec.]

11. A quartz crystal of thickness 0.001 m is at resonance. Calculate its frequency if $\lambda = 7.9\times10^{10}$ N/m^2 and $\rho = 2650$ Kg/m^3.

[Ans. n = 2.73 Hz]

12. Find the velocity of sound in a medium of density 2.7×10^{3} Kg/m^3 and bulk modulus 7.5×10^{10} N/m^2. [Ans. 5.27×10^{3} m/sec.]

ANSWER KEY FOR MULTIPLE CHOICE QUESTIONS

(1)	c	(2)	c	(3)	b	(4)	d	(5)	d
(6)	c	(7)	b	(8)	b	(9)	c	(10)	a
(11)	a	(12)	b	(13)	b	(14)	c	(15)	c
(16)	d	(17)	b						

UNIT - 3

PRINCIPLE OF OPTICS

INTRODUCTION :-

Optics is the branch of Physics which deals with the study of optical phenomena like reflection, refraction, dispersion, interference, differaction etc.

(or)

Optics is the branch of Physics which deals with the light.

The subject of optics has been divided into two categories :-

(i) Wave Optics

(ii) Ray Optics

(i) WAVE OPTICS :-

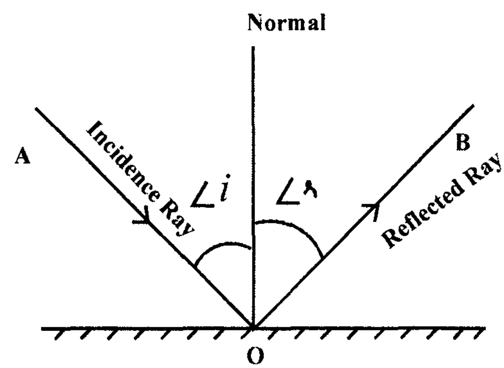
Wave optics are described as the connect between waves and rays of light. The visible light is an electromagnetic wave of wavelength from 3900 Å of violet colour to 7800 Å of Red colour. The wave theory was put forward by Huyghem, according to him, "The light is a form of energy which travels through a medium in the form of a transverse wave motion". The speed of light in a medium depends upon the nature of medium.

(ii) RAY OPTICS :-

In ray optics the ray of light is in a straight line path followed by light passing from one point to another point. It deals with the study of formation of images in mirrors and lenses, construction and working of the optical instruments.

REFLECTION OF LIGHT :-

When a ray of light falls on the surface of a plain mirror, it falls on the incidence point 0. If this beam of light does not change the medium and comes back to same medium then this Phenomenon is known as refection of light. In fig. , AO is the incidence ray of light falling on the surface of the mirror and after that it comes back to same medium say OB is then known as reflection of light. Now Draw Normal on point 0. Then $\angle i$ is the angle of reflection between ray and normal.



LAW OF REFLECTION :-

(1) The incidence ray, reflected ray and normal at the point of incidence all lie in the same plane.

(2) The angle of incidence $\angle i$ is equal to angle of reflection $\angle r$

i.e $\angle i = \angle r$

MIRROR :-

A surface which reflects all of the light falling on it is called mirror. It is of two types :-

(i) Plain Mirror.

(ii) Spherical Mirror.

(i) PLAIN MIRROR :-

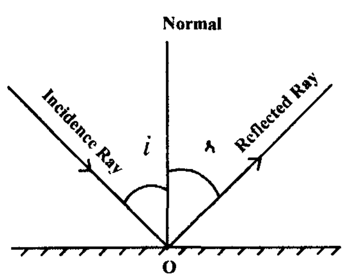
A Plane mirror is flat surfaced, which produces an eract, virtual image of the real object in which front and back are reversed as shown in fig. (3.1)

(ii) SPHERICAL MIRROR :-

A Spherical mirror is a part of spherical reflecting surface. A Spherical mirror is of two types:-

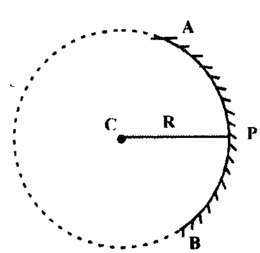
(a) CONCAVE MIRROR. (b) CONVEX MIRROR.

Consider a hollow glass sphere. If a portion of the hollow sphere is cut along a plane and silvered, it serves as spherical mirror. If a part APB is silvered such that the depressed surface becomes the reflecting surface then it is called concave spherical mirror as shown in fig. (3.2). On the other hand if the silvering is done so that the surface is buldging out, serves as the reflecting surface, then it is called convex spherical mirror as shown in fig. (3.3)



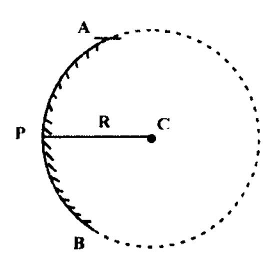
Plane Mirror

Fig (3.1)



Concave Mirror

Fig (3.2)



Convex Mirror

Fig (3.3)

A FEW DEFINITIONS :-

1. CENTRE OF CUVATURE :-

The centre of the sphere of which the mirror forms a part is called centre of curvature. It is denoted by C.

2. **RADIUS OF CUVATURE :-**

The radius of the sphere of which the mirror forms a part is called radius of curvature. It is denoted by R. i.e the distance PC = R.

3. **POLE :-**

The centre of spherical mirror is called its pole. It is denoted by P.

4. **PRINCIPAL AXIS :-**

The line joining the pole and centre of curvature of the mittor is called principal axis of the mirror. The line PC extended both way in fig. (3.2 & 3.3) represents the principal axis of the mirror.

5. **APERTURE :-**

The diameter of the mirror is called aperture of the mirror. The line joining points A and B represents the aperture of the mirror.

6. **PRINCIPAL FOCUS :-**

The point at which a narrow beam of lightis parallel to its principal axis, when incident on the mirror after reflection from the mirror comes from is called principal focus of the mirror. It is represented by F.

In the case of a concave mirror the ray of light incident parallel to principal axis after reflection, it is meet at F as shown in fig. (3.4) and in case of convex mirror the ray of light incident parallel to principal axis, after reflection it does not meet at F but appeares to come from it when produced backward, as shown in fig. (3.5)

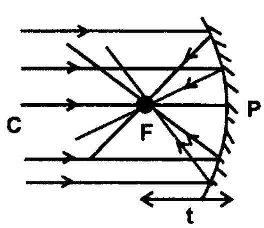


Fig (3.4)

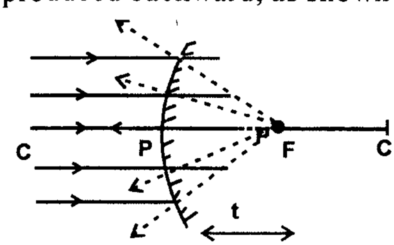


Fig (3.5)

7. **FOCAL LENGTH :-**

The distance between the Pole and the principal axis of the mirror is called the focal length of the mirror. It is denoted by f as shown in fig. (3.4) and (3.5) PF = f.

SIGN CONVENTION :-

1. All the distances are measured from the Pole of the mirror.
2. The distances measured in the direction of the incidence of light are taken as positive and the distance measured in a direction opposite to the direction of incidence of light are taken as negative.

3. Heights measured perpendicular to the principal axis upwords are considered positive while those measured downwords are considered as negative.
4. Distance of the object is always negative. Further the distance of real image is negative while the distance of virtual image is positive.
5. Size of the real object and virtual image is taken as positive while the size of real image is taken as negative.

RELATION BETWEEN f AND R :-

(a) CONCAVE MIRROR :-

Let us assume a concave mirror of small aperture whose pole, focus, centre of cuvature are P, F and C respectivelly. If a ray of light OA travels Palrallel to Principal axis falls on the mirror, then after reflection it will pass through its focus F. Since the line CA is normal to the concave at point A as shown in fig. (3.6)

as $\angle OAC = \angle BAC = \theta$ (say)

also, PF = f and PC = R

$\angle PAC = \angle OAC = \theta$ (alternate angles)

$\angle PFA = \angle FCA + \angle CAF$

$\angle PFA = 2\,\theta$

from point A drawn AN Perpendicular to PC, then in Δ ACN we have.

$$\tan\,\theta = \frac{AN}{NC} \text{ -------(1)}$$

When aperture is small then $\tan\,\theta \approx \theta$ i.e., NC $\approx$ CP

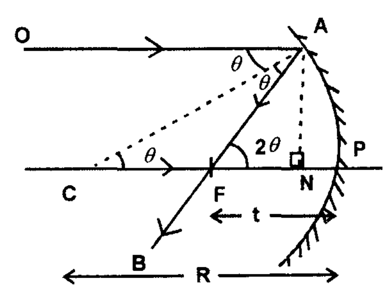


Fig (3.6)

$$\theta = \frac{AN}{PC}$$

$$\theta = \frac{AN}{R} \text{ ---------- (2)}$$

In Δ FNA, $\tan 2\,\theta = \dfrac{AN}{NF}$

As apperture is of small, then $\tan 2\,\theta \approx 2\,\theta$, and NF $\approx$ PF $= f$

$$\text{then, } 2\,\theta = \frac{AN}{f} \text{ or } \theta = \frac{AN}{2\,f} \text{ -----------(3)}$$

from equation from (2) and (3) weget.

$$\frac{AN}{R} = \frac{AN}{2f}$$

or $f = \frac{1}{2} R$

(b) CONVEX MIRROR :-

Similarly we find out the relation between f and R in case of convex m irror. Weget,

$$f = \frac{1}{2} R$$

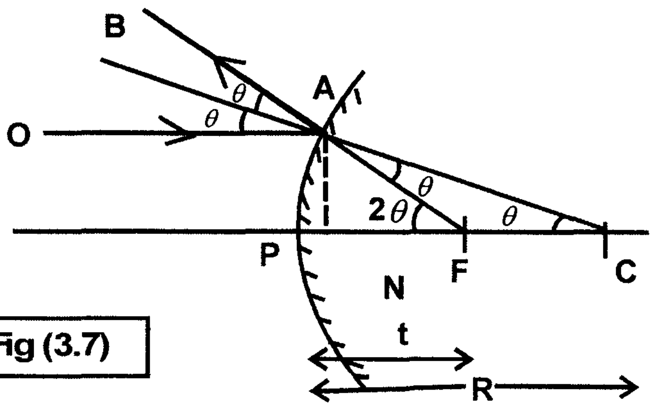


Fig (3.7)

MIRROR FORMULA :-

The formula is the relation between the distance of object (μ), the distance of image (υ) and focal length (f) of the spherical mirror.

(a) CONCAVE MIRROR :-

Let us considered an object AB is placed on the Principal axis beyond the centre of curvatrue C of the mirror. Let P.F. be the Pole and focus of concave mirror. A ray of light from B point of the object travelling Parallel to Principal axis falls on the mirror at point E and cuts focus F. Another beam of light from point B falls on the Pole and reflect according to law of reflection. These two beams of light meet at Point B^1 so that B^1 is the image of the B Point of the object. So $A^1 B^1$ is the real image of object AB as shown in fig. (3.8).

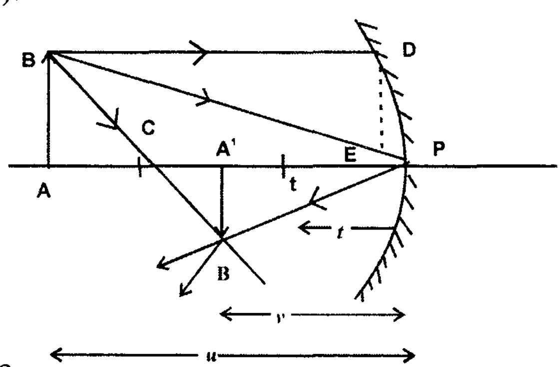


Fig (3.8)

Draw a perpendicular DE to Principal axis.

Now in Δ A^1B^1 F and DEF are similar so,

$$\frac{A^1 B^1}{DE} = \frac{A^1 F}{EF}$$

Since all the distances are to be measured from Pole of the mirror.

So that, $A^1F = PA^1 - PF$

$$\therefore \frac{A^1B^1}{DE} = \frac{PA^1 - PF}{EF}$$

As the aperture of the mirror so small that Point E and P lies very close to other, hence, so that

$$EF \approx PF \text{ and } DE = AB$$

$$\therefore \frac{A^1B^1}{AB} = \frac{PA^1 - PF}{PF} \quad \text{--------(1)}$$

Now in triangle Δ ABP and A^1B^1P, so that

$$\frac{A^1B^1}{AB} = \frac{PA^1}{PA} \quad \text{--------(2)}$$

from equation (1) and (2) weget,

$$\frac{PA^1}{PA} = \frac{PA^1 - PF}{PF} \quad \text{--------(3)}$$

Now applying sign conventions weget,

$$PA = -u,\ PA^1 = -v,\ PF = -f$$

∴ equation (3) becomes :-

$$\frac{-v}{-u} = \frac{-v-(-f)}{-f}$$

or $$\frac{-v}{-u} = \frac{-v+-f}{-f} \Rightarrow \frac{v}{u} = -(\frac{v-f}{-f})$$

or $$\frac{v}{u} = \frac{v-f}{f}$$

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

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

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

Divided by v on both sides weget,

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

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

This equation is known as mirror formula,

LINEAR MAGNIFICATION :-

"The ratio of the size of the image formed by a spherical mirror to the size of the object is called linear magnification produced by spherical mirror."

It is denoted by m.

$$m=\frac{\text{Size of image}}{\text{Size of object}}$$

Let size of object and image are denoted by O and I so

$$m=\frac{I}{O}$$

APPLICATIONS OF SPHERICAL MIRROR :-

(a) CONCAVE MIRROR :-

(1) A cancave mirror has an eract image and highly magnified virtual image is formed so it is used in the plain mirror for sharing.

(2) It is used in the ophthalmoscope.

(3) It is used in reflecting type astronomical telescope.

(b) CONVEX MIRROR :-

An convex mirror is used as a driver's mirror in scooters, car and other vehicles.

REFRACTION OF LIGHT :-

"Reflection of light is the phenomenon of change in the path of light, when it goes from one medium to another". or

"When a ray of light travels from one medium to another medium then it bends towards or away from the normal so the process of the bending of light from its straight path when it change its medium, this phenomenon is known as reflection of light."

When the ray of light passes from optically rarer medium to denser medium, it bends towards the normal and when it travels from denser medium to rarer medium, it bends away from the normal. Let XY be the surface separates two medium rarer and denser. A ray of light AO from rarer medium enters in the denser medium. After the point O then it bends towards the normal NON' and travels along the path OB then AO is called incidence ray, OB is called refrected ray, as shown in fig. (3.9)

The angle between the incidence ray and normal is known as angle of incidence and the angle between refracted ray and normal is known as angle of refraction.

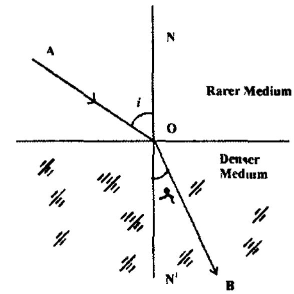


Fig (3.9)

$\therefore \angle AON = \angle i$

$\angle N^{1}OB = \angle r$

LAWS OF REFRACTION :-

The Phenormenon of refraction takes place according to the following laws :-

(i) The incidence ray, refracted ray and normal to the interface at the point of incidence all lie in the same plane.

(ii) The ratio of the sine of the angle of incidence to the sone of the angle of refraction is constant for any two given medio, so that,

$$\frac{\text{Sin } i}{\text{Sin r}} = \text{constant}$$

$$\text{or } \frac{\text{Sin } i}{\text{Sin r}} = {}^{a}\mu_{b} \text{ ----------(1)}$$

Where ${}^{a}\mu_{b}$ is the constant and it is known as REFRACTIVE INDEX of the medium b w.r.t. medium a, and light travels from medium a to medium b.

Equation (1) is also known as SNELL'S LAW.

The value of refractive index depends upon the nature of the pair of the media a and b and wavelength of the light.

Refracting index will be also defined in the terms of velocity of light. "It may be defined as the ratio of velocity of light in vaccum to the velocity of light in a medium."

$$\text{since, } \mu = \frac{\text{Velocity of light in vaccum}}{\text{Velocity of light in medium}} = \frac{C}{v}$$

$$\therefore \mu = \frac{C}{v}$$

A medium having higher value of refractive index ($\mu >> 1$) is called optically denser. While the one having smaller value is called rarer medium.

LENSES :-

"A lens is a portion of a transparaent refracting medium bounded by two spherical surfaces or one spherical surface and the other plane surface."

Lenses are divided into two classes :-

(i) Convex lenses.

(ii) Concave lenses.

(i) CONVEX LENSES :-

Convex lenses are thick at the middle and thin by the edges. These lenses are also known as converging lenses. These are of three types :-

(a) Double convex lens fig. 3.10 (a)

(b) Plano convex lens fig. 3.10 (b)

(c) Concavo convex lens fig. 3.10 (c)

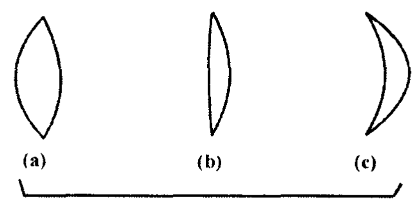


Fig (3.10)

(ii) CONCAVE LENSES :-

A Concave lens is thinner in the middle and thicker at the edges. These lenses are also known as diverging lenses. These are of three types :-

(a) Double concave lens fig. 3.11 (a)

(b) Plano concave lens fig. 3.11 (b)

(c) Convex concave lens fig. 3.11 (c)

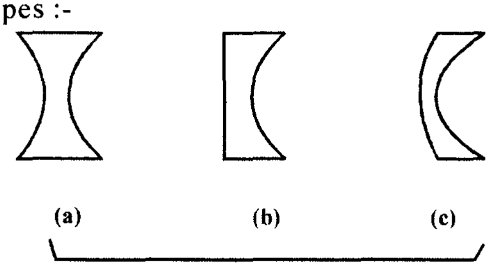


Fig (3.11)

SOME IMPORTANT TERMS RELATED TO LENSES :-

1. POLE :-

The centre of the spherical reflecting surface is called its Pole. It is denoted by P.

2. CENTRE OF CURVATURE :-

The centre of a sphere of which the curved surface forms a part is called centre of curvature. It is denoted by C.

3. REDIUS OF CURVATURE :-

The radius of the sphere of which the curved surface forms a part is called radius of curvature. It is denoted by R.

4. APERTURE :-

The diameter of spherical reflecting surface is called its aperture.

5. PRINCIPAL AXIS :-

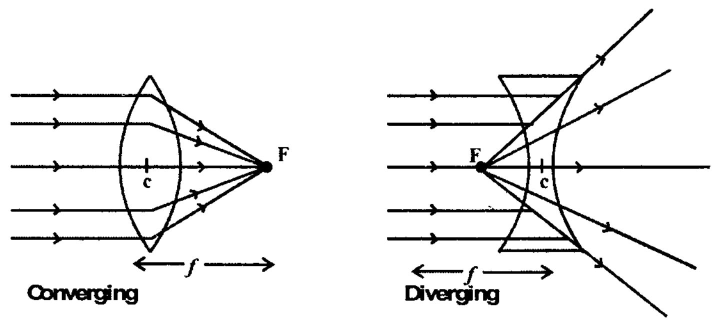
The line passing through the Pole and the centre of curvature of the spherical reflecting surface is called its principal focus.

6. OPTICAL CENTRE :-

The optical centre is a point lying on the principal axis so that a ray of light passes through it does not suffer any deviation from its Path i.e. it goes undeviated. It is denoted by C.

7. PRINCIPAL FOCUS :-

When a beam of light is incident on a lens in a direction that is parallel to the principal axis of the lens. The ray after refraction through the lens converges or appears to diverge from a point on the principal axis as shown in fig. (3.11). This is point F is known as Principal focus.



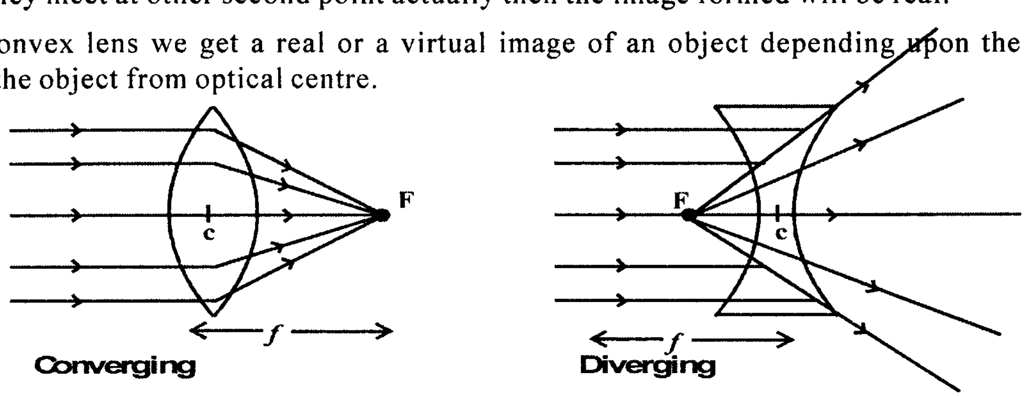
SIGN CONVENTION FOR LENS :-

1. All the distances are measured from the optical centre of the lens.
2. All the distances are measured in the direction of incidence of light are taken as positive, whereas all the distance measured in direction opposite to the direction of incidence of light are taken as negative.
3. For a convex lens f is positive and for a concave lens f is negative.

REAL AND VIRTUAL IMAGE :-

When a ray of light falls on the mirror or lens and then suffering reflection or refraction they meet at other second point actually then the image formed will be real.

In convex lens we get a real or a virtual image of an object depending upon the position of the object from optical centre.



VIRTUAL IMAGE :-

When a ray of light after suffering reflection or refraction do not actually meet but appears to meet from the second point. Then the image formed will be virtual image.

In concave lens we get only virtual image depending upon the position of object from optical centre.

IMAGE FORMATION BY THE LENSES :-

(i) FOR CONVEX LENS :-

(a) OBJECT BETWEEN LENS AND FOCUS F :-

When an object is placed between the lens and focus, then its image can be found behind the object. Virtual, erect and larger then the object as shown in fig. (3.12)

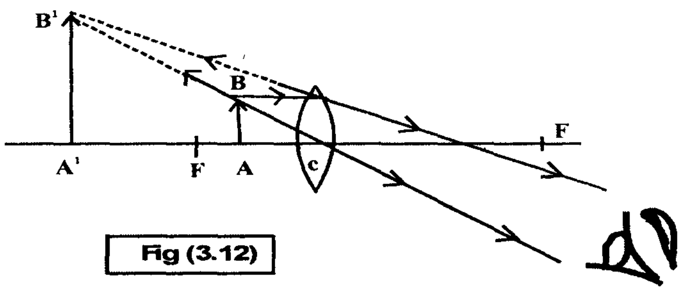


Fig (3.12)

(b) OBJECT AT FOCUS :-

When an object is placed at principal focus then its image will be found at infinity, real and inverted and highly magnified as compared to object as shown in fig. (3.13)

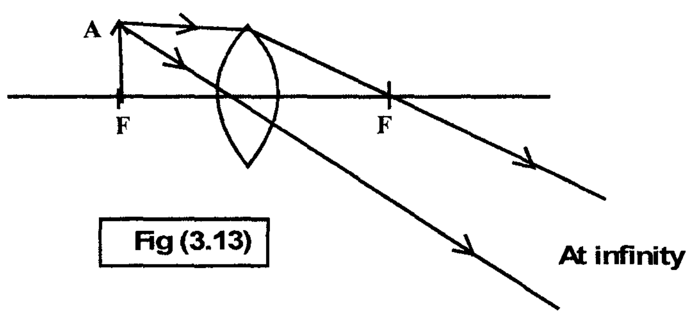


Fig (3.13)

(c) OBJECT BETWEEN F AND 2F :-

When object is placed between F and 2F then its image will be beyoned 2F on the other side, real, inverted and larger than object. as shown in fig. (3.14)

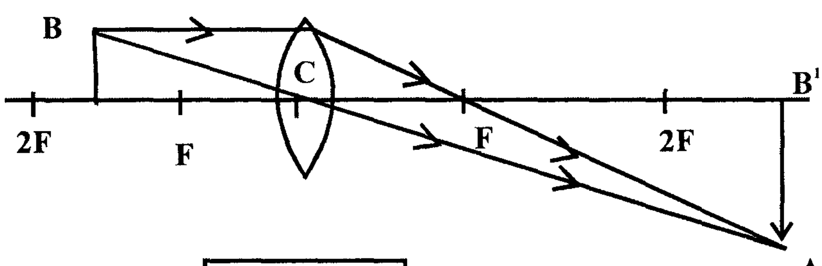


Fig (3.14)

(d) OBJECT AT 2F :-

When object is placed at 2F then its image is at 2F on the other sides, real, inverted and some size of the obje t as shown in fig. (3.15)

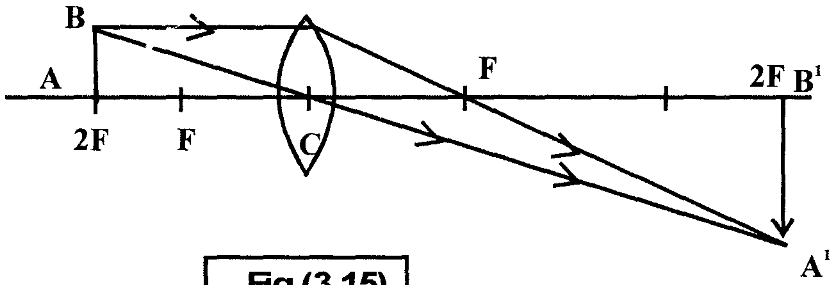


Fig (3.15)

(e) OBJECT BEYONED 2F :-

When an object is placed beyoned the 2F then its image is between the F and 2F, real, inverted and smaller than the object as shown in fig. (3.16)

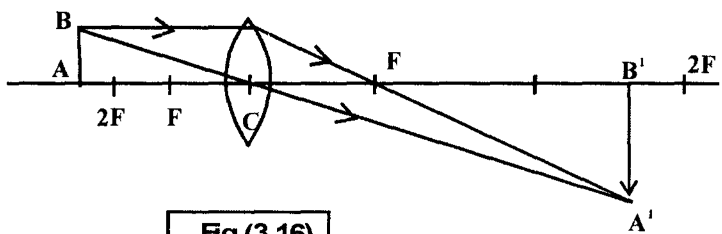


Fig (3.16)

(f) OBJECT AT INFINITY :-

When an object is placed at infinity then its image is at F, real, inverted and smaller than object as shown in fig. (3.17)

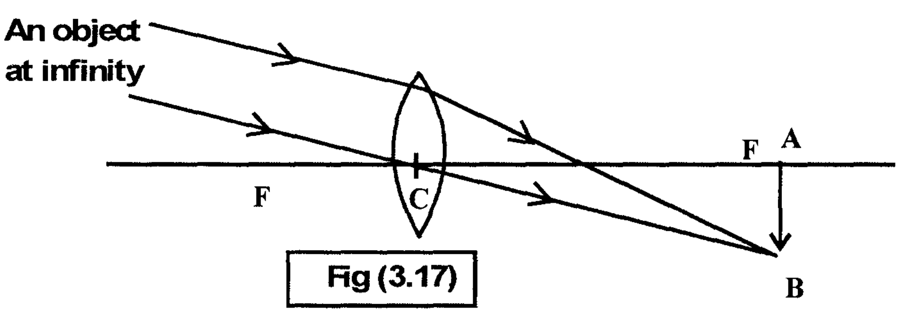


Fig (3.17)

(ii) FOR CONCAVE LENS :-

In case of concave lens the image is always Virtual, erect and larger then the object as shown in fig. (3.18). As we move the object from infinity to the surface of the lens, the image moves from the principal focus to the lens.

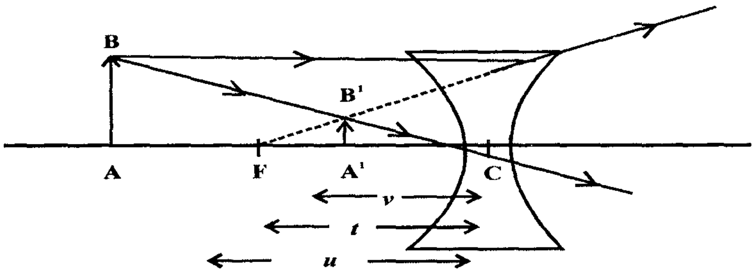


Fig (3.18)

LENS FORMULA :-

Lens formula is the relation between focal length (f), of a lens and distance of object (v) of the lens. i.e.

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

LINEAR MAGNIFICATION :-

The linear magnification of a lens may be defined as the ratio of the size of the image (I) to to the size of object (O). It is represented by m.

$$\text{i.e. } m=\frac{\text{Size of Image}}{\text{Size of Object}}=\frac{I}{0}$$

EXAMPLE (3.1)

A diverging lens of focal length of 15 cm from an image 10 cm from the lens. Calculate the distance of the object from the lens.

SOLUTION :-

Given focal length (f) = 15 cm

Image distance (v) = 10 cm

Object distance (u) = ?

according to lens formula, $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$

$$\frac{1}{15}=\frac{1}{v}-\frac{1}{u}$$

$$\therefore \frac{1}{u}=\frac{1}{10}-\frac{1}{15}$$

$$\frac{1}{u} = \frac{3-2}{30} \Rightarrow \frac{1}{30}$$

$\therefore u = 30$ cm Ans.

POWER OF A LENS :-

Power of a lens is defined as the ability of the lens to converge a beam of light falling on the lens.

or

Te reciprocal of the focal length of a lens measured in meter is known as the power of a lens.

It is denoted by P.

i.e $$P = \frac{1}{f\text{ (meter)}}$$

The S.I. unit of Power of lens is DEOPTRE (D), so which f = 1 m, then

$$P = \frac{1}{1\text{ m}} \Rightarrow 1\text{ D}$$

Hence one dioptre is the powr of a lens of focal length one metre. When f is in cm, then,

$$P = \frac{100}{f}\text{ dioptre}$$

POWER OF COMBINATION OF LENSES :-

The focal length of combination of two lenses is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

If P_1 is the power of focal length f_1 and P_2 IS THE POWER OF FOCAL LENGTH f_2 then P the combination of the focal length F is given by

$$P = P_1 + P_2$$

EXAMPLE (3.2) :-

Two thin lens are in contact and focal length of the combination is 80 cm. If the focal length of one lens is 20 cm then find out the power of the other lens.

SOLUTION :-

Here F = 80 cm

$f_1 = 20$ cm

$P_2 = ?$

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

$$\frac{1}{80} = \frac{1}{20} + \frac{1}{f_2}$$

$$\therefore \frac{1}{f_2} = \frac{1}{80} - \frac{1}{20}$$

$$1/_{f_2} = \frac{1-4}{80} \Rightarrow {}^{-3}/_{80}$$

$$\therefore f_2 = \frac{80}{3}$$

$$\therefore P \quad \frac{1}{f\ (\text{m})} = \frac{100}{f\ (\text{cm})}$$

$$P = \frac{100}{80} \Rightarrow 1.25\ \text{D}$$

or $P = P_1 + P_2$

$$P_1 = \frac{100}{f_1} \Rightarrow \frac{100}{20} \Rightarrow \ 5\ \text{D}$$

$$\therefore\ P = P_1 + P_2 \Rightarrow P_2 = P - P_1$$

$P_2 = 1.25 - 5 \Rightarrow 3.75$ D Ans.

EXAMPLE (3.3)

Find out the focal length and nature of a lens if power of the lens is-2.5 D.

SOLUTION :-

Given, P = 2.5 D

We know that $P = \frac{1}{f}$

$$\therefore f = \frac{1}{P} \Rightarrow -\frac{1}{2.5} \Rightarrow -0.4\ \text{m}$$

As the focal length of the lensj is negative so lens is concave in nature.

EXAMPLE (3.4)

The image obtained by a convex lens is erect and its length is four times to the length of the object. If the focal length of the lens is 20 cm. Find out object and image distance.

SOLUTION :-

Given, $m = \frac{v}{u} = 4$

or $v = 4u$

We know that $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

Given, $f = 20$ cm,

so $\frac{1}{20} = \frac{1}{4u} - \frac{1}{u}$

$\frac{1}{20} = \frac{1-4}{4u} \Rightarrow \frac{-3}{4u}$

or $\frac{1}{20} = -\frac{-3}{4u}$

or $u = -15$ cm

$\therefore v = 4u \Rightarrow 4 \times (-15) \Rightarrow -60$ cm

$u = 15$ cm

$v = 60$ cm Ans.

EXAMPLE (3.5)

An object of size 3 cm is placed at 14 cm in front of concave lens of focal length 2 km. Describe the image produced by the lens.

SOLUTION :-

Given, size of an object (O) = m 3 cm

Size of Image (I) = ?

$u = -14$ cm, $f = -21$ cm and $v = ?$

We know that $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\therefore \frac{1}{-21} = \frac{1}{v} - \frac{1}{-14}$$

$$\text{or } \frac{1}{v} = -\frac{1}{-21} - \frac{1}{-14} \Rightarrow \frac{-5}{42}$$

$v = -8.4$ cm Ans.

Now linear magnification of an lens is given by, $m = \frac{1}{0} \Rightarrow \frac{v}{u}$.

$$\therefore \frac{1}{0} = \frac{v}{u}$$

$$\therefore 1 = 0 \times \frac{v}{u}$$

$$I = 3 \times \frac{(-8.4)}{(-14)}$$

$I = 1.8$ cm Ans.

OPTICAL INSTRUMENTS :-

The optical instruments are the device which help human eyes in observing highly magnified images of tiny objects and observing very for off objects.

Microscope and Telescope are common examples of optical instruments. The optical components of these instruments are lenses and mirrors. The images are formed by refraction through lens and by reflection through mirror.

MICROSCOPE :-

A mircroscope is a device which is used to see the image of tiny object.Microscopes are of two types :-

(i) Simple Microscope.

(ii) Compound Microscope.

(i) SIMPLE MICROSCOPE:-

A convex lens of short focal length can be used to see the magnified image of a small object and it is called a magnifying glass or a simple microscope.

CONSTRUCTION :-

It consists of a converging lens of small focal length ranging between 2.5cm to 15cm. When a small object is placed between the optical centre and focus of a convex lens, its virtual, erect and magnified image is formed on the same side of the lens. The lens is held close to eye and distance of the object is adjusted till the image is formed at "the least distance of distinct vision" from the eye and hence the minimum distance from the eye at which the object are clearly visible is called the least distance of distinct vision. For a normal eye the least distance of distinct vision is 2.5 cm and it is represented by D.

Let an object AB placed between F and C its virtual image $A^1 B^1$ is formed on the same side at the distance D equal to the distance of distinct as shown in fig. (3.19)

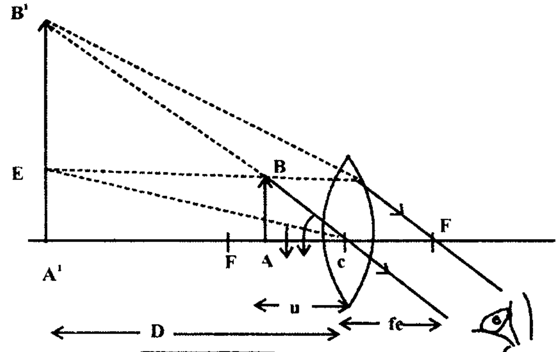


Fig (3.19)

MAGNIFYING POWER :-

"The Magnifying Power of a simple microscope is defined as the ratio of the angle substended by the image at the eye (β) and the angle substended by the object (α) seen directly when both lie at me least distance of distinct vision."

It is represented by 'M'

hence $M = \dfrac{\beta}{\alpha}$

Let $\angle A^1 C B^1 = \beta$ (angle substended by the image at eye)

$\angle A^1 C E = \alpha$ (angle substended by the object seen directly)

$A^1 E = AB$ and join EC, then $\angle A^1 C E = \alpha$

As the angle are small they can be replaced by their tengents i.e.

$$m = \frac{\tan \beta}{\tan \alpha} \text{---------} (1)$$

from Δ ACB, $\tan \beta = \dfrac{AB}{AC}$

Δ A^1CB, $\tan \alpha = \dfrac{A^1E}{A^1C}$

Putting value of $\tan \beta$ and $\tan \alpha$ in equation (1) weget.

$$m = \frac{AB}{AC} \times \frac{A^1C}{A^1E} \text{-----} (2)$$

Now $AC = u$, $A^1C = D$ and $A^1E = AB$

$$\therefore m = \frac{AB}{u} \times \frac{D}{AB}$$

$$\therefore m = \frac{D}{u} \text{ -------------(3)}$$

If F is the focal length of lens used then by lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \text{ ---------------(4)}$$

Now according to new cartesian sign convertions :-

$u = -u,\ v = -D,\ f = +f$

Putting these value in equation no. (4) weget.

$$\frac{1}{f} = \frac{1}{-D} - \frac{1}{(-u)}$$

$$\frac{1}{f} = \frac{1}{-D} - \frac{1}{(-u)}$$

$$\text{or } \frac{1}{u} = \frac{1}{f} + \frac{1}{D}$$

Now multiplying by D on both sides we get,

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

$$\text{or } \frac{D}{u} = \frac{D}{f} + 1 \text{ ----------------(5)}$$

From equation (3) and (5) we have,

$$m = 1 + \frac{D}{f} \text{ ------------------(6)}$$

From this equation we say that if the focal length of the lens is small then magnifying power will be large.

USES :-

. A simple microscope is used by the watch makers and jewellers for having magnified view oftiny part of watch.

2. In science laboratories, a magnifying glass is used to see slides and take the readings of instruments.

(ii) COMPOUND MICROSCOPE :-

A Compound microscope is an optical instrument used for observing highly magnified images of tiny objects.

PRINCIPLE :-

When a small object is placed just outside the focus of the objective lens its real, inverted and magnified image is produced on the other sides of the lens between F and 2 F. The image produced by objective lens acts as object for eye lens. The distance of object from the objective lens is so adjusted that the final image is formed at the least distance of distinct vision from the eye.

CONSTRUCTION :-

It consists of two lenses. A lens of short aperture and small focal length facing an object called objective lens and another lens of short focal length but large aperture is called eye lens. The two lenses are held co-axially at the free ends of two co-axial tubes at a suitable fixed distance from eachother. The distance of the objective lens from the object can be adjusted by rock and pinion arrangement.

Let an object AB is placed just outside the focus Fo of the objective lens. Its virtual image A^1B^1 is form on the other side of the lens. The image A^1B^1 lies between focus Fe and optical centre C^1 of the eye lens and it is acts object for the lens. As shown in fig. (3.20)

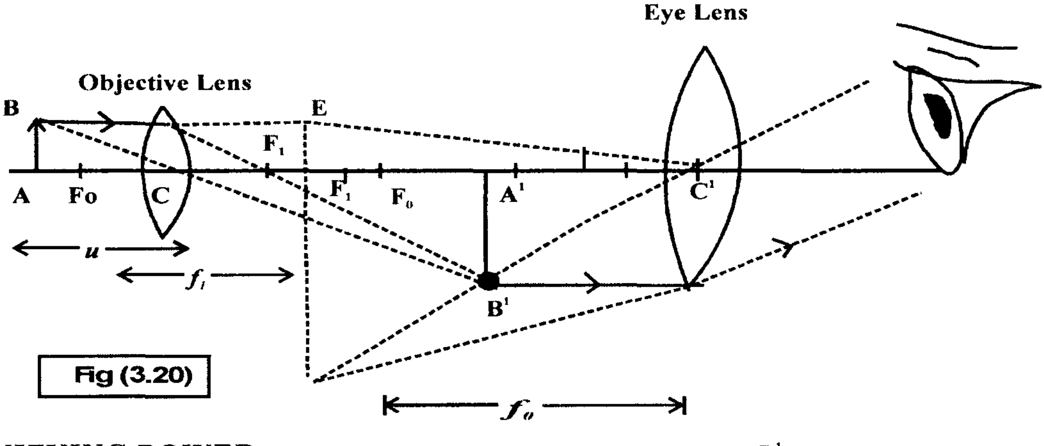


Fig (3.20)

MAGNIFYING POWER :-

"The Magnifying Power of a compound microscope is defined as the ratio of the angle substended by the final image at the eye to the angle substended by the object seen directly when both are placed at the least distance of distinct vision.

Let $\angle A^{11} C^1 B^{11} = \beta$ (angle substended by the final image at the eye.)

and $\angle A^{11} C^1 E = \alpha$ (angle substended by the object) as as $\angle A^{11}E$ equal to AB and join E C^1 so $\angle A^{11}C^1E = \alpha$

Then $m = \beta/\alpha$

Since the angle are so small, so, $\alpha \approx \tan\alpha$ and $\beta \approx \tan\beta$

$$\therefore\ m = \frac{\tan\beta}{\tan\alpha} \text{ ------------- } (1)$$

in Δ A" B' C", $\tan\beta = \dfrac{A''B''}{A''C'}$

in Δ A" C' E, $\tan\alpha = \dfrac{A''E}{A''C'}$

Putting value of $\tan\beta$ and $\tan\alpha$ in equation (1) we have,

$$m = \frac{A^{11}B^{11}}{A^{11}C^{1}} \times \frac{A^{11}C^{1}}{A^{11}E}$$

$$m = \frac{A^{11}B^{11}}{A^{11}E}$$

or, $m = \dfrac{A^{11}B^{11}}{AB}$ $[\because A^{11}E = AB]$

Now multiplying and divided by A^1B^1 wehave,

$$m = \frac{A^{11}B^{11}}{AB} \times \frac{A^{1}B^{1}}{A^{1}B^{1}}$$

$$m = \frac{A^{11}B^{11}}{A^{1}B^{1}} \times \frac{A^{1}B^{1}}{AB}$$

$$\text{or } m = m_e \times m_o \text{ -------- } (2)$$

Where $m_e = \dfrac{A^{11}B^{11}}{A^{1}B^{1}}$, magnifying power of eye lens.

$m_o = \dfrac{A^{1}B^{1}}{AB}$, magnifying power of objective lens.

Now we calculate m_e and m_o,

To find m_o :-

As, $m_o = \frac{A^1B^1}{A\,B} = \frac{\text{distance of image } A^1B^1 \text{from C } (v)}{\text{distance of object A Bfrom C } (\mu)}$

$$\therefore M_0 = \frac{-v}{u} \text{--------} (2)$$

To find m_e :-

As the right angled trangles $A^{11}C^1\ B^{11}$ and $A^1C^1\ B^1$ are similar.

$$\text{so, } \frac{A^{11}B^{11}}{A^1B^1} = \frac{C^1\ A^{11}}{C^1\ A^1}$$

as $C'A'' = D$ and $C'A' = u'$ (say)

$$\therefore\ m_e = \frac{A^{11}B^{11}}{A^1B^1} = \frac{\text{distance of image } A^{11}B^{11}\text{from } C^1\ (D)}{\text{distance of image } A^1B^1\text{from } C^1\ (\mu^1)}$$

$$\therefore M_e = \frac{D}{u'}$$

Now we calculates $\frac{D}{u'}$ by using lens formula,

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

$$\text{or } \frac{1}{v} - \frac{1}{u'} = \frac{1}{f_e} \text{--------} (4)$$

Where f_e = focal length of eye lens and by new cortesian convention,

$$v = -D,\ u' = -u',\ f_e = f_e$$

Putting all the values in equation (4) wehave,

$$\frac{1}{-D} - \frac{1}{u'} = \frac{1}{f_e}$$

$$\text{or } -\frac{1}{-D} + \frac{1}{u'} = \frac{1}{f_e}$$

$$\text{or } \frac{1}{u'} = \frac{1}{D} + \frac{1}{f_e}$$

Now multiplying by D on both sides weget,

$$\frac{D}{u'} = \frac{D}{D} + \frac{D}{f_e}$$

$$\text{or } \frac{D}{u'} = 1 + \frac{D}{f_e}$$

$$\therefore M_e = \frac{D}{u'} = 1 + \frac{D}{f_e} \text{------------(5)}$$

Now putting the value of m_o from equation (3) and m_e from equation (5) we have,

$$m = -\frac{v}{u}(1 + \frac{D}{f_e}) \text{------------(6)}$$

As the focal length of the object lens is very short then object lies very close to its principal focus and so u will be equal to f_o. The focal length of the eye lens also small and therefore the image A^1B^1 will be formed near to eye lens so v will be nearly equal to the distance between the two lens. (L)

$$\therefore\ m_0 = \frac{v}{u'} \Rightarrow \frac{L}{f_0}$$

so putting value of m_o in equation (6) we get,

$$m = -\frac{L}{f_o}\ [1 + \frac{D}{f_e}]$$

EXAMPLE (3.6)

Calculate the magnifying power of an magnifying glass of 5 cm focal length. Distance of distinct vision is 25 cm.

SOLUTION :-

Given, $f_e = 5$ cm

D = 25 cm

$$\text{Now } m = 1 + \frac{D}{f_e}$$

$$\therefore\ m = 1 + \frac{25}{5} \Rightarrow 6 \quad \text{Ans.}$$

EXAMPLE (3.7)

A compound microscope has a magnification is 30. $f_e = 5\text{cm}$. Assuming the final image to be formed at least of distinct vision = 25 cm. Calculate magnification produced by the objectives.

SOLUTION :-

Given, m = 30,

$f_e = 5\text{cm}$

D = 25 cm

$m_o = ?$

We know that, $m = m_e \times m_o$

$$m = m_o\ [1 + {}^{D}/_{f_e}]$$

$$30 = m_o\ [1 + \frac{25}{5}]$$

$$30 = m_o \times 6$$

$m_o = 5$ Ans.

EXAMPLE (3.8)

The focal length of the objective and eye piece of a compound microscope are 4 cm and 6 cm. If an object is place at a distance of 6 cm from the objective, what is the magnifying power of microscope gien D - 25 cm.

SOLUTION :-

Given, f_o = 4 cm

f_e = 6 cm

D = 25 cm

for objective lens, $\frac{1}{v} - \frac{1}{u} = \frac{L}{f_0}$

Now $u = -$ 6 cm and f_e = 4 cm

$$\therefore\ \frac{1}{v} - \frac{1}{-6} = \frac{1}{4}$$

$$\therefore\ \frac{1}{v} = \frac{1}{4} - \frac{1}{6}$$

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

or or $v = 12$ cm

Now $m = m_e \times m_o$

$$\therefore\ m = \frac{v}{u}\ [1+\frac{D}{f_e}]$$

$$m = \frac{12}{6}\ [1+ {}^{25}/_{6}]$$

$$m = 2\times\frac{31}{6} \Rightarrow 10.33$$ Ans.

EXAMPLE (3.9)

A figure divided into square each of size 1mm² is being viewed at a distance of 9 cm through a magnifyined glass of local length 10 cm held closed to the eye.

(a) Find out magnification of the lens.

(b) Magnifying Power of lens.

SOLUTION :-

Given, $f_e =$ 10 cm

$u = -9$ cm

(a) for m, we use, $\frac{1}{v}-\frac{1}{u}=\frac{1}{f_e}$

$$\therefore\ \frac{1}{v}-\frac{1}{-9}=\frac{1}{10}$$

$$\text{or}\ \frac{1}{v}=\frac{1}{10}-\frac{1}{9}$$

or $v = -\ 90$ cm

$$\therefore m = \frac{v}{u}=\frac{-90}{-9}\Rightarrow 10$$ Ans.

(b) Magnifying Power of lens = $\frac{D}{4}$

$$= \frac{25}{9} \qquad = 2.8$$ Ans.

EXAMPLE (3.10)

If we need a magnification of 375 from a microscope of fube length 15 cm and an object of focal length 0.5 cm. What focal length of eye lens should be used.

SOLUTION :-

Given,

$m = -375$
$L = 15$ cm
$D = 25$ cm
$f_e = ?$

as we know that, $m = \frac{-v}{u}[1+\frac{D}{f_e}]$

because focal length of objective lens is small so, $\mu \approx f_0$ to also focal length of eye lens so small, so $v \approx L$

$$\therefore m = -\frac{L}{f_o}[1+{}^{D}/_{f_e}]$$

$$-375 = -\frac{15}{0.5}[1+{}^{25}/_{f_e}]$$

$$\text{or } \frac{25}{f_e} = \frac{375}{30} - 1$$

$$\frac{25}{f_e} = 11.5$$

$$\text{or } f_e = \frac{25}{11.5}$$

$$f_e = 2.2 \text{ cm}$$

TELESCOPE :-

A telescope is an instrument used for seeing faroff objects clearly and magnified though apparently. It is of two types.

1. **ASTRONOMICAL TELESCOPE :-**

   An astromical telescope consists of two lens. The lens facing the object is called objective and it has large aperture and large focal length. Another lens having small focal length and small aperture called eye lens is used. Both the lenses are mounted coaxially in two metallic tubes. The tube holdong the eye piece can be made to slide into the tube holding the objective with the help of rack and Pinion arrangement.

PRINCIPLE :-

The objective forms the real and inverted image of the distant object at its focal. The position of eye lens is adjusted so that the final image is formed at the least distance of distinct vision. If the position of eye lens is so adjusted that the final image is formed at infinity then the telescope is said to be normal adjustment.

WORKING :-

(a) When final image is formed at infinity (normal adjustment) :-

When a parallel beam of light from the distant objects falls on the objective its real and inverted image A^1B^1 is formed on the other side of the lens and if the position of the eye lens is so adjusted that the image A^1B^1 lies at its focus and its final highly magnified image will be formed at infinity as shown in fig. (3.21)

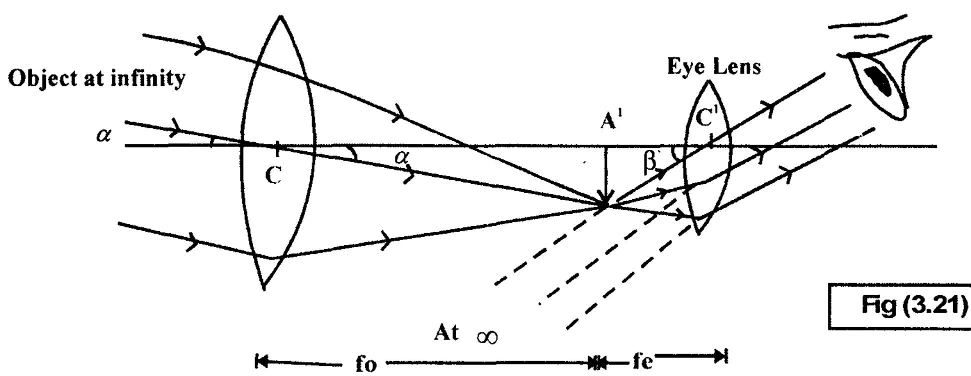


Fig (3.21)

MAGNIFYING POWER :-

Magnifying Power of a telescope in normal adjustment is defined as the ratio of the angle substended by the image at the eye as seen through the telescope to the angle by the object seen directly, when both the object and image lies at infinity.

Now, $m = {}^{\beta}/\alpha$

$\therefore \angle A^1 C B^1 = \alpha$ (angle substended by the object)

$\angle A^1 C^1 B^1 = \beta$ (angle substended by the image)

As these angles are so small, then $\beta \approx \tan\beta$ and $\alpha \approx \tan\alpha$

$$\therefore m = \frac{\tan\beta}{\tan\alpha} \text{ ------------(1)}$$

Now in Δ A' B' C', $\tan\beta = \dfrac{A'B'}{A'C'}$

$$\text{in } \Delta\, A'B'C,\ \tan\alpha = \frac{A'B'}{A'C}$$

Putting value of $\tan\alpha$ and $\tan\beta$ in equation (1) wehave,

$$\therefore\ m = \frac{A^1B^1}{A^1C^1} \times \frac{A^1C}{A^1B^1}$$

$$m = \frac{A^1C}{A^1C^1}$$

Now $A^1C = f_o$ (focal length of the objective)

$A^1C^1 = f_e$ (focal length of the eye lens)

$$\therefore\ m = \frac{f_o}{f_e} \quad \text{-------------(2)}$$

from this expression we say that the magnifying power of a telescope in normal adjustment will be large if objective is of large focal length and eye lens is a of short focal length.

(b) When final image is formed at least distance of distinct vision :-

When the position of the eye lens is so adjusted that the final image A^1B^1 is formed at least distance of distinct vision as shown in fig.(3.22)

Now the magnifying power, $m = \beta / \alpha$

$$m = \frac{\tan\beta}{\tan\alpha} \quad \text{-------------(3)}$$

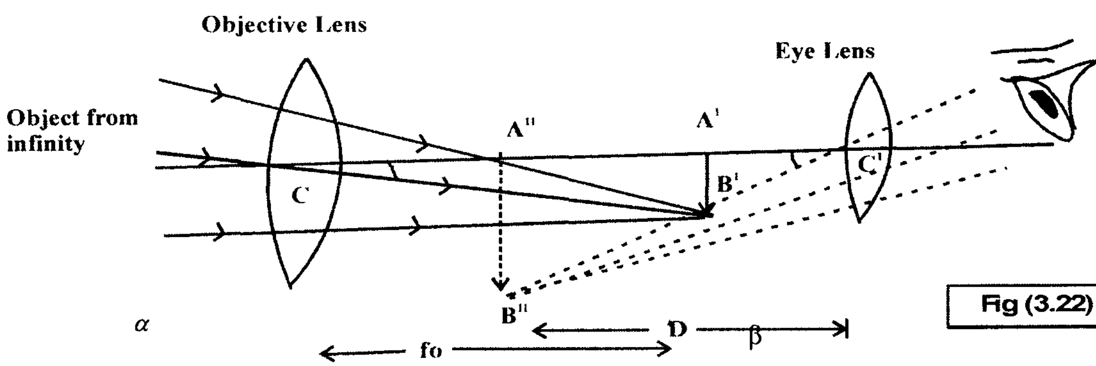


Fig (3.22)

$$\text{in } \Delta\, A^1C^1B,\ \tan\beta = \frac{A^1B^1}{A^1C^1}$$

in $\Delta\ A^1CB^1$, $\tan\alpha = \frac{A^1B^1}{A^1C}$

Putting value of $\tan\alpha$ and $\tan\beta$ in equation (3) weget,

$$m = \frac{A^1B^1}{A^1C^1} \times \frac{A^1C}{A^1B^1}$$

$$\text{or, } m = \frac{A^1C}{A^1C^1}$$

Now, $A'C = f_0$, $A'C' = -u$

$$\therefore m = -\frac{f_0}{u} \text{-------------(4)}$$

Now according to lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f_e}$

By using new cartesian convention,

$$v = -D,\ u = u,\ f_e = +f_e$$

$$\therefore \frac{1}{-D} - \frac{1}{u} = \frac{1}{f_e}$$

$$\text{or } \frac{-1}{D} + \frac{1}{u} = \frac{1}{f_e}$$

$$\frac{1}{u} = \frac{1}{D} + \frac{1}{f_e}$$

Putting value of $\frac{1}{u}$ in equation (4) wehave,

$$m = -f_o\ [\frac{1}{D} + \frac{1}{f_e}]$$

$$\text{or } m = -\frac{f_o}{f_e}\ [1 + \frac{f_e}{D}]$$

from this equation we say that the magnifying power of a telescope will be large if the focal length of objective is large asj compared to that of eye lens.

2. TERRESTRIAL TELESCOPE :-

An astronomical telescope produces erect images. For obtaining an erect image of the object an extra lens is used that is called erecting lens between the objective and eye lens as shown in fig. (3.23). The objective produces the real and inverted image A'B' of object. If the image A'B' lies at 2 F of the erecting lens, then it will be from a real image A''B'' at 2 F on the other sides of erecting lens having no magnification.

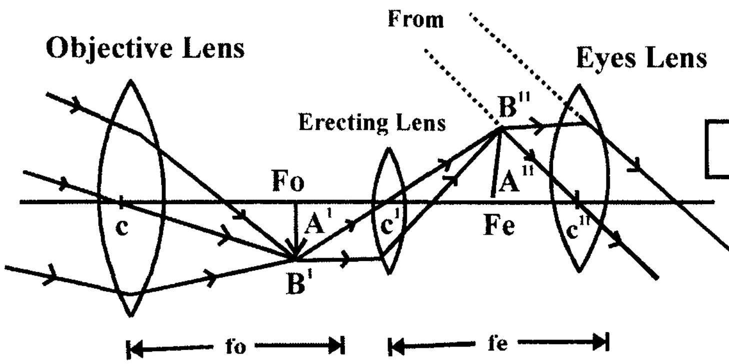


Fig (3.23)

The expression for magnifying power does not change as the erecting lens has not produced any magnification.

So the magnifying power of the telescope

i.e $m = \frac{f_o}{f_e}$ (in normal adjustment)

and $\therefore m = \frac{f_0}{f_e}(1 + \frac{f_e}{D})$ (in final image atlest distance of distinct vision.)

Galileo's Telescope is also a terrestrial telescope. It produced an erect image by making uses of only two lenses.

EXAMPLE (3.11)

An astronomical telescope when in normal adjustment has magnifying power 5 and two thin lens lie 24 cm apart. Find the focal length of the lenses.

SOLUTION :-

Given, $m = \frac{f_o}{f_e} = 5$

or $f_o = 5 f_e$

also $L = f_o + f_e = 24$ cm

Putting value of $f_o = 5f_e$ then,

$5f_e + f_e = 24$

$\therefore\ 6f_e = 24$

$f_e = 4$ cm

and $f_o = 5f_e$

$f_o = 5 \times 4 \Rightarrow 20$ cm.

EXAMPLE (3.12)

A small telescope has an objective lens of focal length 140 cm and eye lens of $f_e = 5$ cm. What is magnifying power of telescope for veiwing distant objects when,

(a) At Normal adjustment

(b) Atleast distance of distinct vision.

SOLUTION :-

Given, $f_o = 140$ cm

$f_e = 5$ cm

m = ?

(a) At normal adjustment, $m = -\dfrac{f_o}{f_e}$

$m = -\dfrac{140}{5} \Rightarrow -28$ Ans.

(b) Atleast distance of distinct vision,

$m = -\dfrac{f_o}{f_e}\left[1+\dfrac{f_e}{D}\right]$

$m = -\dfrac{140}{5}\left[1+\dfrac{5}{25}\right]$

m = -33.6 Ans.

EXAMPLE (3.13)

The Magnifying Power of a telescope will be 5. The focal length of the objective lens is 10 cm then find out the focal length of the eye lens.

SOLUTION :-

Given, M = 5

$f_o = 10$ cm.

We know that, $M = \frac{f_o}{f_e}$

$\therefore\ f_e = \frac{f_o}{M}$

$f_e = \frac{10}{5}$

$f_e = 2$ cm. Ans.

EXAMPLE (3.14)

The focal length of the objective of an astronomical telescope is 75 cm and that of the eye lens is 5 cm. If the final image is formed at the least distinct vision from the eye. Find out the magnifying powr of a telescope.

SOLUTION :-

Given, $f_o = 75$ cm

$f_e = 5$ cm

D = 25 cm.

We know that $M = -\frac{f_o}{f_e}\ [1+\frac{f_e}{D}]$

$M = -\frac{75}{5}\ [1+\frac{5}{25}]$

M = - 18 Ans.

EXAMPLE (3.15)

An astronomical telescope of magnifying powr 7 consists of two thin lens 40 cm apart in normal adjustment. Find out the focal length of the lens.

SOLUTION :-

Given, $M = \frac{f_o}{f_e} = 7$

or, $f_o = 7f_e$ -------------(1)

Now $L = f_o + f_e = 40$

$\therefore 7f_e + f_e = 40$

$8f_e = 40$

$f_e = 5$ cm

and, $f_o = 7f_e \Rightarrow 7\times5 \Rightarrow 35$ cm Ans.

TOTAL INTERNAL REFLECTION :-

Let the surface XY separates the two rarer medium (a) and denser medium (b). Let a ray of light OA from object O in denser medium incident normally on the surface of separation pass into the rarer medium as such. Another ray of light OA, incident along the oblique path and refracted away from the normal along the path A_1B_1 in rarer medium. As the angle of incidence is increased the angle of refraction in air also goes on increasing till a certain angle of incidence C called the "critical angle," the refracted ray goes along the surface XY, means the angle of refraction becomes 90°.

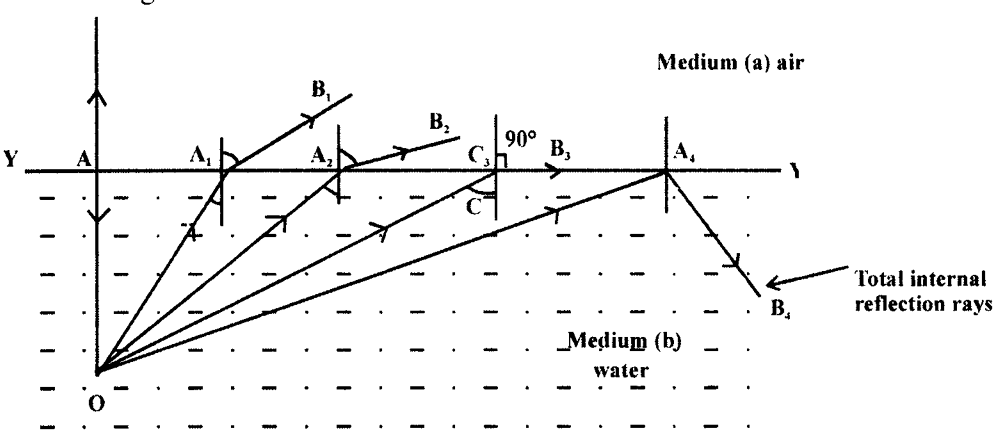


Fig (3.24)

For that ray, refractive index of medium a w.r.t. medium b is given by

$${}^b\mu_a = \frac{\sin C}{\sin 90^\circ} = \sin C \qquad [\because \sin 90^\circ = 1]$$

But $^{b}\mu_{a} = \frac{1}{^{a}\mu_{b}}$

Now refractive index of medium b w.r.t. medium a is given by

$$^{a}\mu_{b} = \frac{1}{\sin C}$$

Now if the angle of incidence is further incresed then there will be no refracted ray. A ray OA_4 incidence at angle greater than critical angle gets reflected along A_4B_4 according to the law of reflection. This phenomenon is known as "Total Internal reflection."

or

"It may be defined as the angle of incidence of a ray of light travelling in a denser medium is greater than the critical angle for the two media, than the ray totally reflected back into the same medium this phenomenon is known as Total internal reflection."

CONDITION FOR TOTAL INTERNAL REFLECTION :-

1. The incident light must be travel from denser medium to rarer medium.
2. The angle of incidence should be greater than the critical angle for the given pair of medium.

MULTIPLE CHOICE QUESTION

1. The speed of light in vaccum depends upon
   (a) Colour (b) Wavelength
   (c) frequency (d) None of these.

2. The velocity of light is maximum in
   (a) Dimond (b) Water
   (c) Vaccum (d) Glass

3. Which of the following has the longest wavelength
   (a) Blue light (b) X-rays
   (c) White light (d) Red light

4. When a light travels from rarer medium to denser medium then.
   (a) It bends away from normal (b) It bends towards the normal
   (c) goes in straight line (d) None of these

5. According to the law of reflection the angle of incidence $\angle i = ?$
   (a) $\angle \theta$ (b) $\angle a$
   (c) $\angle r$ (d) None of these

6. A person standing in front of mirror finds his image larger than himself. This implies that the mirror is.
   (a) Convex (b) Concave
   (c) Plane (d) Perabolic

7. The focal length (f) of a spherical mirror if radius of wrvature R is
   (a) R/2 (b) R
   (c) 3/2 R (d) 2 R

8. Image formed by a convex mirror is
   (a) Real (b) Inverted
   (c) Virtual, erect and diminished (d) None of these.

9. Image formed by a concave mirror is
   (a) Real (b) Inverted
   (c) Real, Inverted and equal in size of Image
   (d) None of these.

10. Out of a convex, a plano convex, a concave lens of equal focal length which are must we use a obtain a sharp image of an object ?
    (a) Only Lens (b) Conves Lens
    (c) Concave Lens (d) Plano Conves Lens.

11. A concave mirror has radius of curvature of 0.2 m its focal lenght is
    (a) -0.2 m (b) -0.1 m
    (c) +0.1 m (d) 0.4 m

12. The spherical mirror formula is written as
    (a) $\frac{1}{v}-\frac{1}{u}=\frac{1}{f}$ (b) $\frac{1}{f}=\frac{1}{f+v}$
    (c) $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$ (d) $f=\frac{R}{2}$

13. When a ray of light travels from one medium to another medium and bent towards the normal then this phenomenon is known as
    (a) Reflection (b) Refraction
    (c) Diffraction (d) Total internal reflection

14. According to Shell's Law
    (a) $\frac{\text{Sin i}}{\text{Sin r}}=0$ (b) $\frac{\text{Sin i}}{\text{Sin r}}=\infty$
    (c) $\frac{\text{Sin i}}{\text{Sin r}}=\mu$ (d) None of these.

15. The unit of Power of a lens is
(a) cm (b) metre
(c) Dioptre (d) Kg.

16. A Lens of Power of -2.5 D, Then its focal length will be
(a) 0.4 m (b) -0.4 m
(c) .02m (d) -0.2 m

17. The magnification m, Image distance v, focal length f of a spherical mirror are related as

(a) $m = \frac{f-v}{f}$ (b) $m = \frac{f}{f-v}$

(c) $m = \frac{-f}{v-f}$ (d) $m = \frac{f+v}{f}$

18. The relation between magnification m, object distance u, focal length of a

(a) $m = \frac{f-u}{f}$ (b) $m = \frac{f}{f-v}$

(c) $m = \frac{-f}{v-f}$ (d) $m = \frac{f+v}{f}$

19. The magnifying Power (M) of a microscope will be given by

(a) $M = \frac{\alpha}{\beta}$ (b) $M = \frac{\beta}{\alpha}$

(c) $M = \frac{R}{2}$ (d) None of these

20. Two thin lens of Power +5 D and -2 D are put in contact with each other. Focal length of the combination is
(a) + 3 m (b) 0.33 m
(c) -3 m (d) -0.33 m

21. If mo are me are the magnification produced an objective and eye lens of a microscope. The magnifying Power of microscope is
(a) mo - me (b) mo + me
(c) mo × me (d) mo / me

22. A simple microscope consisting of a lens of focal length f froms final image at distance of distinct vision D. It magnifying power is

(a) $1-\frac{D}{f}$ (b) $\frac{D}{f}-1$

(c) $\frac{D}{f}$ (d) $1+\frac{D}{f}$

23. The final image formed by an terrestrial telescope is
(a) Erect (b) Inverted
(c) Sometimes erect, sometimes inverted
(d) None of these

24. The magnifying power of an telescope can be increased by using
(a) Eye lens of large focal length
(b) Objective of large focal length
(c) Objective of short focal length
(d) None of these

25. The value of atleast distance of distinct vision is
(a) 23 cm (b) 24 cm
(c) 25 cm (d) 26 cm

26. The objective of a telescope has a focal length f_1 and eye lens of f_2 . The magnifying power (M) of the telescope in the normal adjustment is
(a) $f_1 \times f_2$ (b) $f_1 + f_2$
(c) $f_1 - f_2$ (d) $\frac{f_1}{f_2}$

27. In normal adjustment of an astronomical telescope, final image is at
(a) 25 cm (b) 25 cm
(c) Finite distance (d) Infinity

28. In which jof the following, the final image is erect ?
(a) Compound Microscope (b) Simple Microscope
(c) Astronical telescope (d) None of these

29. Total internal reflection takes place when light is incident
(a) On concave mirror
(b) from air on a plane glass surface at a certain given angles.
(c) from air on a plane glass surface at any angle
(d) from inside glass surface in water at a certain given angle

30. For total internal reflection, the angle of incidence always
(a) Less than critical angle
(b) Greater than critical angle

(c) Equal to critical angle
(d) None of these

31. A plane mirror produced a magnification of
(a) -1 (b) +1
(c) Zero (d) Between 0 and ∞

32. An object is placed at a distance of 40 cm infront of concave mirror of focal length 20 cm. The image produced.
(a) Virtaul and inverted
(b) Real and erect
(c) Real, inverted and diminished
(d) Real, inverted and same size of an object.

33. The image formed by an objective of a compound microscope is
(a) Virtaul and diminished (b) Real and diminished
(c) Real and enlarge (d) Virtual and enlarge.

VERY SHORT QUESTIONS-ANSWER :-

1. What do you mean by optics ?
2. What are the Laws of reflection ?
3. Define concave and convex mirror.
4. Define Pole.
5. Define centre of curvature.
6. Define Aperture.
7. What is principal focus ?
8. What is focal length ?
9. Give the relationshiop between f and R.
10. Write down the mirror formula for convex mirror.
11. Define magnification.
12. What are the Laws of refrection ?
13. State Shell's Law. [IMP.]
14. Define refractive index. [IMP.]
15. Define Lenses.
16. What do you mean by Real and Virtual image ?
17. Write down the Len's formula.
18. Define Power of Lens. [IMP.]
19. What is optical Instruments ?

20. What is Microscope ? [IMP.]
21. What do you mean by Telescope ?
22. Define Magnifying Power. [IMP.]
23. What are the condition for total internal reflection ? [IMP.]
24. Define critical angle.
25. Define Total internal reflection Phenomenon. [IMP.]
26. What is least distance of distinct vision ? [IMP.]
27. What are the sign convention for the lens ?
28. Write down the relation between critical angle and refractive index.

SHORT TYPE QUESTIONS :-

1. Explain the reflection of light and discuss its Law.
2. Drive the relationship between focal length f and radius of curvature (R) of a convex mirror.
3. Drive mirror formula for a convex mirror.
4. What are the applications of spherical mirror ?
5. Explain refraction of light and discuss its Laws. [IMP.]
6. What do you mean by lens ? Explain its types.
7. Define the terms of a lens.
   (i) Principal focus
   (ii) Pole
   (iii) Optical centre
   (iv) Radius of curvature.
8. Explain the image formation by the lens.
9. What do you mean by Power of an lens. Explain. [IMP.]
10. What do you mean by Total internal reflection Phenomena and what are the essential conditions for that ? [V. IMP.]
11. What is compound microscope ? Draw its lebelled ray diagram.
12. What do you mean by astronomical telescope ? Draw its lebelled ray diagram.
13. Discuss linear magnification by the lenses.
14. What is linear magnification of spherical mirror ? Explain.

LONG TYPE QUESTIONS :-

1. Explain the image formation by the lenses.
2. What do you mean by Total internal reflection Phenomena also Give its conditions ?
3. What is microscope. Describe Construction, Principal, Working and find out the

Magnifying Power of a simple microscope by draw a lebelled ray diagram. [V. IMP.]

4. What do you mean by compound microscope ? With the help of ray diagram. Give its Principal, Construction, Working and find out its magnifying Power. [V. IMP.]

5. What is Telescope ? Explain astronomical Telescope with the help of ray diagram and also find out Magnifying Powr in case of normal adjustment and at the least distance vision. [V. IMP.]

6. Explain the Principal, Construction and Working of a terrestrical telescope with the help of ray diagram. Also find out its Magnifying Power.

NUMERICAL PROBLEMS

1. What is the refractive index of glass w.r.t. water if refractive index of water is $^{4}/_{3}$ and that of glass is $^{3}/_{2}$. [Ans. $^{9}/_{8}$]

2. A lens has a Power of - 2.5 D. What is the focal length and the nature of the lens ? [Ans. -0.4m, concave in nature]

3. Two lens of Power 4 D and 5 D are placed in contact. Find out the resultant focal length and Power. [Ans. $f = -100$ cm, Power = - 1 D]

4. Two lens one of focal length 20 cm and another of -15 cm are placed in contact what is focal length ? [Ans. =- 59.9 cm]

5. A Telescope has lenses of focal length 25 cm and 2.5 cm. Find out the Magnifying Power and length of tube of telescope. [Ans. m = 10, L = 27.5 cm]

6. Find out the position of the image formed by the less combination given in fig. (3.25)

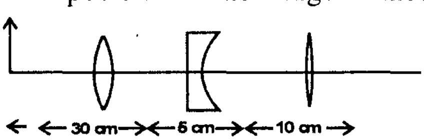


Fig (3.25)

Ans : Ist - 15cm
2nd - ∞
3rd - 30 cm

7. Determine the critical angle for a glass air surface, if a ray of light is incident in air on the surface is deviated through 15° when its angle of incidence is 40°. [Ans. C = 41.1°]

8. Velocity of light in a liquid is 1.5×10^8 m/s. and in air is 3×10^8 m/s. If a ray of light passes from liquid into the air, find the value of critical angle. [Ans. C = 30°]

9. Calculate the critical angle for tatal internal feflection of light travelling from water into air and glass into water. Given $^{a}\mu_{w} = 1.33$ and $^{a}\mu_{g} = 1.5$.

[Ans. (i) C = 48°, 44^1]
(ii) C = 62° 27^1

10. A marked Placed on the surface of a sphere is viewed through glass from a position directly opposite. If the diameter of the sphere is 10 cm and refractive index of glass is 1.5. Find the positive of image.

[Ans. v = -20 cm]

11. An object is placed at 0.06 m from a convex lens of focal length 0.10 m. Find out the position and nature of the image.

[Ans. v = -15 cm, negative image formed in virtual]

12. A beam of light converges to a point P. A lens is placed in the path of the convergent beam 12 cm from P. At what point does the beam converge if the Lens is.

(i) Convex Lens of $f = 20$ cm

(ii) Concave Lens of $f = 16$ cm

[Ans. (i) v = 7.5 cm]
(ii) v = 48 cm

13. A concave lens is kept in contact with a convex lens of focal length 20 cm. The combination works as a convex lens of focal length 50 cm. Find out the Power of concave lens.

[Ans. P = - 3D]

14. The focal length of the objective and eye lens of a compound microscope are 4 cm and 6 cm respectivelly. If an object is placed at a distance of 6 cm away from the objective. What is the magnification produced by the microscope ? Also find out the distance b/w objective and eye lens. [Ans.10.33, 16.84 cm]

15. An angular magnification of 30% is desired using an objective of focal length 1.25 cm and an eye lens of focal length 5 cm. How will you set up the compound microscope ?

[Ans. Placing two lenses 11.67 m apart and object at a distance of 1.5 cm from objective.]

16. The Magnifying Power of an astronomical telescope is 5. When it is set for normal adjustment the distance between b/w the two lenses is 24 cm. Calculate the focal length of its eye lens and that of its objective. [Ans. 4 cm, 20 cm]

17. For a astronomical telescope the focal length of the objective glass is 75 cm and for eye lens is 5 cm. Find out the Magnifying Power and the distance between the two lenses when the final image of the distant object is seen at a distance of 25 cm from the eyes. [Ans. 18, 79.17]

18. For a Galileio Telescope with f_o = 150 cm, f_e = - 7.5 cm. What is the separation between the objective and the eye lens ? [Ans. 142.5 cm]

19. The objective of telescope A has a diameter 3 times that of the objective of telescope B. How much greater amount of light is gathered by A as compared to B ?

[Ans. 9]

ANSWER KEY FOR MULTIPLE CHOICE QUESTIONS

(1)	d	(2)	c	(3)	d	(4)	b	(5)	c
(6)	b	(7)	a	(8)	c	(9)	c	(10)	d
(11)	b	(12)	c	(13)	b	(14)	c	(15)	c
(16)	b	(17)	a	(18)	b	(19)	b	(20)	b
(21)	c	(22)	d	(23)	a	(24)	b	(25)	c
(26)	d	(27)	d	(28)	b	(29)	d	(30)	b
(31)	b	(32)	d	(33)	c				

UNIT - 4

ELECTROSTATICS

ELECTROSTATICS (OR) FRICTIONAL ELECTRICITY :-

Electrostatics is the study of electric charge at rest, therefore it is also known as "static electricity." The charges at rest are produced because of the friction between two insulating bodies, which are rubbed against eachother, that is why electrostatics is also known as "fritional electricity".

When a glass rod is rubbed with a piece of silk, the rod acquires the property of attracting small pieces of papers, leaves or dust particles towards its. Then this rod is said to be charged with electricity. Similarly if on a dry day. We comb dry hair with a rubber comb, the comb acquires the property of attracting the small bits of hair and dry grass.

The Phenomenon of frictional electricity was discovered in the year 600 B.C. by a Greek Philosopher "Thales of Miletus".

TWO KINDS OF CHARGES :-

With the help of several experiments, it can concluded that frictional electricity is of two types. When a glass rod is rubbed with silk, glass rod is said to becomes +vely charged and the silk is also found to be charged with electricity. Since the nature of charge on silk is found to be oppsite to that of glass, silk is said have become negatively charged, on the other hand when ebonite rod is rubbed with flanner, the charge on ebonite is found to be of same kind as on silk, Thus ebonite rod becomes negatively charged when rubbed with flannel, white flannel itself becomes positively charged.

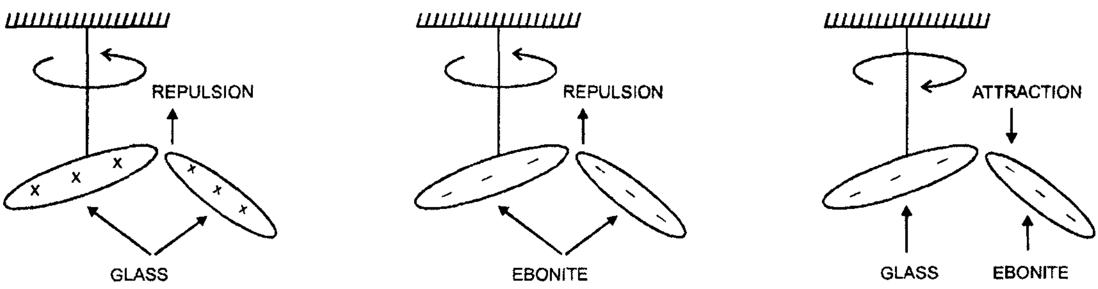


Fig. 4.1 (a) Fig. 4.1 (b) Fig. 4.1 (c)

From fig. 4.1 (a) we can say that, two glass rods repel each other, similarly two ebonite rods each rubbed with fur, repel each other as shown in fig 4.1 (b). But when a glass rod rubbed with silk it attracts an ebonite rod rubbed with fur. fig. 4.1 (c). Thus we say that bodies having same kind of charge repel each other, while those with an opposite kind of charge attract each other.

PROPERTIES OF ELECTRIC CHARGE :-

(i) Electric charge is quantisised, means it exist only in discrete lumps or packets which consist of an integral multiple of a certain minimum charge i.e any positive or negative charge q that can be written as.

$$q = \pm ne$$

where n = 1,2,3,4, ---------

e = charge on elctron = -1.6×10^{-19}C.

(ii) Electric charge is additive in nature. It implies that the total charge on an extended body is the algebric sum of the charges located at different points of the body.

(iii) Electric charge is always conserved, means charge can neither be created nor be destroyed in isolation i.e. charge can be created or destroyed only in equal and opposite pairs.

(iv) It is a sealer quantity.

(v) Electric charge is of Two type namely positve or negative.

(vi) The S.I. unit of charge is coulomb and it is represented by C.

(vii) Charge carried by a body does depend upon velocity of the body.

COMPARISON OF CHARGE AND MASS:-

CHARGE	MASS
1. Electric charge on a body may be positive, negative or zero.	1. Mass of the body is a Positive quantity.
2. Charge is quantised.	2. The quantization of mass is yet to be established.
3. Electric charge is always conserved.	3. Mass is not conserved as it can be changes into energy and vica-versa.
4. Force between charges can be attractive or repulsive accordingly as the charges are unlike or like charges in nature.	4. The gravitational force between two masses is always attractive.
5. Charge carried by a body does not depend upon velocity of the body.	5. Mass of a body increase with its velocity. as $M=\frac{m_o}{\sqrt{1-\upsilon^2/C^2}}$ Where C is velocity of light in vaccum, $M \rightarrow$ mass of body moving with velocity υ, m_o = is rest mass of the body.

COULOMB'S LAW OF ELECTROSTATICS :-

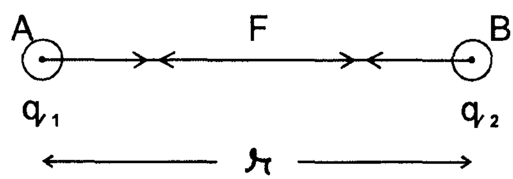
In 1785, Coulomb measured the force of attraction or repulsion between two stationary electric charges by using a torsion balance. His observation is known as the Coulomb's Law of elctrostatics.

"It states that the force of attraction or repulsion between the two stationary electric charges is directly proportional to the product of the magnitude of the charges and inversly proportional to the square of the distance between them."

Consider that two charges q_1, q_2 at a distance r apart as shown in figure (4.2), Then force of attraction or repulsion between the two charges is given by

$$F \alpha\, q_1 q_2 \text{ ----------- (i)}$$

$$\text{or } F \alpha \frac{1}{r^2} \text{ ----------- (ii)}$$



Combing equation (i) and (ii) We have,

$$F \alpha \frac{q_1 q_2}{r^2} \text{ ----------- (iii)}$$

$$\text{or } F = K\frac{q_1 q_2}{r^2} \text{ ----------- (iv)}$$

Where K is constant of Proportionality. Its value depends upon the nature of the medium in which two charges are located and also the system of units adopted to measure F, q_1,q_2 and r.

In S.I. Unit, when two charge are located in vaccum or air,

$$K = \frac{1}{4\pi \epsilon_o} \text{ ------------- (v)}$$

Where ε_0 is called absulute permitivity of free space.

Putting value of K from equation (v) into equation (iv), Weget,

$$F = \frac{1}{4\pi \epsilon_o} \frac{q_1 q_2}{r^2} \text{ ------------- (vi)}$$

From this equation the valure of absulute permitivity is given by,

$$\varepsilon_o = \frac{1}{4\pi F} \frac{q_1 q_2}{r^2}$$

in S.I., charge is measured in coulomb (c), Force in Newton (N), and distance in metre (m). so that

$$\varepsilon_o = \frac{\text{Coulomb} \times \text{Coulomb}}{\text{newton} \times \text{metre}} \Rightarrow \text{Coulomb}^2 \,\text{Newton}^{-1}\, \text{metre}^{-1}$$

i.e. $C^2\ N^{-1}\ m^{-1}$

The value of absolute permitivilty of free space is given by

$$\varepsilon_o = 8.854 \times 10^{-12}\ C^2\ N^{-1}\ m^{-1}$$

Now Putting the value of ε_o in equation (v) we get,

$$K = \frac{1}{4 \times \frac{22}{7} \times 8.854 \times 10^{-12}\ C^2\ N^{-1}\ m^{-1}}$$

$$K = 9 \times 10^9\ N\,M\,C^2$$

Now putting the value of K in equation (vi) we have,

$$F = 9 \times 10^9 \times \frac{q_1 q_2}{r^2}\ N\,M\,C^{-2} \times \frac{C^2}{m}$$

$$\therefore\ F = 9 \times 10^9 \frac{q_1 q_2}{r^2}\ N$$

UNIT OF CHARGE :-

In S.I. force between two charges q_1 and q_2 held at a distance r apart in vaccum is given by.

$$F = 9 \times 10^9 \frac{q_1 q_2}{r^2}$$

suppose $q_1 = q_2 = q$ (say)

$r = 1$ m

and $F = 9 \times 10^9$ N

Then $9 \times 10^9 = 9 \times 10^9 \frac{q \times q}{1}$

oı $q^2 = 1$ or $q = \pm 1$ Coulomb (C)

"So one coulomb is that charge which will repel an equal and similar charges with a force of 9×10^9 N, when placed in vaccum at a distance of 1 m from it."

EXAMPLE 4.1

Which is bigger a coulomb or a charge on an electron ? How many electronic charges form one coulomb of charge ?

SOLUTION :-

A Coulomb of charge is bigger than the charge of an electron. Magnitude of charge on 1 election $e = 1.6 \times 10^{-19} C$.

Number of electronic charges in one coulomb.

$$n = \frac{q}{e} = \frac{1}{1.6 \times 10^{-19}} \Rightarrow 0.625 \times 10^{-19} \text{ [Ans.]}$$

EXAMPLE 4.2

Two equal and similar charges kept 3 cm apart in air repel each other with a force equivalent of 4.5 kg f. Find charges in coulomb.

SOLUTION :-

Let each charges be q c, then $q_1 = q_2 = q\,c$

$$F = 4.5 \text{ kg f} = 4.5 \times 9.8 \text{ N}$$

$$r = 3 \text{ cm} = 0.03 \text{ m}$$

$$\text{Now, } F = \frac{1}{4\pi \varepsilon_o} \frac{q_1 q_2}{r^2}$$

$$\therefore 4.5 \times 9.8 = 9 \times 10^9 \frac{q \times q}{(0.03)^2}$$

$$\text{or } q^2 = \frac{4.5 \times 9.8 \times (0.03)^2}{9 \times 10^9} \Rightarrow q = \pm 2.1 \times 10^{-4} C.$$

EXAMPLE 4.3

What is the force between two small charged sphere having charge of $2 \times 10^{-7} C$, and $3 \times 10^{-7} C$ **placed 30 cm apart in air.**

SOLUTION :-

Here, $q_1 = 2 \times 10^{-7} C$

$q_2 = 3 \times 10^{-7} C$

$r = 30 \text{ cm} \Rightarrow 30 \times 10^{-2} \text{m}$

$F = ?$

so, $F = \frac{1}{4\pi \varepsilon_o} \frac{q_1 q_2}{r^2}$

$$F = 9 \times 10^9 \frac{(2 \times 10^{-7})(3 \times 10^{-7})}{(30 \times 10^{-2})^2}$$

$F = 6 \times 10^{-3}$ N (Ans.)

EXAMPLE 4.4

Calculate force between two charges of 1c each separated by 1m in vaccum.

SOLUTION :-

Here, $q_1 = q_2 = 1$ C

$r = 1$m, $F = ?$

so, $F = \frac{1}{4\pi\ \varepsilon o} \times \frac{q_1 \times q_2}{r^2}$

$$F = 9 \times 10^9 \frac{1 \times 1}{1} \Rightarrow 9 \times 10^9 \text{ N (Ans.)}$$

EXAMPLE 4.5

A polythene piece rubbed with wool is found to have a negative charge of 3.2×10^{-7} C

(a) Estimate the no. of electrons transferred from which to which ?

(b) Is there a transfer of mass from wool to polythene ?

SOLUTION :-

(a) Here, $q = -3.2 \times 10^{-7}$ C

charge on electron, $e = -1.6 \times 10^{-19}$ C

∴ number of electrons transferred to polythene piece from wool.

$\therefore\ n = \frac{q}{e}$

$$n = \frac{-3.2 \times 10^{-7}}{-1.6 \times 10^{-19}} \Rightarrow 2 \times 10^{+2}$$

(b) Yes there is a transfere of mass.

as mass of each electron $= 9\times10^{31}$ Kg.

$\therefore$ Mass transfered to polythene, $= 2\times10^{12}\times9\times10^{-31}$ Kg.

$=1.8\times10^{-18}$ Kg.

EXAMPLE 4.6

An electron and a proton are at a distance of 10^{-9}m from eachother in a free space. Compute the force between them.

SOLUTION :-

q_1 = charge of an proton = 1.6×10^{-19}C

q_2 = charge of an proton = -1.6×10^{-19}C

$r = 10^{-9}$m

$$F = \frac{1}{4\pi\,\varepsilon_o}\,\frac{q_1\,q_2}{r^2}$$

$$F = 9\times10^{9}\,\frac{(1.6\times10^{-19})\,(-1.6\times10^{-19})}{(10^{-9})^2}$$

$F = -23.04\times10^{-11}$ N [Ans.]

The negative sign indicates that force is of attraction.

ELECTRIC FIELD :-

"The space around an electrical charge in which its effect can be experienced is known as electric field."

Consider an electric charge q located in space. If we bring another charge q_o near the charge q, it will experience a force of attraction or repulsion due to charge q. The force experienced by charge q_o is said to be due to the electric field set up of charge q.

"Thus electric field may be defined as the space around the charge in which electromotive force of attraction or repulsion due to the charge can be experienced by the another charge."

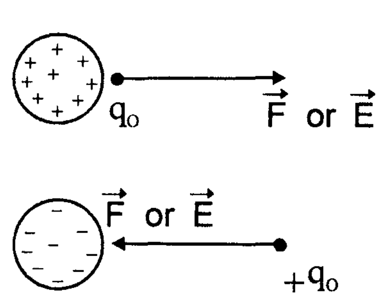
If in a test charge q_o experiences no charge at a point then electric field of that point must be Zero.

ELECTRIC FIELD INTENSITY :-

"The electric field intensity or strength of electric field at a point may be defined as force experienced by unit positive test charge ($+q_o$) placed at that point."

If $\vec{F}$ is the force acting on test charge $+q_o$ at any point a, then electric field intensity may be given by.

$$\vec{E}=\frac{\vec{F}}{q_0}$$



The S.I unit of electric field intensity is NEWTON PER COULOMB (NC^{-1}) another units are v/m and J/m/Coulomb.

PHYSICAL SIGNIFICANCES :-

The Physical significance of an electric field is that, we can calculate the same by reading the magnitude and direction of the force experienced by any charge held at that point in the electric field.

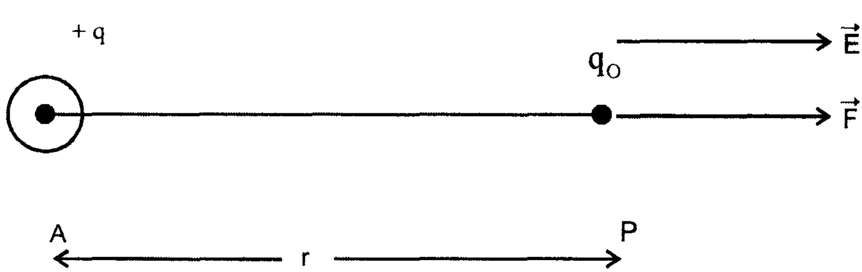
i.e. $\vec{F} = q_0 \vec{E}$

The direction of force on positive charges in the direction of electric field intensity.

ELECTRIC FIELD DUE TO A POINT CHARGE :-

Consider a point charge q located in vaccum at a point A. Suppose we have to find out the electric field at a point P due to charge q such that AP = r fig. (4.4), Now place a small test charge q_o at that point P.

Fig. (4.4)



Now according to coulom's Law, force on test charge q_o due to source charge q is given by

$$\vec{F} = \frac{1}{4\pi \epsilon_0} \frac{q\, q_0}{r^2} \text{ ---------- (i)}$$

If $\vec{E}$ is the electric field intensity at a point P, Then $\vec{E}$ is given by,

$$\vec{E} = \frac{\vec{F}}{q_0} \text{ ------- (ii)}$$

Now putting the value of F from equation (i) into equation (ii) weget,

$$\vec{E} = \frac{\frac{1}{4\pi \epsilon_0} \frac{q\, q_0}{r^2}}{q_0}$$

or $$\boxed{E = \frac{1}{4\pi \epsilon_0} \frac{q}{r^2}}$$

ELECTRIC POTENTIAL :-

"The electric potential may be defined as the amount of work done in moving a unit positive test charge from infinity to that point against the electrostatics."

It is represented by V.

Hence methematically, $V = \frac{W}{q_0}$

unit of electric potential is Joule/coulomb or Volt.

Electric potential is a scater quantity. If W=1J. & q_o =1C Then,

$V = 1$ Vote, $\quad 1\ V = \frac{1J}{1C}$

"Hence electric potential at a point is said to be one Volt when one Joule of work is done in moving one coulomb of unit positive charge from infinity to that Point."

ELECTRIC POTENTIAL DIFFERENCE :-

"The electric potential difference between two points in an electric field is defined as the amount of work done in moving a unit positive test charge from one point to another point against the electrostatic force.

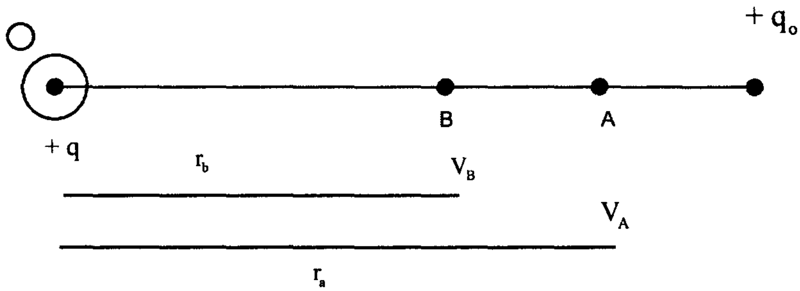


Fig. (4.5)

Consider the electric field due to a point charge +q at the point O. Suppose V_A and V_B are electric potential at point A and B, which are the distance at r_a and r_b respectivelly from the charge +q as shown in fig. (4.5).

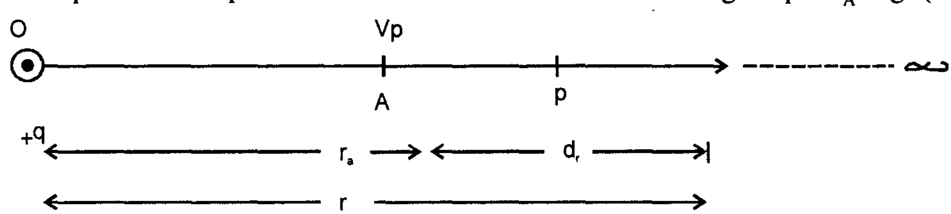
If Π_{AB} is the amount of work done in moving a small positive test charge q_o from the point A to B, then,

$$V_B - V_A = \frac{W_{AB}}{q_0}$$

Electric potential difference is a scaler quantity as work is a scaler. The unit of electric potential difference are, 1 Volt or JC^{-1} or Nmc^{-1}

EXPRESSION FOR POTENTIAL AT A POINT :-

Consider the electric field due to a point charge +q placed at point 0, Suppose that V_A is electric potential at point A. Whose distance from the charge +q is r_A fig. (4.6)



(Fig. 4.6)

Suppose that any instant, the test charge at point P. The electric field **E** due to charge +q exerts force $q_0\vec{E}$ on test charge placed at point P. The test charge q_0 can be moved against this force without acceleration by applying on external force is given by.

$$F = - q_0\vec{E} \text{ ------- (i)}$$

If the test charge q_0 is moved through small displacement dr = AP, then small work done is given by.

$$dw = F.\ dr \qquad [\because\ W = F \times D\ ]$$

$$dw = (-\ q_0\vec{E}\ )\ dr \text{ ------- (ii)} \qquad [\text{using eq}^n\ (i)]$$

Now electric field intensity $\vec{E}$ at a point is given by

$$\vec{E} = \frac{1}{4\pi \epsilon_0} \frac{q}{r^2} \text{ ---------- (iii)}$$

Putting the value of $\vec{E}$ in equation (ii) we have,

$$dw = -\ q_0\ (\frac{1}{4\pi\epsilon_0} \frac{q}{r^2})\ dr$$

$$dw = \frac{-1}{4\pi\epsilon_0} \frac{q\,q_0}{r^2}\ dr \text{ -------- (iv)}$$

Now we determine the total work done in moving a unit positive test char l ge from infinity to point P at distance r from charge +q at point O,

Then, $W = \int_\infty^r dw = \int_\infty^r \frac{1}{4\pi\epsilon_0} \frac{q\,q_0}{r^2}\ dr$

$$W = -\frac{1}{4\pi\epsilon_0} q\,q_0 \int_\infty^r \frac{1}{r^2}\ dr$$

$$= -\ \frac{1}{4\pi\epsilon_0} qq_0\ [\frac{r^{-1}}{-1}]_\infty^r$$

$$= \frac{1}{4\pi\epsilon_0} q\,q_0\ [\frac{1}{r}]_\infty^r$$

$$= \frac{1}{4\pi\epsilon_0} q\,q_0 \left[\frac{1}{r}\right]_\infty^r$$

$$= \frac{1}{4\pi\epsilon_0} qq_0 \left[\frac{1}{r} - 0\right]$$

$$W = \frac{1}{4\pi\epsilon_0} \frac{qq_0}{r}$$

Now potential at a point A is given by

$$V_A = \frac{W}{q_0}$$

$$V_A = \frac{\frac{1}{4\pi\epsilon_0}\frac{qq_0}{r}}{q_0}$$

$$\boxed{V_A = \frac{1}{4\pi\epsilon_0}\frac{q}{r}}$$

ELECTRICAL LINES OF FORCE :-

The electric line of force is the path traced by the movement of a unit positive charge, how it would move if it is free to do so.

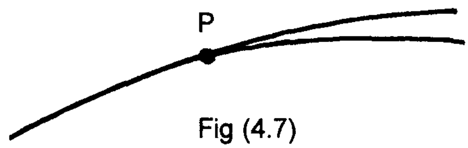


Fig (4.7)

The electric lines of force, points in the direction of electric field. The electric lines of force may be straight or curve. In case, electric lines of force are in a curve, the direction of electric field at any point is given by a tangent to the line of force at that point. Fig. (4.7)

PROPERTY OF ELECTRIC LINES OF FORCE :-

1. Electric lines of force are, discontinuous curves. They starts from a positively charged body and end at a negatively charged body.
2. The lines of force emanate or terminate at a surface always at a right angle to the surface.
3. The electric lines of force do not pass through the conductor.
4. The electric lines of force does not interact each other.
5. Tangent to the lines of force at any point gives the direction of electric intensity at that point.
6. The lines of force contract longitudinally.
7. The lines of force exert a lateral pressure on each other.
8. When two electric lines of force are trevelling in same direction they repel each other.

EXAMPLE 4.7

If 100 J of work is done in carying a charge of 2 C from a place where the potential is -10 V to another point where potential is V. Find the value of V.

SOLUTION :-

Here, $V_A = -10V, V_B = V, W_{ab} = 100\ J, q_0 = 2\ C$

Now, $V_B - V_A = \frac{W_{AB}}{q_0}$

or $V- (-10) = \frac{100}{2}$

$V+10 = 50$

$V = 40\ V$

EXAMPLE 4.8

What is the megnitude of a point charge chosen so that electric field 50 cm away has the magnitude 2.0 N/C ?

SOLUTION :-

Here, E = 2.0 N/C

$r = 50\ cm \Rightarrow .05\ m$

Let the magnitude of point charge is = q coulomb

so Electric field intensity at a point is given by.

$E = \frac{1}{4\pi \epsilon_0} \frac{q}{r^2}$

$\therefore\ q = E \times 4\pi \epsilon_0 \times r^2$

$q = 2 \times 4 \times \frac{22}{7} \times 8.854 \times 10^{-12} \times (0.5)^2$ $\qquad (\because\ \epsilon_0 = 8.854 \times 10^{-12})$

$\therefore\ q = 2 \times 4 \times \frac{22}{7} \times 8.854 \times 0.25 \times 10^{-12}$

$q = 0.556 \times 10^{-8}\ C$ Ans.

EXAMPLE 4.9

A charge of 20μc produces on electric field. Two points are 10 cm and 5 cm from this charge. Find the value of potentials at these points and also find the amount of work done to take an electron from are point to the other.

SOLUTION :-

Here, $q = 20\ \mu c = 20\times10^{-6}C$

Let A and B be two points at distance 10 cm and 5 cm from the charge,

Thus, $r_1 = 10\text{ cm}, = 0.1\text{ cm}$
$r_2 = 5\text{ cm} = 0.05\text{ m},$

$$\text{Now, } V_A = \frac{1}{4\pi\epsilon_o}\frac{q}{r_1} = 9\times10^9\times\frac{20\times10^{-6}}{0.1} \Rightarrow 1.8\times10^6V$$

$$\text{also, } V_B = \frac{1}{4\ \pi\ \epsilon_o}\frac{q}{r_2} = 9\times10^9\times\frac{20\times10^{-6}}{0.05} \Rightarrow 3.6\times10^6V$$

Potential difference $V_B - V_A = 3.6\times10^6 - 1.8\times10^6 \Rightarrow 1.8\times10^6V$

work done to take an elctron from A to B,

$$W_{BA} = (V_B - V_A)\times \text{ charge on electron.}$$
$$= 1.8\times10^6 - 1.6\times10^{-19} \Rightarrow 2.88\times10^{-13}J$$

EXAMPLE 4.10

Find the potential at the centre of square of side $\sqrt{2\,m}$ at the four corners of which, charges of $q_1 = 2\times10^{-8}C, q_2 = 2\times10^{-8}C, q_3 = 3\times10^{-8}C,$ and $q_4 = 6\times10^{-8}C,$ are placed.

SOLUTION :-

Here, $q_1 = 2\times10^{-8}C$

$q_2 = 2\times10^{-8}C$

$q_3 = 3\times10^{-8}C$

$q_4 = 6\times10^{-8}C$

AB = BC = CD = AD = $\sqrt{2\,m}$

Let r be the distance of each charge from the centre of the squaare, then

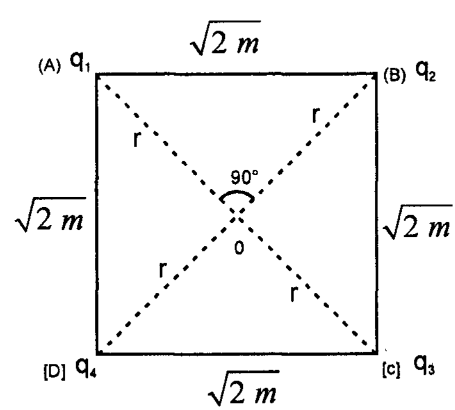


Fig (4.8)

$$\sqrt{r^2 + r^2} = \sqrt{2}$$

$\sqrt{2r^2} = \sqrt{2}$

$or\ \sqrt{2r^2} = \sqrt{2}$

$or\ r^2 = 1 \Rightarrow r = 1\ m$

Potential at O due to charges at four corners

$$V=\frac{1}{4\pi\epsilon_0}\left[\frac{q_1}{r}+\frac{q_2}{r}+\frac{q_3}{r}+\frac{q_4}{r}\right]$$

$$V=\frac{1}{4\pi\epsilon_0}\ \frac{1}{r}\ [q_1+q_2+q_3+q_4]$$

$$V = 9\times10^9 \times \frac{1}{1}[2\times10^{-8}+(-2\times10^{-8})+(3\times10^{-8})+6\times10^{-8}]$$

V = 270 V. Ans.

AREA VECTOR :-

Area is a scaler quantity, But in some problems the area of a surface has to be represented by a vector.

Consider a small area element d_s of a closed surface as shown in fig. (4.9). The arrow representing the area vector is drawn perpendicular to the area of the element. If $n^{\wedge}$ represents unit vector along the outdrawn normal to the area element. then,

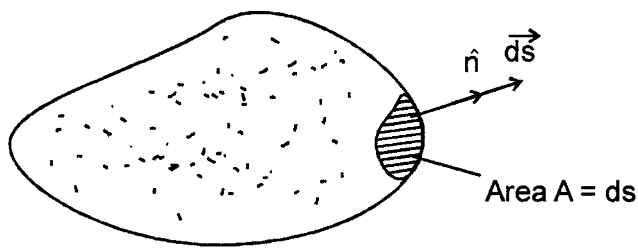


Fig. (4.9)

$ds = \hat{n}\ ds$

SLIDE ANGLE :- (Ω)

For plane geometry, unit is radion. The angle substained by an area of length $d\ell$ of a circle of redius r at its centre is given by

$$d\,\theta = \frac{d\,L}{r},\ \text{for a circle} = \frac{\text{Circumference}}{\text{diameter}} = \frac{2\pi r}{2\,r} = \pi$$

for solid Geometry, the concept of solid angle follows the surface area of a sphere to the square of its diameter. i.e $\Omega = \frac{\text{Surface are}}{(\text{diameter})^2} = \frac{4\pi r^2}{(2\,r)^2} = \pi$

Let us consider a sphere of radius r and centre O. Let ds be the small area element of the sphere. Then small solid angle $d\,\Omega$ substended by area element ds at the centre is given by

$$d\,\Omega = \frac{d\,s}{r^2}$$

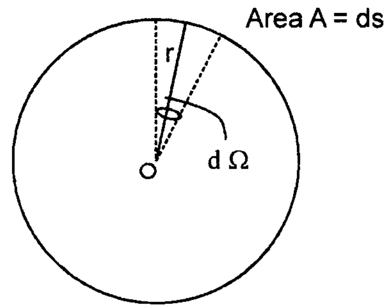


Fig. (4.10)

The unit of solid angle is steradion, and it is dimensionless quantity.

$$\Omega = \frac{\text{Surface area of sphere}}{r^2} = \frac{4\pi r^2}{r^2} = 4\,\pi \text{ steradian.}$$

ELECTRIC FLUX :-

"Electric flux may be defined as the total number of electric lines of force passing through the surface area."

It is represented by ϕ

Consider a small area element ds of a closed surface S. E be the electric field at the area element. Let θ be the angle between area vector ds and electric field $\vec{E}$, Then electric flux (ϕ) through the area element ds is given by.

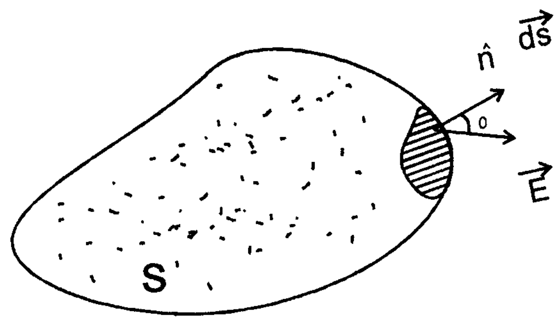


Fig. (4.11)

$$d\phi = \vec{E}.\,ds \qquad \text{-------------(1)}$$

Now ϕ is angle between area element ds and electric field E, then

$$d\phi = \vec{E}.\,\vec{ds}\cos\phi \qquad \text{-------------(2)} \qquad [\because A.B = AB\cos\phi]$$

Equation (2) represent the electric flux for a small area element, and the normal component of the electric field. The electric flux thruogh the whole surface S. may be calculate by Integrating eq^n (1) in both sides. Over the surface S,

$$\int d\,\phi = {}_s\int \vec{E}.\vec{ds}$$

$$\text{or } \phi = \int d\,\phi = {}_s\int \vec{E}.ds$$

"Thus electric flux linked with a surface in an electric field may be defined as the surface intergral of the electric field over the surface."

GAUSS'S THEOREM :-

"It states that the total electric flux through a closed surface is equal to $1/E_0$ times the magnitude of charge on it."

Mathematically, $$\phi = \frac{1}{E_0} q$$

PROOF :-

Let us take a closed surface S enclosing a charge q. suppose ds is the area element at a distance r from the centre where charge q is enclosed. If E is the electric field at the area element as shown in fig. (4.12). Then electric flux through area element is given by.

$$d\phi = \vec{E}.\vec{ds} \text{ ----------------- (1)}$$

Now total electric flux through closed surface S is given by,

$$d\phi = {}_s\int \vec{E}.\, ds$$

$$\therefore \phi = \int \vec{E}.\vec{ds} \text{ ------------(2)}$$

If θ be angle between E and ds, then,

$${}_s\int \vec{E}.\vec{ds} = {}_s\int E.\, ds \cos\theta$$

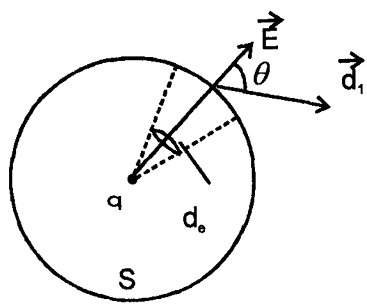


Fig (4.12)

$\therefore$ equition (2) becomes $\phi = {}_s\int E.\, ds \cos\theta$ .... (3)

Now, electric field at a point due to charge q is given by,

$$E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$$

Putting the value of E in equation (3) we have,

$$\phi = {}_s\int \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} ds \cos\theta$$

$$\phi = \frac{1}{4\pi\epsilon_0} q \; {}_s\int \frac{ds}{r^2} \cos\theta$$

Direction of the electric field E and a area vector ds are same, in that condition the angle between E and ds is Zero,

i.e $\theta = 0°$

Put $\theta = 0°$ in eq^n (4) we get,

$$\phi = \frac{1}{4\pi \epsilon_0} q_s \int \frac{ds}{r^2} \cos\theta°$$

$$\phi = \frac{1}{4\pi \epsilon_0} q_s \int \frac{ds}{r^2} x1$$

$$\phi = \frac{1}{4\pi \epsilon_0} q_s \int d\Omega \quad \left[\because d\Omega \frac{ds}{r^2}\right]$$

$$\phi = \frac{1}{4\pi \epsilon_0} q\Omega$$

$$\phi = \frac{1}{4\pi \epsilon_0} q x 4\pi \ [\because \ \Omega = \frac{\text{Surface area to sphere}}{r^2} \Rightarrow \frac{4\pi r^2}{r^2} = 4\pi]$$

$$\boxed{\phi = \frac{q}{\epsilon_0} \quad \text{Hence proved}}$$

ELCTRIC FIELD INTENSITY DUE TO A LINE CHARGE (OR) DUE TO STRAIGHT CHARGE CONDUCTOR :-

Let us assume a thin infinitely long straight line charge L having a uniform linear charge density along xx' The magnitude of electric field intensity E at every point on the curved surface of the cylinder is the same because all such points are at the some distance from the xx' as shown in fig (4.13). Now we have to find out the E at point P, distance r from it , a cylinder of redius r, and length ℓ with the line charge as its axis may be treated as Gaussian surface fig. (4.13)

"Gaussian Surface may be defined as an imaginary closed surface enclosing a charge of the cylinder.

Now calculate the electric flux at both ends of cylinder and curved surface of the cylinder.

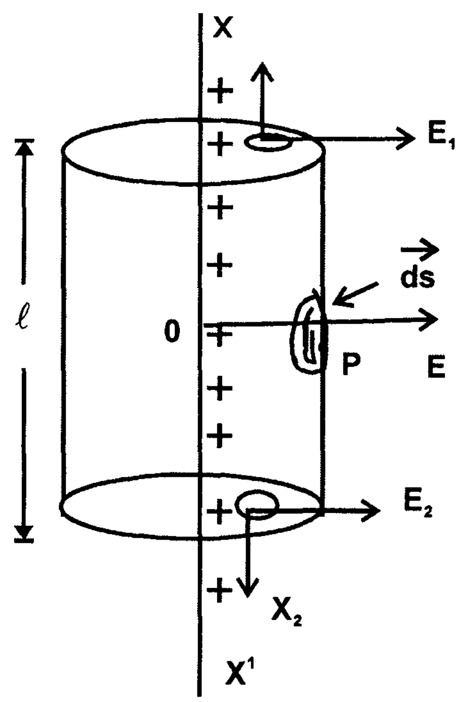


Fig (4.13)

At the Ist end of cylinder, $d\phi_1 = E_1 . ds_1$

$$d\phi_1 = E\ ds\ \cos\theta$$

as θ is angle between E and ds, and at bothe end $\theta = 90°$

$$\therefore d\phi_1 = Eds \cos 90°$$

$$\therefore d\phi_1 = 0 \text{ Similarly } d\phi_2 = 0$$

This shows that the electric flux at both ends is equal to zero. so only curved surface of the cylinder contributes electric flux.

It $\vec{E}$ is the electric field at point P, then electric flux through gaussian surface is given by.

$$d\phi = E.ds$$

$$\therefore \int d\phi = \int_s E.ds$$

$$\phi = E \int_s ds$$

ϕ = Ex area of the curved surface of a cylinder of radius r and length ℓ.

$$\therefore \phi = E \times 2\pi r \ell, \text{ -------(1)}$$

Now linear charge density (r) may be defined as it is the ratio of charge per unit length.

$$\therefore \lambda = \frac{q}{\ell}$$

$$\text{or } \therefore \phi = E \times 2\pi r \ell$$

Now according to Gauss Theorem, $\phi = \frac{q}{\epsilon_0}$

By using equation (1) and (2) we get,

$$E \times 2\pi r \ell = \frac{\lambda \ell}{\epsilon_0}$$

$$\therefore E = \frac{\lambda}{2\pi \epsilon_0 r}$$

$$\text{or } E \propto \frac{1}{r} \text{ as } \frac{\lambda}{2\pi \epsilon_0} = \text{constant.}$$

The electric field intensity E due to a point charge is inversly proportional to the radius of the sphere.

ELCTRIC FIELD INTENSITY DUE TO A INFINATE PLAIN SHEET OF CHARGE:

Let us take an infinite plain sheet of positive charge having a uniform surface density (σ) on both sides of the sheet. By symmetry, the electric field is perpendicular to the plain charge of sheet and in outword direction.

To find out the electric field intensity at point P at a distance r from it, assume a cylinder of cross-section area A through the point P as Gaussian surface shown in fig. (4.14)

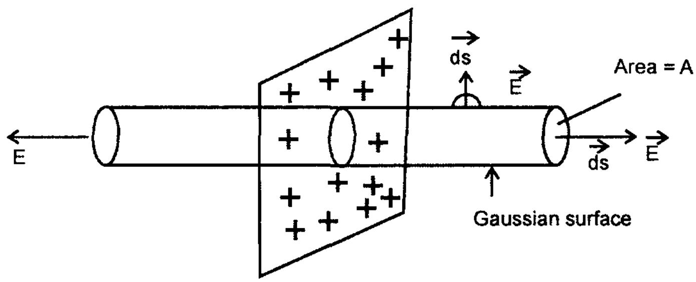


Fig (4.14)

Now we calculate the electric flux over the cylinder. Electric flux due to curved surface.

$$d\,\phi = E.\,ds$$

$$d\,\phi = E\,ds\cos\theta$$

Due to angle between E and ds is 90° at the curved face means electric lines of force are parallel to curved face. so

$$d\,\phi = E.\,ds\cos 90^\circ$$

$$d\,\phi = 0$$

Hence electric flux at curved is zero, so only at the both ends electric flux contributed. Now electric flux at point P at a distance r is given by.

$$d\,\phi = E.\,ds$$

$$\int d\,\phi = \int E.\,ds$$

$$\phi = E\int ds$$

ϕ = E × area of the end faces i.e. circular caps of the cylinder.

$$\phi = E \times 2\,A \text{ --------(1) } \left(\because \int ds = A\right)$$

"Now surface charge density (σ) may be defined as it is the ratio of charge per unit area."

i.e. $\sigma = \frac{q}{A}$

or $q = \sigma A$

according to Gauss Theorem, $\phi = \frac{q}{\epsilon_0}$

using equation (1) and (2) we have,

$$E \times 2A \frac{\sigma A}{2\epsilon_0}$$

$$\therefore E = \frac{\sigma}{2\epsilon_0}$$

Thus we find the magnitude of the field due to infinite plain charge sheet is independent of the distance from the sheet.

ELCTRIC FIELD INTENSITY DUE TO UNIFORMALY CHARGED/ CONDUCTING OR HOLLOW SPHERE :-

Consider a thin spherical shell of radius R and centre O. Let q be the charge on spherical shell. The electric field due to charged spherical shell is radial. When we find out the electric field intensity at point P, then there are three cases for finding out E.

Case-I when point P lies outside the spherical shell.

Let P be a point at a distance of r from the centre where we find out the electric field due to charge q. At every point on the surface of shell, E will be same magnitude and normal to surface.

So total electric flux through Gaussian surface is given by,

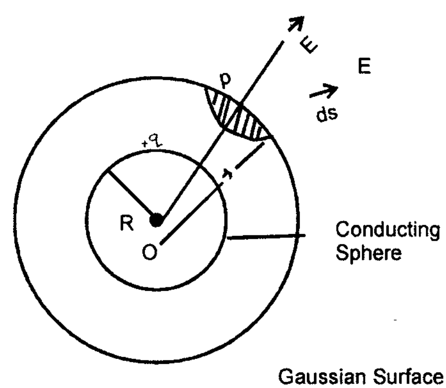


Fig (4.15)

$$d\phi = E.ds$$

$$\therefore \phi = \int_s E.\, ds$$

$$\phi = \int_s E.\, ds \cos\theta \Rightarrow \int_s E\, ds \Rightarrow E \int_s ds$$

[$\therefore 0 = 0°$, E, ds are in some direction.]

$$\therefore \phi = E \int ds$$

$$\phi = E \times 4\ \pi\ r^2 ----(1)$$

According to Guass Theoroem, $\phi = \frac{q}{\epsilon_o}$ --------(2)

from eq^n (1) and (2) we get, $\therefore \phi\ E = \frac{1}{4\ \pi \epsilon_o} \frac{q}{r^2}$ --------(3)

If σ is uniform surface charge dinsity of spherical shell then,

$$\sigma = \frac{q}{A}$$

$$\sigma = \frac{q}{4\ \pi\ R^2}$$

$$\therefore q = 4\ \pi\ \sigma\ R^2$$

Putting value of q in eq^n (3) we get,

$$E = \frac{1}{4\ \pi \epsilon_o} \times \frac{4\ \pi\ \sigma\ R^2}{r^2}$$

$$\therefore E = \frac{\sigma\ R^2}{\epsilon_o r^2} \text{ --------(4)}$$

Case II : When point P lies on the surface of spherical shell :-
When point P lies on the surface of spherical shell in that case r=R., so put r =R, in eq^n. (4) we get,

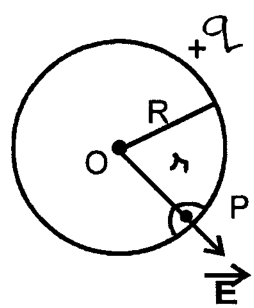


Fig (4.16)

$$E = \frac{\sigma\ R^2}{\epsilon_o r^2}$$

$$\therefore E = \frac{\sigma}{\epsilon_o}$$

Case - III : When Point P lies inside the sphere :

A conducting charge sphere is also known as hallow sphere, means there is no charge inside the sphere. The charge is only enclosed over the surface of shell. So In this case the guassian surface through point P will not enclose any charge and hence according to Gauss Theorem, or eq^n no. (3) We have,

$$E=\frac{1}{4\pi\epsilon_0}\times\frac{0}{r^2}$$

$$\therefore\ E=0$$

ELCTRIC FIELD INTENSITY DUE TO A SOLID OR NON-CONDUCTING SPHERE :-

Consider an isolated sphere of charge q having radius R and centre O. for calculating electric field intensity E at a point, There are three case follows as :-

Case - I : When point P lies outside the sphere :-

Let P be a point at a distance of r from the centre where we calculate Electric field intensity. The electric field E is symmetric due to spherical charge. At every point on the surface, the field has the same magnitude and is along the normal to the surface.

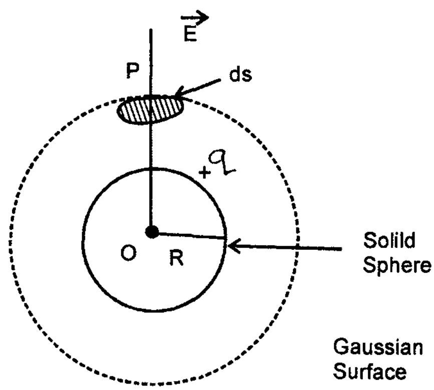


Fig (4.17)

Then total electric flux is given by,

$$\phi = \int_s E.\,ds$$

$$\phi = \int_s E\,ds\cos\theta$$

$$\phi = \int_s E\,ds\cos\theta^{\circ}$$

[$\because$ angle between E and ds is O° as they have in same direction.]

$$\therefore \phi = \int_s E\,ds$$

$$\therefore \phi = E\int_s ds \Rightarrow E.\,4\pi\,r^2$$

$$\phi = E.\,4\pi\,r^2 \text{ ---------(1)}$$

Now according to Gauss Theorem, $\phi = q/E_0$ ----(2)

using equation (1) and (2) we have, $E.\,4\pi\,r^2 = q/E_0$

$$\therefore E.\ \frac{1}{4\pi\epsilon_0}\ \frac{q}{r^2} \text{ ------(3)}$$

In case of solid sphere, the charge distributed jin sphere is defined as uniform volume charge density (ρ) and it is the ratio of charge per unit volume of the sphere.

$$\therefore \rho = \frac{q}{V}$$

$$\rho = \frac{q}{4/3\ \pi\ R^3} \qquad [\because \text{ volume of sphere } V = \frac{4}{3}\ \pi\ R^3]$$

$$\text{or } q = \frac{4}{3}\ \pi\ R^3\ \rho$$

Putting value of q in equation (3) weget,

$$E = \frac{1}{4\pi\epsilon_0}\ \frac{4/3\pi\ R^3\ \rho}{r^2}$$

$$\text{or } E = \frac{1}{3}\ \frac{R^3}{\epsilon_0\, r^2} \text{ ------(4)}$$

Case- II : When Point P lies on the sphere :-

When point P lies on the sphere in that case r=R, so putting r=R in equation (4) weget,

$$E = \frac{1}{3}\ \frac{\rho}{\epsilon_0}\ \frac{R^3}{R}$$

$$\text{or } E = \frac{\rho}{3}\ \frac{R}{\epsilon_0} \text{ ------ (5)}$$

Case III : When Point P lies inside the sphere :-

In this case Gaussian surface is spherical surface, whose centre is O and redius is OP = r as shown in fig. (4.18) If q^1 is charge enclosed by the Gaussain surface, then,

$$\phi = \int E\ ds$$

$$\phi = E \int ds$$

$$\phi = E\ 4\ \pi\ r^2$$

or $\phi = \frac{q^1}{\epsilon_o}$ (according to Gauiss Law)

$\therefore$ E. $4 \pi r^2 = \frac{q^1}{\epsilon_o}$

or E $\frac{1}{4 \pi \epsilon_o} \frac{q^1}{\epsilon_o}$ ----------- (6)

Now, $q^1 = \frac{1}{4/3 \pi R^3} \times \frac{4}{3} \pi r^3 \Rightarrow q \frac{r^3}{R^3}$

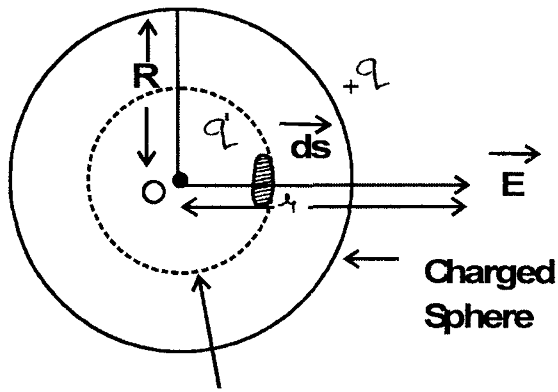


Fig (4.18)

Putting value of q^1 in equation (6) we get,

$$E = \frac{1}{4 \pi \epsilon_o} \frac{q r^3}{R^3 \times r^2}$$

$$E = \frac{1}{4 \pi \epsilon_o} \frac{q r}{R^3}$$

Putting $q = \frac{4}{3} \pi R^3 \rho$ we get,

$$E = \frac{1}{4 \pi \epsilon_o} 4/3 \frac{\pi R^3 \rho r}{R^3}$$

$$\boxed{E = \frac{\rho r}{3 \epsilon_o}}$$

EXAMPLE 4.11

A Point of $2 \mu c$ is at the centre of a cubic Gausion surface 9 cm on edge. What is the electric flux through the surface ?

SOLUTION :-

Here, $q = 2 \mu c \Rightarrow 2 \times 10^{-6} C$

$\ell = 9 cm$

$\therefore \phi = q/\epsilon_o$

$$\phi = \frac{2 \times 10^{-6}}{8.85 \times 10^{-12}} \Rightarrow 2.26 \times 10^5 \ Nm^2 \ c^{-1}$$

EXAMPLE 4.12

A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density of 80 $\mu c/m^2$ Find the charge on sphere and the total electric flux leaving the surface of the sphere ?

SOLUTION :-

Here, $D = 2r \Rightarrow 2.4m$, $r = 1.2$ m

$$\sigma = 80\mu c/m^2 \Rightarrow 80\times10^{-6}\ c/m^2$$

surface charge density $\sigma = 80\mu c/m^2 \Rightarrow 80\times10^{-6}\ c/m^2$

$$\sigma = \frac{q}{4\pi r^2}$$

$$\therefore q = \sigma\times4\pi r^2$$

$$q = 80\times10^{-6}\times4\times\frac{22}{7}\times(1.2)^2 \Rightarrow 1.45\times10^{-3}c$$

Electric flux, $\phi = q/\epsilon_o$

$$\phi = \frac{1.45\times10^{-3}}{8.85\times10^{-12}} \Rightarrow 1.6\times10^8\ Nc^{-1}m^2.$$

EXAMPLE 4.13

An infinite line charge produces a field of 9×10^4 N/C at a distance of 2cm. calculate lineor charge dinsity.

SOLUTION :-

Here, $E = 9\times10^4$ N/C

$$r = 2cm = 2\times10^{-2}m$$

$$\lambda = ?$$

$$\text{As}\quad E = \frac{\lambda}{2\pi\epsilon_o r}$$

$$\therefore \lambda = 2\pi E \epsilon_o r$$

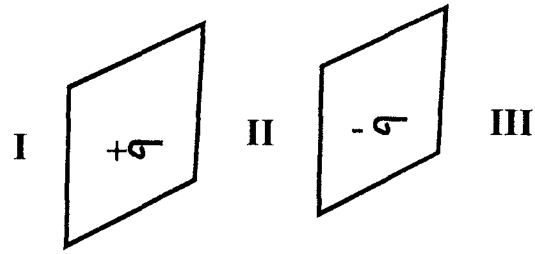
$$\lambda = 2\times\frac{22}{7}\times9\times10^4\times8.85\times10^{-12}\times2\times10^{-2}$$

$\lambda = 10^{-7}\ cm^{-1}$ Ans.

EXAMPLE 4.14

Two large thin metal plates are parallel and close to each other on their innerfaces the plates having surface charge density of opposite sign and magnitude $17\times10^{-22}cm^{-2}$. What is electric intensity (a) to the left of Plates (b) to the right plates (c) between the plates ?

SOLUTION :-



Here, $\sigma = 17\times10^{-22}\ cm^{-2}$

In the region I and III. The electric field intensity will be zero. So in region III, in between the plates E will be given as

$$E = \frac{\sigma}{\epsilon_o}$$

$$E = \frac{17\times10^{-22}}{8.854\times10^{-12}}$$

$E = 1.92\times10^{-10}$ N/C Ans.

EXAMPLE 4.15

A point charge of $10^{-9}C$ is placed at point P then calculate,

(i) The intensity of electric field on the sphere of radius 5cm, and centre P.

(ii) Potential difference between the points 20 cm and 10 cm, away from the charge at P.

SOLUTION :-

q at point P$=1\times10^{-9}$C

radius r= 5 cm ⇒ 0.05 m

(i) Electric field on the surface of sphere $(E) = \frac{1}{4\pi\epsilon_o}\frac{q}{r^2}$

$$= \frac{1}{4\times\frac{22}{7}\times8.854\times10^{-12}}\times\frac{1\times10^{-9}C}{(0.05)^2}$$

= 3600 v/m Ans.

(ii) Potential of Ist point which is at distance of 20 cm ⇒ 0.2 m

$$V_1 = \frac{1}{4\pi \epsilon_0} \frac{q}{r}$$

$$= \frac{1}{4\times\frac{22}{7}\times 8.854\times10^{-12}} \times \frac{1\times10^{-9}}{(0.1)} \Rightarrow 90 \text{ V}$$

Potential differece B/W two points $= 90-45 \Rightarrow 45$ V Ans.

EXAMPLE 4.16

A uniformly charged conducting sphere of 2.4 m diameter has a surface charge density (σ) of 80×10^{-6} c/m^2 find the following :-

(i) Charge on the sphere.

(ii) Total electric flux leaving the surface of the sphere ?

SOLUTION :-

Here, $\sigma = 80\times10^{-6}$ c/m^2

Diameter r = 2.4 m

$$\therefore r = \frac{D}{2} \Rightarrow \frac{2.4}{2} \Rightarrow 1.2 \text{ m}$$

Now surface charge density $\sigma = q/A$

$$\therefore\ q = \sigma A$$

Area $A = \pi\ r^2 \Rightarrow \frac{22}{7}\times(1.2)^2\ m^2$

$$\therefore\ q = 80\times10^{-6}\times\frac{22}{7}\times(1.2)^2$$

$q = 1.45\times10^{-3}$C Ans.

(ii) Now Total electric flux leaving the surface, $\phi = q/\epsilon_0$

$$\therefore\ \phi = \frac{1.45\times10^{-3}}{8.854\times10^{-12}} \Rightarrow 0.16\times10^{9} \text{Nm}^2/\text{c}$$

or 1.6×10^{8} Nm^2/c Ans.

ELECTRICAL CAPACITANCE :-

"Electrical capacitance of a isolated conductor is a measure of the ability to store charge on it."

When we give a charge to a conductor, it is raised to some potential. As we give more charge to the conductor its potential also increases accordingly. If q is a charge given to the conductor so that its potential increases by an amount V, then it is found that

$$q \alpha V$$

$$q \alpha \ CV \text{------------------(i)}$$

Where C is constant of proportionality and here it is called CAPACITANCE of the conductor. The value of C depends upon the shape and size or dimensions of the conductor and also on nature of the medium in which conductor is located. It does not depend upon the nature of material of the conductor.

From equation (i) we have,

$$C=q/V$$

"Thus capacitance of a conductor may be defined as the ratio of the electric charge on it to its potential due to that charge."

if V= 1 Volt, then

$$C = q$$

"Therefore capacitance of a conductor is numerically equal to the electric charge required to augment its potential through one Volt."

The S.I. Unit of CAPACITANCE is FARAD

$$\therefore \ 1 \text{ FARAD (F)} = \frac{1 \text{ COULOMB (C)}}{1 \text{ VOLT (V)}} \Rightarrow 1 \text{ CV}^{-1}$$

"A conductor is said to have a capacitance of one farad, if 1 coulomb of charge raises its potential through one Volt."

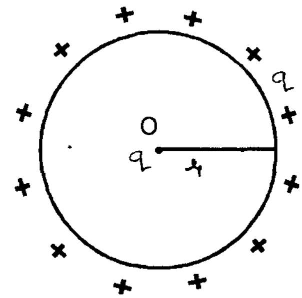
The farad is a very big unit of capacitance, similar units of capacitance are :-

1 microfarad (μF)= 10^{-6} Farad

1 micromicrofarad ($\mu\mu$F) =10^{-12} Farad

1 $\mu\mu$F is also known as 1 picofard (PF)

CAPACITANCE OF AN ISOLATED SPHERE :-



Suppose an isolated spherical conductor of radius r and centre O. Let a charge +q be given to the sphere. The charge +q spreads uniformly over the outer surface of the sphere whether the sphere is hollow or solid. Then the potential at every point on the surface of the sphere is same.

The Potential at any point on the surface of sphere in free space is given by,

$$V = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

as C=q/V

$$\therefore\ C = \frac{q}{\frac{1}{4\pi\epsilon_0}\frac{q}{r}}$$

$$\text{or } C = \frac{4\pi\epsilon_0 r\, q}{q}$$

$$\text{or } C = 4\pi\epsilon_0 r$$

Where r is in metre, c is in farad

Now taking earth to be sphere of radius r = 6400 km

$$r = 6400 \text{ km} = 6.4\times10^{6}\text{m}$$

Then, $C = 4\times\frac{22}{7}\times8.854\times10^{12}\times6.4\times10^{6}$

$C = 0.711\times10^{-3}$ farad

$C = 711\ \mu$F.

PRINCIPLE OF CAPACITOR :-

"A capacitor is a device for storing a large quantity of electric charge."

To understand the principle of capacitor, considered an insulated metal plate A. Suppose, it is giving a positive charge till its potential becomes maximum. No further charges can be given to this plate, as it would leak out.

Now place another metallic plate B near metal plate A. Due to induction a negative charge is produced on the nearer face of B and positive charge on the farther face of B as shown in fig. 4.19 (a) The induced negative charges on B lower the potential of A while. The induced positive charge raised its potential.

As the induced negative chage on B is nearer to the metal plate than the induced positive charge on B. Hence it is more effective. Therefore on the whole the potential of the metal plate A is lowered through by an small amount. In order to make the potential of the metal plate A again the same, a small amount of more charge has to be given. It indicates that the capacitance of a conductor increase by an small amount, when another uncharge capacitor is placed near it.

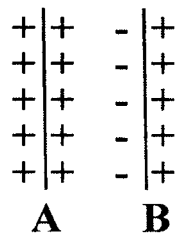


Fig (4.19) (a)

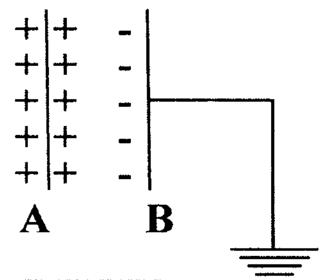


Fig (4.19) (b)

Now connect B to the earth. The induced positive charge will immediatly flow to the earth as it is repelled by the positive charge on A. as shown in fig 4.19 (b). The induced negative charge on B, however stays as it is attracted by a positive charge on plate A. Thus metal plate B have negative charges. Due to negative charge on plate B, the potential of A will be lowered by a large amount. In order to raise the metal plate A to the same potential again, a large amount of charge has to be given. Thus it follows that the capacitance of a conductor greatly increases, when earth connected is placed near it.

Capacitors or condensers are used in many electrical appliances, like oscillator circuits, in radio tunning, in ignition system of engines in vehicles, in fans, in electric motors and in filter circuits etc.

CAPACITANCE OF PARALLEL PLATE CAPACITOR :-

It is most commonly used capacitor. It consists of two conducting plates placed parallel to each other. The distance between the plates is very small as campared to the area of the plates. Due to small distance between the plates. The electric field E at the boundries of plate is negligilble. If +q charge is placed on plate A, Then due to induction phenomena -q charge is induced on left face of plate B and +q charge on right face of plate B, as shown in fig. (4.20) when plate B is earthed, the charge +q on the right face of plate B flows to the earth. Due the charge +q on plate A and -q charge on plate B, an electric field will be setup. If σ is surface charge density of the plates, then electric filed (E) between the plates is given by

$$E = \frac{\sigma}{E_0} \text{ -------(1)}$$

Where E_0 is absulute permitivity of free space. It is assumed that medium between the plates is vacuum or air. Then potential difference between the plates is given by.

$$V = E\, d \text{ ------------------------(2)}$$

Putting value of E in equation (2) weget,

$$V = \frac{\sigma}{\epsilon_0} d$$

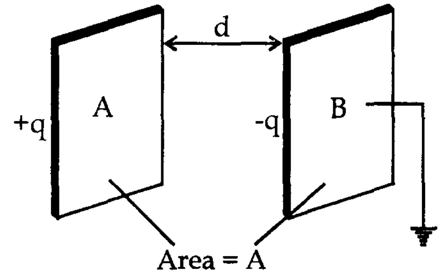


Fig. 4.20

Since surface charge density $\sigma = q / A$ we have,

$$V = \frac{q}{A\epsilon_0} d \text{ ----------------(3)}$$

If C is capacitance of Parallel Plate capacitor, then,

$$C = \frac{q}{V} \text{ --------(4)}$$

Putting value of V from equation (3) in equation (4) we get,

$$C = \frac{q}{\frac{q}{A\epsilon_0} d}$$

$$\text{or } C = \frac{\epsilon_0 A}{d}$$

GROUPING OF CAPACITORS :-

In practices, the capacitor are grouped in the two ways i.e in the series and in a parallel format. When the capacitor are connected in series, the net capacitance decreases, while when connected in parallel format the net capacitance increases.

(i) SERIES COMBINATION :-

Let us take three or more capacitor connected in a series combination as shown in figure (4.21)

When charge +q is given to plate A of the capacitor C_1, then -q charge induced on left face and +q charge on right face of the plate B.

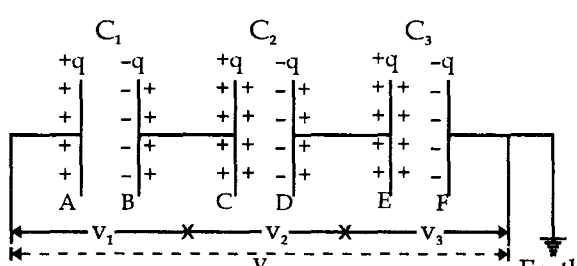


Fig. 4.21

Thus plate C is +q charge and inner face of plate D is -q and outer face becomes +q due to induction. Similarly plate E is induced +q charge and inner face of plate F is -ve charge and outer face of F is becomes +q charge. Thus the outer face of F plate is connected to the earth os all the +q flow s. Thus three capacitor C_1, C_2 and C_3 are charged with same amount of charge +q, when charge +q is given to first capacitor,

Let V_1, V_2 and V_3 ar ethe Potential difference across the three capacitor C_1, C_2 and C_3 Then,

$$V = V_1 + V_2 + V_3 \text{ ----------- (1)}$$

By defination of capacitance, $C = \frac{q}{V}$

$$\text{or } V = \frac{q}{C}$$

$$\text{Thus, } V_1 = \frac{q}{C_1}$$

$$V_2 = \frac{q}{C_2}$$

$$\text{and, } V_3 = \frac{q}{C_3}$$

Putting the value of V, V_1, V_2 and V_3 in equation (1) we get,

$$\frac{q}{C} = \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3}$$

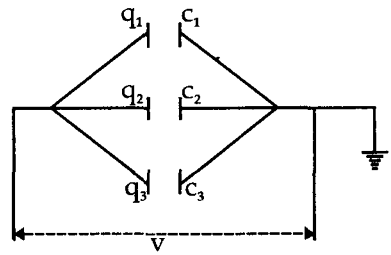
$$\text{or } \frac{q}{C} = q\left[\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right]$$

$$\text{or } \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

"Thus the reciprocal of the net capacitance of series combination of the number of capacitor is equal to the sum of the reciprocal of the capacitance of individual capacitors."

(ii) Parallel Combination :-

Let 3 capacitors C_1, C_2 and C_3 be connected in such a way that, one plate of each capacitor is connected to the source of e.m.f. and another Plate of all the capacitor is connected to the earth. It means that all the capacitors are connected directly between the source of e.m.f. and earth, and thus passes same potential difference across their plates. As the capacitors have different capacitance, they will draw different amount of charge from the source of e.m.f.



$c = \frac{q}{a\in 0} d$

Fig. 4.22

If V has the same Potential drawn in all the capacitors, and q_1, q_2 and q_3 are the charge on capacitors C_1, C_2 and C_3 then,

$$q = q_1 + q_2 + q_3 \text{ ------ } (1)$$

By defination of capacitance,

$$C = \frac{q}{V}$$

or $q = CV$

$\therefore\ q_1 = C_1V$

$q_2 = C_2V$

and $q_3 = C_3V$

Putting the value of q, q_1, q_2, q_3 in equation (1) weget,

$$CV = C_1V + C_2V + C_3V$$

or $CV = V\,[C_1 + C_2 + C_3]$

$\therefore\ C_P = C_1 + C_2 + C_3$

"Thus the net capacitance of the parallel combination of the number of capacitors is equal to the sum of the capacitance of the individual capacitors."

ENERGY STORED IN A CAPACITOR :-

If we connect a battery across the two plates of the capacitors. The battery transfers a positive charge from negative to the positive Plate. So work is done in transferring this charge, which is stored in the condenser in the form of electrical energy.

Suppose a capacitor of capacitance C, its Potential is V on being connected to battery. If q is charge on the Plate of the capacitor at that time, then,

$$q = CV \text{ ------------- } (1)$$

Small amount of work done in giving an additional charge dq to the condensor is,

$$dw = V\ d_q$$

$$dw = \frac{q}{c}\ d_q \quad [\therefore \text{ from eq}^n. (1), V = q/c]$$

Therefore total amount of work done in delivering charge q to the capacitor is given by, Integrating both sides weget,

$$W = \int_0^q \frac{q}{C}\ dq$$

$$= \frac{1}{C} \int_0^q q\ dq$$

$$= \frac{1}{C} \left|\frac{q^2}{2}\right|_0^q dq$$

$$= \frac{1}{C} [\frac{q^2}{2} - \frac{0}{2}]$$

$$W = \frac{1}{2}\frac{q^2}{C}$$

$\therefore$ Energy stored in the condenser $U = W = \frac{1}{C}\ \frac{q^2}{C}$

Put q = CV

$$\therefore\ U = \frac{1}{2}\ C\ V^2$$

Now Put C V = q

$$\therefore\ U = \frac{1}{2}\ C.V.V$$

$$U = \frac{1}{2} q v$$

Hence $U = \frac{1}{2} \frac{q^2}{C} = \frac{1}{2} C V^2 = \frac{1}{2} q v$

When q is in coulomb, V is in Volt, C is in farad then energy U is in Joule.

DIELECTRICS :-

"A di-electric is a non conducting material which separates the plates of a capacitor."

Hence we define di-electrics as the insulating materals which transmit electric effects without conducting. Di-electric is also known as Insulators. Common examples of di-electrics are glass, ruber, plastic, mica, ebonite, wax, paper, wood etc.

They are called di-electrics because they prevent charge from moving in an undesired manner. Such substances posses a negligibly small number of free electrons.

EFFECT OF DI-ELECTIC ON CAPACITANCE :-

Di-electrics increase the capacity of the condensor. Let us suppoe a parallel plate capacitor of charge q, capacitance C without di-electric means the medium between the Plates is vaccum or air. The Potential difference across the plates of capacitors is given by

$$V = q c$$

and capacitance in Parallel Plate capacitor is given by

$$C = \frac{\epsilon A}{d} \quad [\text{Where } \epsilon = \epsilon_0 \epsilon_r]$$

When di-electrics Placed between the plates then, $C = \frac{\epsilon_r \epsilon_0 A}{d}$

$$C = \frac{\epsilon_r \epsilon_0 A}{d}$$

$$C_m = \epsilon_r C_0$$

Where C_m - Capacitance in medium

C_0 - Capacitance in Vaccum

E_r - relative permitivity

or $C_m = K C_0 \quad \backslash \ \epsilon_r = K$

When Plates are seprated by a di-electric medium of relative permitivity $\epsilon_r = K$ then its capacity, becomes K times the capacity with air/vacuum as di-electric.

DIELECTRIC CONSTANT :-

According to coulomb's Law the force of attraction or repulsion between the two charges q_1 and q_2 separated by a distance r placed in vacuum is given by,

$$F_0 = \frac{1}{4\pi \in_0} \frac{q_1 q_2}{r^2} \qquad \text{----------(1)}$$

Where E_0 = absolute permitivity of free space.

Now when same charges q_1, q_2 are placed in medium metarial, then force of intraction is given by,

$$F_m = \frac{1}{4\pi \in_0} \frac{q_1 q_2}{r^2} \qquad \text{-------- (2)}$$

Where E = absolute permitivity of the medium or

Now Divided equation (1) by equation (2) weget,

$$\frac{F_0}{F_m} = \frac{\frac{1}{4\pi \in_0} \frac{q_1 q_2}{r^2}}{\frac{1}{4\pi \in} \frac{q_1 q_2}{r^2}}$$

$$\frac{F_0}{F_m} = \frac{\in}{\in_0} = \in_r = K$$

Where E_r = is relative permitivity or dielectric constant (K) of the medium. "Hence it may be defined as the ratio of the electrostatic force of interaction between two given point charges held certain distance apart in vacuum/air to the force of interaction between the same two charges held the same distance apart in the medium."

Faraday observed that when an insulating meterial is introduced in between the plates of capacitor, its capacitance increase. The factor by which capacitance is depends upon the nature of dielectric and it is called relative permitivity E_r or dielectric constant (K) of the medium.

$$\therefore \in_r = K \frac{C_m}{C_0} = \frac{\text{Capacitance of capacitor with dielectric between the plates}}{\text{Capacitance of capacitor with cacuum/air between the plates}}$$

$$\text{Thus } C_m = KC_0 = \in_r \frac{\in_r A}{d} = \frac{\in A}{d}$$

"Thus di-electric constant is defined as the ratio of the capacitance of a given capacitor completely filled with material, to the capacitance of some capacitor placed in vacuum or in air."

DI-ELECTRIC STRENGTH :-

(OR) DI-ELECTRIC BREAKDOWN :-

As the strength of electric field applied is increased, molecules of dielectrics undergo more and more stretching. A stage is reached when the stretching is so strong that electrons break up from the molecules of the di-electric. This is known as Dielectric breakdown or dielectric strength.

"We define dielectric strength of a dielectric as the maximum value of the electric field intensity that it can tolerate without its electric Breakdown."

For reasons of safety. The maximum electric field actually applied is only 10% of the dielctric strength of the material.

The value of dielectric Breakdown of air is 3×10^6 v/m.

TYPES OF CAPACITORS :-

The various types of capacitor are following catagories :-

(i) Those having solid dielectric

(ii) Those having air dielectric and

(iii) Electrolytic Capacitors.

(1) Capacitors with solid Dielectric :-

(a) LEYDEN JAR :-

It consists of a glass jar which is covered on both in and outside the bottom upto about three-fourth of its weight with tin foil. The tin foil coating acts as parallel plates of a capacitor with glass acting as the separating dielectric. Though the capacity of the leyden jar is not large, it is able to stand high potential difference.

(b) MICA CAPACITOR :-

To secure large capacity in a parallel plate condenser, a number of plates are used together in order to have large area but still have overall dimensions within reasonable limits.

A schematic diagram of such a multiplate condenser is shown in fig. (4.23) for capacitors of good qualtiy mica is used as dielectric. Metal plates such as those of tin foil (shown black) are asembled with mica sheets (shows

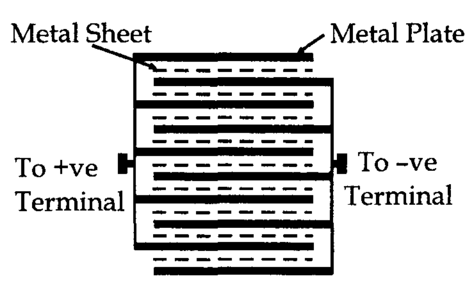


Fig. 4.23

dotted) placed between them to serve as dielectric. The alternate sets of tin foil are soldered with copper wire connected to well-insulated terminals. It is evident that both the faces of all the metal plates, except the top and the bottom one contribute to the area. A for the capacitor so that the capacity becomes large.

(c) PAPER CAPACITOR :-

These are cheap type of condensers which are usually made of alternate layers of tin or Alminium foil with waxed paper in between them. The whole arrangement is rolled into a tight cylinder in an appropriate order so that it may occupy less space and may be of more convenient shape in order to be installed in equipment. Such fixed condensers, particularly those using mica as dieletric, are arranged in boxes in a manner similar to that of resistance boxes as shown in fig. (4.24) and can be used in series and parallel format by means of plugs so as to use any desired value of the capacitance in circuit.

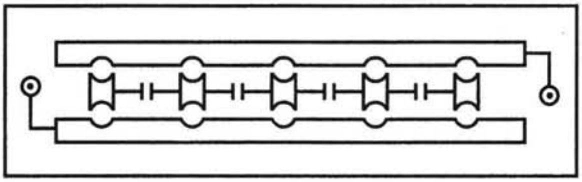


Fig. 4.24

(2) VARIABLE AIR CONDENSERS :-

These consist of two sets of Brass or Alminium plates, one fixed and another movable as shown in fig. (4.25). The fixed set is semicircular in shape. The movable set is like a cam related with knobs. All the fixed plates are connected to one terminal while all the movable plates are connected to another terminal. The air between the plates acts as dielectric. By rotating the knobs, the area overlaped between the two sets of plates varies and thus the capacity of condenser changes. These variable condensers are used in radio sets for tunning and also in other electronic devices.

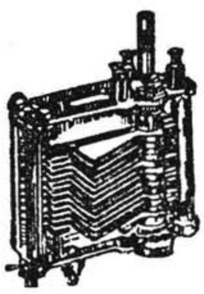


fig. (4.25)

(3) ELECTROLYTIC CONDENSERS :-

It consists of two Alminium plates A and B in solution containing ammonium (or a paste of borates). The plate A serves as anode and B as a catnode fig. (4.26). On passing a direct current, a very thin film of Alminium oxide is formed on the anode and serves as the dielectric between the plates. Since the dielectric layer is very thin, the capacity of this arrangement is very large.

In wet type eletrolytic condensers, the electrolyte is contained in an Alminium container and the anode is adjusted in its centre, the container being connected to the negative terminal. In the dry type, the plate consists of two long strips of Alminium foil. A thin layer of Alminium oxide is deposited on one of them electrically. The two plates are separated by paper soaked in electrolyte and the Alminium foils are then rolled up in the form of a cylinder.

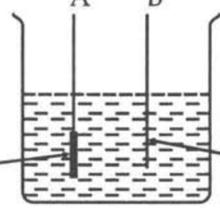


Fig. 4.26

EXAMPLE 4.17

A potential difference of 250 V is applied across the plates of capacitor of 10 PF. Calculate charge on the plates of the capacitor.

SOLUTION :-

Here V = 250 V

$C = 10\ PF = 10\times10^{-12}F \Rightarrow 10^{-11}F$

accordingly to , q = Cv

$\therefore q = 250\times10^{-11} \Rightarrow 2.5\times10^{-9}C.$

EXAMPLE 4.18

Calculate the capacitance of the earth, when it is taken as a spherical conductor of radius $6.4\times10^{6}m$ **Given,** $\frac{1}{4\pi\epsilon_0}=9\times10^{9}NM^2\ C^{-2}$

SOLUTION :-

Here, $r = 6.4\times10^{6}m$

$$\frac{1}{4\pi\epsilon_0}=9\times10^{9}NM^2\ C^{-2}$$

The capacitance of a spherical conductor is given by

$$C = 4\pi\epsilon_0 r$$

$$C = \frac{1}{9\times10^{9}}\times6.4\times10^{6} \Rightarrow 7.11\times10^{-4}F \Rightarrow 711\ \mu F.$$

EXAMPLE 4.19

What is the area of the plates of a 2 F parallel plate capacitor, given that the distance between the plates is 0.5 cm ?

SOLUTION :-

Here, $C = 2\ F$

$d = 0.5\ cm = 0.5\times10^{-2} m$

we know, $\epsilon_0 = 8.854\times10^{-12}\ C^2\ N^{-1}\ m^{-2}$

Now, $C = \frac{\epsilon_0 A}{d}$

$C = \frac{\epsilon_0 A}{d}$

$\therefore A = \frac{c\,d}{\epsilon_0} \Rightarrow \frac{2\times0.5\times10^{-2}}{8.854\times10^{-12}} \Rightarrow 1.13\times10^{9} m^2$ Ans.

EXAMPLE 4.20

What distance should th two plates each of area 0.2 m×0.1 m of an air capacitor be placed in order to have the same capacitance as an spherical consuctor of radius 0.5 m ?

SOLUTION :-

Area $A = 0.2\ m\times0.1\ m \Rightarrow 0.02\ m^2$

$r = 0.5\ m$

Now $C = \frac{\epsilon_0 A}{d}$ (for parallel plate capacitor)

capacitance of a spherical conductor,

$C = 4\pi\ \epsilon_0 r$

According to question, capacitance of Parallel plate capacitor is equal to capacitance of a spherical conductor.

$\therefore \frac{\epsilon_0 A}{d} = 4\pi\ \epsilon_0 r$

or $d = \frac{A}{4\ \pi\ r} \Rightarrow \frac{0.02}{4\ \pi\times0.05} \Rightarrow 3.18\times10^{-3} m \Rightarrow 3.18\ mm$ Ans.

EXAMPLE 4.21

Calculate the capacitance of parallel plate capacitor of two plates 100 cm×100 cm each separated by 2 mm thick glass sheet of K = 4.

SOLUTION :-

Here, $A = 100\ cm\times100\ cm \Rightarrow 10^4 cm^2 \Rightarrow 1\ m^2$

$d = 2 \text{ mm} = 2\times10^{-3}$ m,

$K = 4, C = ?$

$$\therefore \quad C = \frac{K \epsilon_0 A}{d}$$

$$C = \frac{4\times8.854\times10^{-12}\times1}{2\times10^{-3}} \Rightarrow 1.77\times10^{-8} \text{ F} \quad \text{Ans.}$$

EXAMPLE 4.22

The capacity of capacitor becomes 10 μF when air between the plates is replaced by a dielectric slab of K = 2, What is the capacity of capacitor with air in between the plates ?

SOLUTION :-

Here, Cm = 10 μF

Co = ?

as K = 2

We know that $K = \frac{Cm}{Co}$

$$\therefore \ Co = \frac{Cm}{K}$$

$$Co = \frac{10}{2} = 5 \ \mu F \qquad \text{Ans.}$$

EXAMPLE 4.23

Calculate the capacitance of a combination of three capacitors of capacitance 8, 12 and 24 μF when they are joined in series and parallel. Find the charge on each plate in the series arrangement, if the potential difference across the system is 100 V.

SOLUTION :-

Here, $C_1 = 8\times10^{-6}$ F

$C_2 = 12\times10^{-6}$ F

$C_3 = 24\times10^{-6}$ F

in series, $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

$$\therefore \frac{1}{C_S} = \frac{1}{8\times10^{-6}} + \frac{1}{12\times10^{-6}} + \frac{1}{24\times10^{-6}}$$

$$\frac{1}{C_S} = (\frac{1}{8} + \frac{1}{12} + \frac{1}{24})\ 10^6 \Rightarrow \frac{1}{4}\times10^6$$

$$\therefore C = 4\times10^{-6} F \Rightarrow 4\ \mu F \qquad \text{Ans.}$$

in parallel, $C_p = C_1 + C_2 + C_3$

$$C_p = 8 + 12 + 24 \Rightarrow 44\ \mu F \qquad \text{Ans.}$$

Now charge on plate is given by, q = cv (when connected in series)

$$\therefore\ q = 4\times10^{-6}\times100$$

$$\therefore\ q = 4\times10^{-4}\ C \qquad \text{Ans.}$$

EXAMPLE 4.24

A 900 PF capacitor is charged by a 100 V battery. How much electrical energy is stored by the capacitor ?

SOLUTION :-

Here, C = 900 PF = 9×10^{-10} F
V = 100 V

Energy stored $U = \frac{1}{2}\ CV^2$

$$= \frac{1}{2}\times9\times10^{-9}\times(100)^2$$

$$= 4.5\times10^{-6}\ J \qquad \text{Ans.}$$

EXAMPLE 4.25

The Plates of Parallel plated capacitor have an area of 90cm² each and are seprated by 2.5 mm. The capacitor is charged by connecting it to a 400 V supply. How much electrical energy is stored by the capacitor ?

SOLUTION :-

Here, $A = 90\ cm^2 = 90 \times 10^{-4}\ m^2$

$d = 2.5\ mm \Rightarrow 2.5 \times 10^{-3}\ m$

$V = 400\ V$

Now, $C = \dfrac{\epsilon_0 A}{d} \Rightarrow \dfrac{8.854 \times 10^{-12} \times 90 \times 10^{-4}}{2.5 \times 10^{-3}} \Rightarrow 3.187 \times 10^{-11} F$ Ans.

and $W = \dfrac{1}{2} cv^2 \Rightarrow \dfrac{1}{2} \times 3.187 \times 10^{-11} \times (400)^2 \Rightarrow 2.25 \times 10^{-6}\ J$ Ans.

EXAMPLE 4.26

Three capacitors of $1\,\mu F$, $2\,\mu F$ and $3\,\mu F$ are joined in series. How many times will the capacity becomes when they are joined in parallel ?

SOLUTION :-

Here, $C_1 = 1\,\mu F, C_2 = 2\,\mu F, C_3 = 3\,\mu F$

in series, $\dfrac{1}{C_S} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$

$\dfrac{1}{C_S} = \dfrac{1}{1} + \dfrac{1}{2} + \dfrac{1}{3}$

$\dfrac{1}{C_S} = \dfrac{11}{6}\ \mu F$

or $C_S = \dfrac{6}{11}\ \mu F$

in parallel, $C_P = C_1 + C_2 + C_3$

$C_P = 1 + 2 + 3 \Rightarrow 6\ \mu F$

$\therefore \dfrac{C_P}{C_S} = \dfrac{6}{6/11} \Rightarrow 11$

Hence, $C_P = 11\ C_S$ Ans.

EXAMPLE 4.27

A parallel plate capacitor having plate area 25cm^2 and sepration 1.00 mm is connected to a battery of 6.0 V calculate the charge flawn through battery. How much work has been done by the battery during the process ?

SOLUTION :-

Here, $A = 25\ cm^2 \Rightarrow 25\times10^{-4}\ m^2$

$d = 1.00 \Rightarrow 10^{-3}\ m$

$V = 6.0$ Volt,

$q = ?$

as $q = cv$

$$q = \frac{\epsilon_0 A}{d}.V$$

$$q = \frac{8.85\times10^{-12}\times25\times10^{-4}\times6}{10^{-3}}$$

$$q = 1.33\times10^{-10}\ C$$

work done by the battery during the process,

$W = q\times V$

$W = 1.33\times10^{-10}\times6 \Rightarrow 8\times10^{-10}\ J$ Ans

MULTIPLE CHOICE QUESTIONS

1. Coulomb's Law is given by $F = q_1\ q_2\ r^n$ where n is equal to
   (a) 1/2 (b) -2 (c) 2 (d) -1/2

2. The Law that governs the force between the two electric charges is called
   (a) Ampears Law (b) Hook's Law (c) Ohm's Law (d) Coulomb's Law

3. The value of absolute permitivity ϵ_0 = ---------- $C^2\ N^{-1}\ m^{-2}$
   (a) 8.85×10^{-10} (b) 8.85×10^{-11} (c) 8.85×10^{-12} (d) 8.85×10^{-13}

4. The unit of electric charge is
   (a) Ohm (b) Ampear (c) Coulomb (d) Volt.

5. The unit of permitivity of free space ϵ_0 is
   (a) Newton metre^2 / Coulomb^2 (b) Coulomb^2 / Newton-metre^2
   (c) Coulomb^2 / (Newton-metre)^2 (d) Coulomb / Newton-metre

6. The unit of electric field Intensity is
   (a) Volt/Joule (b) Volt × Joule (c) Volt/metre (d) Volt × metre

7. According to Gauss Law, $\int E.\, ds =$
   (a) $q = \in_0$ (b) $q/\in_0$ (c) $\in_0$ (d) None of these

8. Electricd field intensity due to a finite sheet of charge is given bys
   (a) $E = \dfrac{\lambda}{2\pi \in_0 r}$ (b) $E = \dfrac{\sigma}{2 \in_0}$ (c) $E = \dfrac{\sigma}{\in_0}$ (d) None of these

9. The S.I. Unit of electric Potential is
   (a) Watt (b) Joule (c) Volt (d) Ampear.

10. Electrifield intensity insed a charged conducting sphere is
    (a) Zero (b) Infinite (c) Negative (d) Positive.

11. Which of the following relaction is correct ?
    (a) q = c/v (b) c = q/v (c) v = qc (d) None of these.

12. The S.I unit of coapcitance is
    (a) Volt (b) Amper (c) Ohm (d) Farad

13. $1\,\mu F = ?$
    (a) 10^{-5} F (b) 10^{-6} F (c) 10^{-3} F (d) 10^{-12} F

14. An electron initailly at rest is accelerated through a potential difference of one Volt. The energy required by electron is
    (a) 1 J (b) 0.6×10^{-16} J (c) 10^{-19} J (d) 0.6×10^{-19} erg.

15. Increasing the charge on plate of capacitor means.
    (a) Increasing the capacitance
    (b) Increasing the P.D. between the plates
    (c) Both a and b (d) None of these.

16. The capacitance of a parallel plate capacitor is given by :-
    (a) C = a/v (b) $C = \in_0 A/d$ (c) $C = dA/\in_0$ (d) $C = \in_0 Ad$

17. When three capacitors C_1, C_2, C_3 are connected in series them resulatantant is given by
    (a) $C_S = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$ (b) $C_S = C_1 + C_2 + C_3$
    (c) $\dfrac{1}{C_S} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$ (d) None of these

18. When three capacitors $C_1 + C_2 + C_3$ connected in parallel then resultant is given by

(a) $C_P = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ (b) $C_P = C_1 + C_2 + C_3$

(c) $\frac{1}{C_P} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ (d) None of these

19. The diclectric constant of metal is
(a) 1 (b) Zero (c) Infinity (d) None of these

20. If we place a dielectrics constant k in between the plates of capacitance then capacitance will be
(a) Increase by factor k (b) Decrease by factor k
(c) Zero (d) Infinite.

21. Three capacitors of capacitance $4\,\mu F$, $6\,\mu F$ and $12\,\mu F$ are connected first in series and then in parallel. What is the ratio of equivalent capacitance in the two case ?
(a) 2 :3 (b) 1 :11 (c) 11 :1 (d) 1 :3

22. The capacity of Parallel Plate capacitor is C. If the distance between the plates is halved then its capacity is
(a) C/2 (b) C/4 (c) 2 C (d) 4 C

23. Three different capacitors are connected in series then :-
(a) They will have equal charges (b) They will have same potential
(c) Both a and b (d) None of these.

24. Two plates are 10 cm apart and potential difference between them is 1 volt . The electric field between the plates is
(a) 10 N/C (b) 500 N/C (c) 10^3 N/C (d) 250 N/C

25. Capacity of an conductor depends upon
(a) Size of conductor (b) Thickness of counductor
(c) Nature of material (d) None of these.

26. When the distance between the charges is halved then force will be
(a) One half (b) One fourth (c) Double (d) Four times

VERY SHORT ANSWER QUESTIONS :-

1. What is Electrostatics ?
2. Define electric charge.
3. Define frictional electricity.

4. State coulomb's Law of Electrostatics.
5. Define one coulomb of charge.
6. Define electric flux.
7. Define electric lines of force.
8. Define solid angle.
9. What is area vector.
10. State Gauss Theorem. [May-June-2007]
11. Define Electric field intensity. [May-June-2004] [May-June-2007]
12. Define on Volt.
13. What is Electric Potential ? [May-June-2004]
14. What is electric potential difference ?
15. What is Gaussian surface ?
16. Define capacitance. [May-June-2007]
17. Define one farad.
18. 1 μF = ----------------------farad ?
19. Define surface charge density.
20. Define volume charge density.
21. Give ues of the capacitance.
22. Write down the different types of capacitors.
23. Define Dielectric.
24. What is the effect fo Dielectric on capacitance ? [M. Imp.]
25. Define Dielectric constant or relatives permitivity. [May-June-2007]
26. What do you mean by dielectric strength ?
27. Why is coulomb's Law is known as Inverse square Law ?
28. Can two lines of force cross each other ?
29. Can potential difference be Zero.
30. Electric field is a scaler or vector ?
31. Write down the methematically expression for electric field due to linear charge conductor.
32. What is unit of charge and define it ? [May-June-2007]

SHORT ANSWER QUESTIONS :-

1. State and explain coulomb's Law of electrostatics. [May-June-2004] [2007]
2. Differentiate between charge and mass.
3. What are the property of electric charge ?

4. Define Electric field intensity and find out the electric field intensity at a point. [May-June-2007]
5. Define potential difference and find out the potential difference at a point.
6. What are electric lines of force ? Explains their property.
7. State and Explaon Gauss Theorem. [May-June-2007]
8. What is electric field intensity and hence find out electric field intensity due to a straight charge conductor ?
9. What is Electric field intensity and hence find out electric field intensity due to infinite plane sheet of charge ? [May-June-2007]
10. Find out the electric field intensity due to conducting and not-conducting sphere.
11. Explain the Principle of capacitance.
12. Find out the capacitance for a parallel plate capacitor.
13. Explain the grouping of capacitance in series and parallel. [May-June-2007]
14. What is dielectric, and Explain what is effect of dielectric on capacitance ?
15. Explain different types of capacitor.
16. What is dielectric constant and dielectric Breakdown ?

LONG ANSWER QUESTIONS :-

1. State and Proof Coulomb's Law of Electrostatics.
2. State and Proof Gauss Theorem.
3. Find out Electric field intensity due to a straight charge conductor and due to infinite plane charge of sheet.
4. Find out Electric field intensity due to a conducting and non-conducting sphere. [May-June-2007]
5. Define electrical capacitance, Explain its Principle.
6. Find out the capacitance for a parallel plate capacitor.
7. Find out the equivalent capacitor when three or more capacitor are connected in
   (i) Series combination
   (ii) Parallel combination

NUMERICAL PROBLEMS

1. Determine the force between two charges, each one coulomb when they are separated at one metre distance in air. [Ans. 9×10^{9} N]
2. An electron and proton are at a distance of 10^{-9} M from each other in a free space. Calculate Force between them. [Ans. -23.04×10^{-11} N]

3. What is magnitude of a point charge choosen so that electric field 50 cm away has the magnitude 2 n/m ? [Ans. 0.55×10^{-8} C]

4. Calculate the force between two protons separated by a distance of 1.6×10^{-15} m. [Ans. 90 N]

5. Calculate the force between α- particle and a proton separated by 5.12×10^{-15} m.

   Given, q_1 = change on α- particle = $2\times1.6\times10^{-19}$ C.

   q_2 = change on proton = 1.6×10^{-19} [Ans. 17.58 N]

6. How far apart from two electrons be so that their electrostatics repulsion on each other, equals the weight of the electron ?

   Take g = 10 m s^2 [Ans. 5.1 m]

7. Compare coulomb's force with Gravitational force. $\left[\frac{F_e}{F_G}=2.4\times10^{39} \text{ Ans.}\right]$

8. A sphere with positive charge of 16 μc is placed in air. Then find out

   (i) Electric flux.

   (ii) Electric field at a distance of 20 cm from the centre of sphere.

   [Ans. 36×10^5 N/C]

9. A charge of 1500 μc is distributed over a very large sheet having surface area of 300 m^2. Calculate electric field intensity at a distance of 25 cm from the sheet. 300 m^2. [Ans. 56.472×10^4 N/C]

10. What is the magnitude of an isolated positive point charge to give an electric potential of 100 V at 10 cm from the charge. [Ans. 1.09×10^{-9}C]

11. A sphere of radius 60 cm is charged to a potential of 1500 calculate (i) charge (ii) The energy of the sphere.

    [(i) q = 0.11 μc]

    [(ii) Energy = 75×10^{-6} J]

12. The capacitance of a capacitor increase from 2 μF to 6 μF by the use of a dielectric. Find the dielectric constant of the dielectric used. [Ans. = 3]

13. Find out capacitance of a capacitor of a charge 0.01 C when the potential difference is 500 V. [Ans. 20 μF]

14. A Parallel Plate capacitor has circular plates of 8 cm radius and 1 mm separated in air. What charge will appear on the plates if Potential difference of 100 V is applied?

[Ans. 178.1×10^{-10}C]

15. What must be the capacitance of a capacitor which when connected in series with a capacitor of 20 μF, reduced the effective capacitance to 5 μF ?

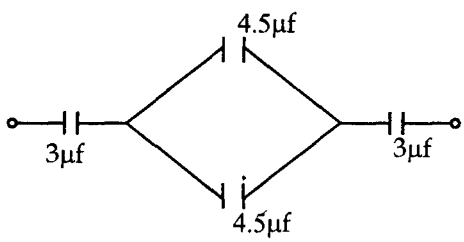
[Ans. 6.67 μF]

16. Capacitor of 4, 5 and 6 μF are connected in parallel and in series compare the effective capacitance in the two cases.

[Ans. C_S=15 μF, C_S=1.62 μF, $\frac{C_P}{C_S}$=9.25]

17. The electirc Potential at a point distance 0.9 m from a point charge is +50V. Find the magnitude and nature of the charge. [Ans. 5 nc]

18. Calculate equivalent capacity of following circuit. [May-June 2003]



[Ans. C_s=1.28 μF]

19. A Parallel Plate capacitor has plates of $200\ cm^2$ and separation between the plates is 2 mm . What potential difference will be developed if a charge of 1.0 nc (i.e. 1×10^{-9} C) is given to the capacitor.

[Ans. C=8.85×10^{-11} F]
V=11.23 V

20. Two capacitors of equal capacitance, when connected in series, have a net capacitance C_1 and when connected in parallel have a net capacitance C_2. What is value of C_1/C_2 ?

[Ans. $\frac{C_1}{C_2}=\frac{1}{4}$]

21. 20 C charge is uniformly distributed on the surface of hollow sphere of radius 20 cm. Find electric field intensity at 30 cm from the centre of the sphere.

[May-June 2003] [Ans. 2×10^{12} N/C]

22. At what distance should the circular plates capacitor 40 mm in diameter, be order to have the same capacitance as sphere of radius 1 m ? [Ans. 0.1 mm]

23. A Thin metal sphere has a radius of 25 cm and carries a charge of 2×10^{-7} C. Find electric field intensity of a point

(i) Inside the sphere.

(ii) Just outside the sphere and

(iii) 300 m from the centre of sphere

[Ans. (i)=0, (ii)= 2.88×10^{4} N/C, (iii) 2×10^{-2} N/C]

24. Three capacitor of 1 μF, 2 μF and 3 μF are joined in series and then in Parallel. Calculate the ratio of equivalent capacitance in two cases.

[Ans. $\frac{C_P}{C_S}=11$]

25. Two Parallel plate capacitor are 2 cm apart and a potentail difference of 50 V is applied across them. Find the electric field intensity between the two plates.

ANSWER KEY FOR MULTIPLE CHOICE QUESTIONS

(1)	b	(2)	d	(3)	c	(4)	c	(5)	b
(6)	d	(7)	b	(8)	b	(9)	c	(10)	a
(11)	b	(12)	d	(13)	b	(14)	b	(15)	b
(16)	b	(17)	b	(18)	c	(19)	d	(20)	a
(21)	b	(22)	d	(23)	a	(24)	c	(25)	a
(26)	d								

UNIT - 5
ELECTRICITY

ELECTROSTATICS (OR) FRICTIONAL ELECTRICITY :-

In last unit of Electrostatics, we have learnt about the various characteristics of the charges at rest, In this unit we study about the charges in motion and the various effect and its phenomena.

So current electricity may be defined as "The branch of Physics which deals with the charges in motion is called current electricity.

Suppose, two conductors charged to diffierent potentials are supported on an insulating stands, seprated by a certain distance, there is no flow of electric charge from one conductor to another conductor through potential difference that exists between them, due to that charges on the conductors seprated by air which is an insulator. If these conductors are connected by a metallic wire, it will result in flow of charges from conductor at higher potential to another conductor of lower potential. The flow of charges continues till the electric potential becomes equal. So if we maintain the potential difference between two conductors, we get a constant flow of charge in metallic wire. This is known as Electric current.

ELECTRIC CURRENT :

The Electric current is defined as the rate of flow of electric charge through any cross-section of wire or conductor. It is denoted by (I). Thus if charge (q) flows in a wire in time then,

$$I \text{ (electric current)} = \frac{\text{Total charge flowing (q)}}{\text{Time taken (t)}}$$

$$I = q/t \text{---(1)}$$

If n be the number of electron crossing any section of wire in time t. Then the quntization of charge q is writen as

$q = ne$ - - - (2)

$$I = \frac{ne}{t}$$

where I = ectric, current,

e=charge of one electron.

& The Value of $e = 1.6 X 10^{-19} C$.

UNIT OF ELECTRIC CURRENT:

S.I. unit of electric, Unit of current is Ampere (A). The electric current through a wire is called one Ampere (1A), if one coulomb (1C) of charge flow through the wire in one second

$$1 \text{ Ampere (A)} = \frac{1 \text{ Coulomb (C)}}{1 \text{ Second (S)}} \qquad = 1 \text{ CS}^{-1}$$

We say that 1 Ampere current constitute of $6.25X10^{18}$ electrons & direction of current is conventionally taken as the direction opposite to the direction of flow of electron.

EXAMPLE-5.1.

What is the current flowing through a conductor if one million electrons are crossing in one milisecond through a cross-section of it.

Solution :- Here q = ne

Given n= one million = 10^6

charge on electron, e = 1.6×10^{-19}

so q = $10^6\times106\times10^{-19}$ C

q = 1.6×10^{-13} C

t = One mili second

t = 10^{-3} second

Now current I = q / t

$$\therefore \; I = \frac{1.6\times10^{-13}}{10^{-3} = 1.6\times10\text{-}10 \text{ Ampere.}} = 1.6\times10^{-10} \text{ Ampere}$$

EXAMPLE-5.2.

How many electrons pass through a lamp in one munute, if the current is 300 mA ? (Given e=$1.6X10^{-19}$c)

Solution :- Given I= 300 mA = 300×10^{-3}A

T = 1 minute = 60 sec.

e = 1.6×10^{-19} C.

We find the value of n = no. of electrons.

$\therefore$ q = ne --- (1)

Now, I =q/t

$\therefore$ q = I t

q = $300\times10^{-3}\times 18000\times10^{-3}$C

from eq^n. (1), q = ne

n = q/e

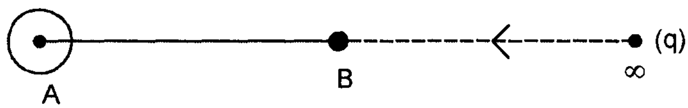
$$n = \frac{18000\times10^{-3}}{1.6\times10^{-19}} = \frac{1.8\times10^{4}\times10^{-3}}{1.6\times10^{-19}} = \frac{1.8\times10^{1}}{1.6\times10^{-19}}$$

$$n = \frac{1.8}{1.6}\times10^{20} =)1.125\times10^{20} \text{ Answer.}$$

ELECTRIC POTENTIAL :-

Electric potential at all points may be defined as the work done in bringing a unit positive charge from infinity to that point.

Electric potential may be denoted by (V).



Let us consider, electric potential at Point B. so we bring the charge q from infinity to point B, hence for bringing the charge q from ∞ to point B, We give effect to work, so electric potential at point B is given by.

$$V = \frac{W}{q} \text{------}(1)$$

UNIT OF ELECTRIC POTENTIAL :-

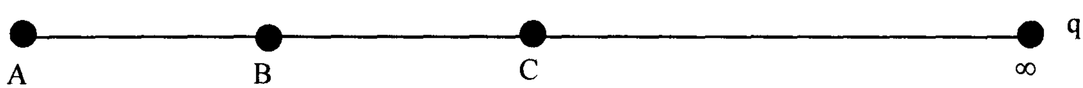
UNIT of electric potential is Volt (V).

$$\text{from eq}^n.\ (1)\ 1(\text{Volt}) = \frac{1\ \text{Joule}}{1\ \text{Coulomb}}$$

Hence the potential differecne is said to be one volt if one Joule of work is done in bringing are coulomb charge from ∞ to that point.

POTENTIAL DIFFERENCE :-

Potential difference between the two points is defined as the work done in bringing a unit positive charge from one point to another point.



Potential difference between points B and C is given by

$$V_B - V_C = \frac{\text{Work done (W)}}{\text{Charge (q)}}$$

OHM'S LAW :-

It is the most fundamental Law of elctricity and was given by George Simon Ohm in 1828.

"It states that if the Physical condition like, temperature, remians unchanged, then the current (I) flowing through a conductor is always directly propoational to the potential diffeence (V) across its two ends."

Mathematically,

$$V \propto I$$

$$V = RI \text{----}(1)$$

Where R is constant of proportionality and here R is known as electrical resistance of conductor.

The value of resistance (R) depends upon the nature of conductor, its dimensions and Physical conditions.

The value of resistance (R) independent of the value of V and I,

ELECTRICAL RESISTANCE :-

"Electrical resistance may be defined as the force which opposes the flow of electric current through it."

According to Ohm's law, V = IR

Here, $R = \frac{V}{I}$ ---- (1)

from this eq^n., "resistance of a conductor is also defined as the ratio of Potential difference (V) across the ends to of the conductor to the current (I) flowing through it."

UNIT OF RESISTANCE :-

S.I. Unit of resistance is Ohm. It is denoted by (Ω) known as Omega.

"Resistance of a conductor is said to be one Ohm, if one Ampere of current flows through it, when a potential difference of one Volt is applied across the conductor."

$$\text{Hence 1 ohm } (\Omega) = \frac{1\text{Volt (V)}}{1\text{ Ampere (A)}} = 1VA^{-1}$$

EXAMPLE-5.3

A Potential difference of 200 Volt is maintained across a conductor of resistance $100\,\Omega$, **calculated the number of electrons flowing through it in one second. Given** $e = 1.6\times10^{-19}C.$

SOLUTION :-

Given V = 200 Vot,

$R = 100\,\Omega,$

$e = 1.6\times10^{-19}C.$

by Ohm's law, V = IR

$$I = V/R = \frac{200}{100} = 2\text{Ampere.}$$

Time t = 1 second

No. of electrone (n) = ?

Electric current I = q/t

$$\therefore q = I t$$

$$q = 2 \times 1 = 2 C$$

Hence, $q = n e$

so, $n = q/e$

$$n = \frac{2}{1.6 \times 10^{-19}} = 1.25 \times 10^{19} \text{ Ans}$$

SPECIFIC RESISTANCE OR RESISTIVITY : -

The resistance of a conductor depends upon the following factors :-

(i) It is directly Proportional to the length of conductor i.e.

$$R \,\alpha\, l \text{ ------ } (1)$$

(ii) It is inversly Proportional to the area of cross - section of the conductor. i.e.

$$R \,\alpha\, \frac{l}{A} \text{ ------ } (2)$$

(iii) The resistance of condutor also depends upon the nature of material and temperature of the conductor.

By combining eqution (1) and (2) we get,

$$R \,\alpha\, \frac{l}{A}$$

$$R = \rho \frac{l}{A} \text{ -----}(3)$$

Where f is constant of proportionality and is known as specific resistance or electrical resistivity of the material of the conductor.

If $l = 1$, $A = 1$, then from eg$^{n.}$ (3)

$$R = \rho \frac{1}{1}$$

$$\text{or } R = \rho$$

Hence Resistivity or specific resistance of the material of a conductor is the resistance offered by a wire of this material of unit length and unit area of cross-section.

(or)

It is also defined as the resistance of unit cube of a material of given conductor.

UNIT OF RESISTIVITY :-

From equation No. - (3) we have,

$$\rho = R.\frac{A}{l}$$

In S.I. Unit of resistivity,

$$\rho = \frac{ohm \times m^2}{m} = Ohm - m \text{ or } \Omega - m$$

CONDUCTANCE :-

The reciprocal of resistance of a conductor is called conductance.

It is denoted by C.

Thus conductance of a conductor having resistance R is given by,

$$C = \frac{1}{R} \text{ -----(1)}$$

S.I. Unit of conductance is ohm^{-1} (Ω^{-1}) which is also called mho. Now days, unit of conducatance, is termed as simen and it is represented by the symbol s .

CONDUCTIVITY :-

The reciprocal of resistivity of the material of a conductor is called conductivity.

It is denoted by. σ, thus,

$$\sigma = \frac{1}{\rho}$$

S.I. Unit of conductivity is $ohm^{-1}m^{-1}$ $(\Omega^{-1}\ m^{-1})$ or mho $metre^{-1}$ or simen $metre^{-1}$ (Sm^{1-}).

EXAMPLE-5.4

A nefligibly small current is passed through a wire of length 15, and uniform cross-section 6.0×10^{-7} m^2 and its resistance is 5Ω. Find out its resistivity ?

SOLUTION :- Given ℓ = 15 M

$A = 6.0 \times^{-7} m^2$

$R = 5\Omega$

By using formula, $R = \rho\frac{\ell}{A}$

so, $\rho = R.\rho\frac{A}{\ell}$

$$\rho = \frac{5 \times 6 \times 10^{-7}}{15}$$

$$= 2 \times 10^{-7} \Omega \, m \quad \text{Answer.}$$

EXAMPLE-5.5

Calculated the resistivity of a wire of resistance 0.01 Ω, Area of cross-section $10^{-4} m^2$, and length of 10 cm.

SOLUTION

Given $R = 0.01 \, \Omega$

$A = 10^{-4} m^2$

$\ell = 10 \text{ cm} = \frac{10}{100} = 0.1 \text{ m}$

By using, $R = \rho \cdot \frac{\ell}{A}$

$\therefore \quad \rho = R . \frac{A}{\ell}$

$\rho = 0.01 \times \frac{10^{-4}}{0.1}$

$\rho = 10^{-5} \Omega \, m$ Answer.

EXAMPLE-5.6

Calculated the resistivity of a wire of 1.0 m long, 0.4 mm in diameter and having resistance of 2.0Ω

SOLUTION :-

Given, $\ell = 1.0 \text{ m}$

Diameter $d = 0.4 \text{ mm} = 0.4 \times 10^{-3} \text{ m}$

radius $r = \frac{d}{2} = \frac{0.4 \times 10^{-3} m}{2} = 0.2 \times 10^{-3} m$

so Area of cross-section is given by $A = \Pi r^2$

$$A = \frac{22}{7} \times (0.2 \times 10^{-3})\ m^2$$

$$\text{so } R = \rho \cdot \frac{\ell}{A}$$

$$\therefore \rho = R.\frac{A}{\ell}$$

$$\rho = 2 \times \frac{22}{7} \times \frac{(0.2 \times 10^{-3})^2\ m^2}{1\ m}$$

$$\rho = \frac{44}{7} \times 0.2 \times 0.2 \times 10^{-6}\ m$$

$$\rho = 2.5 \times 10^{-7}\ \Omega\text{-m} \quad \text{Answer.}$$

EXAMPLE-5.7

A wire of resistance 5 Ω is drawn out so that its length is increased by twice its original length. Calculate its new resistance.

SOLUTION :-

Here, $R_1 = 5\ \Omega$, $\ell_1 = \ell$ say.

$A_1 = A$ say

$R_2 = ?$, $\ell_2 = 2\ell + = 3\ell$, $A_2 = ?$

As volume of wire remains the same, so,

$\therefore A_1 \ell_1 = A_2 \ell_2$ ($\because A \times L = \text{Volume}$)

$$\text{or } A_2 = \frac{A_1 \ell_1}{\ell_2} \quad (\therefore \text{Area} \times \text{length} = \text{Volume})$$

$$A_2 = \frac{A \times \ell}{3\ell} = \frac{A}{3}$$

As specific resistance of wire remains the same.

$$\therefore R_1 = \rho \frac{\ell_1}{A_1} \text{ or } R_2 = \rho \frac{\ell_2}{A_2}$$

$$\text{Hence, } \frac{R_2}{A_1} = \frac{\ell_2}{A_2} \times \frac{A_1}{\ell_1}$$

$$\frac{R_2}{5} = \frac{3\ell}{A/_3} \times \frac{A}{\ell}$$

$$\frac{R_2}{5} = \frac{3\ell \times 3}{A} \times \frac{A}{\ell}$$

$$\frac{R_2}{5} = 9$$

$R_2 = 9 \times 5 = 4.5\ \Omega$ Answer.

EXAMPLE-5.8

A wire of resistance 5 Ω is drawn out so that its length is increased to twice its original length. Calculate its new resistance and its resistivity.

S OLUTION :-

Here, $R_1 = 5\ \Omega$, $\ell_1 = \ell$ say, $A_1 = A$ say

$R_2 = ?$, $\ell_2 = 2\ell$ $A_2 = ?$

A volume of wire remains the same,

$\therefore A_1 \ell_1 = A_2 \ell_2$

$$A_2 = \frac{A_1 \ell_1}{\ell_2} = \frac{A \times \ell}{2\ell} = \frac{A}{2}$$

As specific resistance of wire remains same.

$$\therefore R_1 = \rho \frac{\ell_1}{A_1}, R_2 = \rho \frac{\ell_2}{A_2}$$

$$\therefore = \frac{R_2}{R_1} = \frac{\ell_2}{A_2} \times \frac{A_1}{\ell_1}$$

$$= \frac{2\ell}{A/2} \times \frac{A}{\ell}$$

$$= \frac{2\ell \times 2}{A} \times \frac{A}{\ell}$$

$$\frac{R_2}{5} = 4$$

$R_2 = 20\ \Omega$

Resistivity of the wire remains unchanged as it does not change with change in dimensions of the meterial without change in its temperature.

GROUPING OF RESISTANCE :-

There are mainly two method of connecting resistance. These are :-

(i) Series combination.

(ii) Parallel combination.

(1) SERIES COMBINATION :-

"When two or more resistances are connected in such a way that the same current passes through each resistance, when some potential difference is applied across the combination."

Figure 5.1 shows the combination of three resistance R_1, R_2 and R_3 in series. If a battery of Volt V is connected across the two ends point A and B. Then current I will be same in all resistance R_1, R_2 and R_3 . If V_1, V_2 and V_3 are the value of Potential difference across R_1, R_2 and R_3 respectively, then.

$$V = V_1 + V_2 + V_3 \text{ -----(i)}$$

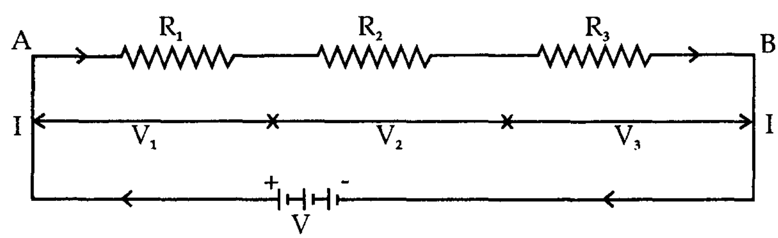


Fig. 5.1

Current I will be some in all resistance.

According to Ohm's Law,

$$V = I\,R \text{ --------(2)}$$

Then $V_1 = I\,R_1$

$$V_2 = I\,R_2$$

$$V_3 = I\,R_3$$

Putting the value of V_1, V_2, and V3 in en$^{n.}$ (1) Weget.

$$V = IR_1 + IR_2 + IR_3$$

$$V = I(R_1 + R_2 + R_3)$$

By using equation (2), $I\,R = I(R_1 + R_2 + R_3)$

$$R_s = (R_1 + R_2 + R_3) \text{ ------(3)}$$

Thus, the equivalent resistance of a series combination is equal to the sum of individual resistance.

In series combination, it should be remembered that,

(i) The current is same for every resistor.

(ii) The current in the circuit is independent to the relative position of the various resitors in the series.

(iii) The voltage across any resistor is directly proportional to resistance of that resistor.

(iv) The total resistance in a circuit is equal to the sum of the individual resistance, including the internal resistance of a cell, if any,

(v) The total resistance in series circuit is more than the greatest one in the circuit.

PARALLEL COMBINATION :-

"Two or more resistors are said to be connected in parallel combination if potential difference across each of them is the same and is equal to the applied potential difference."

If three resistance R_1, R_2 and R_3 are connected as shown in figure 5.2. They are said to be connected in Parallel conmbination.

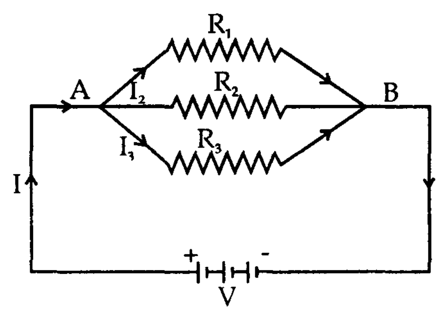


Fig. 5.2

Let V be the Potential difference applied across A and B. with the help of a Battery. Let I be the main current in the circuit and I_1 , I_2, and I_3 be the currents passes through the resistance R_1, R_2 and R_3 respectively.

Then, $I = I_1 + I_2 + + I_3$ -------(1)

Because three Resistance R_1, R_2 and R_3 are connected in Parallel combination across its two ends A and B so, Potential difference V be the same in all three resistors,

According to Ohm's Law, $V = I\,R$ -----------(2)

$\therefore I = V/_R$ -------(3)

$$I_1 = \frac{V}{R_1}$$

$$I_2 = \frac{V}{R_2}$$

$$I_3 = \frac{V}{R_3}$$

Putting the value of I_1 , I_2, and I_3 in eg^n (1)

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R} = V \frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3}$$

$$\therefore \frac{I}{R_P} = \frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3} \text{ ---------(4)}$$

"Thus the receprocal of equivalent resistance of number of resistance connected in Parallel is equal to the sum of the receprocals of the individual resistance."

When two resistors R_1 and R_2 are connected in Parallel combination then,

$$\frac{I}{R_P} = \frac{I}{R_1} + \frac{R}{R_2}$$

$$\frac{I}{R_P} = \frac{R_2 + R_1}{R_1 R_2}$$

or $$R_P = \frac{R_1 + R_2}{R_1 R_2}$$

In a Parallel resistance circuit, it should be noted that :

(i) Total current through the combination is the sum of individual currents through the various branches.

(ii) The Potential difference across each resistor is the same and it is equal to the applied Potential difference.

(iii) The total resistance in Parallel combination is less than the least resistance used in the circuit.

(iv) The current through each resistor is inversly proportional to the resistance of that resistor.

(v) The reciprocal of total resistance of the Parallel combination is the sum of the reciprocal of individual resistance.

EXAMPLE-5.9

Three resistors $2\,\Omega$, $4\,\Omega$ and $5\,\Omega$ are combined in Parallel. What is the total resistance of the combination ?

S OLUTION :-

Here, $R_1 = 2\,\Omega$

$R_2 = 4\,\Omega$

$R_3 = 5\,\Omega$

Then in Parallel combination R_P is given by,

$$\frac{I}{R_P} = \frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3}$$

$$\frac{I}{R_P} = \frac{I}{2} + \frac{I}{4} + \frac{I}{5}$$

$$\frac{I}{R_P} = \frac{19}{20}$$

$$R_P = \frac{19}{20}\,\Omega.$$ Answer.

EXAMPLE-5.10

The resistance of two conductor in series is 40Ω and their resistance becomes 6.4Ω when connected in Parallel. Find the individual resistance.

ANSWER :-

Let R_1, R_2 be the two resistance of conductor. Then

Given $R_S = R_1 + R_2 = 40\,\Omega$ ----------(1)

$$\frac{I}{R_P} = \frac{I}{R_1} + \frac{I}{R_2} = 6.4\,\Omega$$

$$\text{or } \frac{I}{R_P} = \frac{R_1 R_2}{R_1 + R_2} = 6.4$$

or $R_1 R_2 = 6.4 (R_1 + R_2)$

$R_1 R_2 = 6.4 \times 40$ (By using equation (i))

$R_1 R_2 = 256$ ------(ii)

from eg^n (1), $R_1 = 40 - R_2$ --------(iii)

Putting Value of R_1 in equation No. - (ii). We get,

$(40-R_2) R_2 = 256$

$$40R_2 - R_2^{\,2} = 256$$

or $$R_1^{\,2} - 40R_2 + 256 = 0$$

$$R_2^{\,2} - 32R_2 - 8R_2 + 256 = 0$$

$$R_2(R_2 - 32) - 8(R_2\ 32) = 0$$

or $$(R_2 - 8)(R_2\ 32) = 0$$

$$R_2 - 8 = 0 \Rightarrow R_2 = 8\ \Omega$$

$$R_2 - 32 = 0 \Rightarrow R_2 = 32\ \Omega$$

Putting value of R_2 in eg^n (3)

$$R_1 = 40 - R_2$$

when $R_2 = 8\ \Omega,\ R_1 = 40 - 8 = \Rightarrow 32\ \Omega$

when $R_2 = 32\ \Omega.\ R_1 = 40 - 32 = \Rightarrow 8\ \Omega$

EXAMPLE-5.11

Find the value of the current the circuit shown in figure.

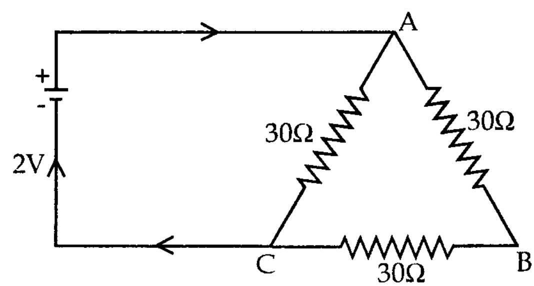


Fig. 5.3

ANSWER :- In this circuit the resistance of arm ABC $(30 + 30 = 60\ \Omega)$ is in parallel to the resistance of arm AC= $30\ \Omega$

Their effective resistance will be $R_P = \dfrac{R_1 R_2}{R_1 + R_2}$

Here $R_1 = 30\Omega,\ R_2 = 60\Omega$

$$\therefore\ R_P = \frac{30 \times 60}{30 + 60}$$

$$R_P = \frac{1800}{90}$$

$$R_P = 20\Omega$$

$\therefore$ Current $I = \frac{V}{R_P}$ ($\because V = 2V$)

$\therefore I = \frac{2}{20} \Rightarrow 0.1\ A$

EXAMPLE-5.12

Given the three resistance of 1Ω, 2Ω 3Ω, how will you combine them to get an equivalent resistance of (i) $\frac{11}{3}\Omega$, (ii) $11/_5\Omega$, (iii) 6Ω, (iv) $6/_{11}\Omega$

SOLUTION :-

It is to be noted that a

(a) The effective resistance of Parallel combination of resistor is less than the individual resistance and,

(b) The effective resistance of series combination of resistors is more than individual resistance.

case- (i) Parallel combination of 1Ω and 2Ω is connected in series with 3Ω

$$R_P = \frac{R_1 \times R_2}{R_1 + R_2}$$

$$R_P = \frac{2 \times 3}{2+3} \Rightarrow \frac{6}{5}\Omega$$

$\therefore$ Equivalent resistance *of* $\frac{6}{5}$ Ω and 1Ω in series

$$= \frac{6}{5} + 1 \Rightarrow \frac{11}{5}\ \Omega \text{ (Proof)}$$

case - (iii) All the resistance are to be connected in series, Now,

$$R_s = 1+2+3 \Rightarrow 6\ \Omega \text{ (Proof)}$$

case - (iv) All the resistance are to be connected in Parallel,

$$\frac{1}{R_P} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} \Rightarrow \frac{6+3+2}{6} = \frac{11}{6}$$

$$\therefore R_P = \frac{6}{11}\ \Omega \text{ (Proof)}$$

EXAMPLE-5.13

(a) Three resistors 2Ω, 4Ω and 5Ω are combined in Parallel. What is total resistance of Combination ?

(b) If the combination is connected to a battery of emf 20V and negligible internal resistance, determine the current through each resistor and the total current drawn from the battery.

SOLUTION :-

(a) Here, $R_1 = 2\Omega$, $R_2 = 4\Omega$, $R_3 = 5\Omega$

$V = 20V$

In Parallel combination, total resistance R_P is given by,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$= \frac{1}{2} + \frac{1}{4} + \frac{1}{5}$$

$$= \frac{10+5+4}{20}$$

$$\Rightarrow \frac{19}{20}$$

or $R_P = \frac{20}{19}\Omega$

(b) current through $R_1 = \frac{V}{R_1} \Rightarrow \frac{20}{2}$ 10A

current through $R_2 = \frac{V}{R_2} \Rightarrow \frac{20}{4}$ 5A

current through $R_2 = \frac{V}{R_2} \Rightarrow \frac{20}{4}$ 5A

$R_3 = \frac{V}{R_3} \Rightarrow \frac{20}{20} \times 19 \Rightarrow 19A$

EXAMPLE-5.14

A resistor of 5Ω resistance is connected in series with a Parallel combination of a number of resistors each of 6Ω. If the total resistance of the combination is 7Ω, How many resistors are in Parallel ?

SOLUTION :-

Let n resistors each of 6Ω be connected in Parallel and then the combination be connected is series with the resistor of 6Ω. The resistacne of the Parallel combination of n resistors each of 6Ω is given by

$$\frac{1}{R_P} = \frac{1}{6} + \frac{1}{6} + \frac{1}{6} + \text{--------n times}$$

$$\frac{1}{R_P} = \frac{n}{6}$$

$$R_P = \frac{6}{n}\Omega$$

As the Parallel combination is connected in series with the resistor of 5Ω, the total resistance of the combination is given by

$$R = R_P + 5$$

$$R = \frac{6}{n} + 5$$

Since resistance of the combination is 7Ω

$$\therefore \frac{6}{n} + 5 = 7$$

$$\text{or } \frac{6}{n} - 2 = 0$$

$\therefore 6 - 2n = 0$

$2n = 6$

$n = 3$ Answer.

EFFECT OF TEMPERATURE ON RESISTANCE :-

(i) METALS OR CONDUCTOR :-

For a given conductor the Resistance is given by

$R = \frac{1}{\tau}$ ---------(1) (where τ = relaxation Time)

When the tempreture of a metal conductor is raised. The atoms of metal vibrate with greatest amplitude and greatest frequency about their mean positions. Due to increase in thermal energy. The frequency of collision of free electron with atoms drifting towards +ve end of the conductor increase. This reduced the relaxation time and from eq^n.(1) We can say that when τ is decreased, then resistance will be incresed.

In metal the resistivity increase linearly with temreature upto about 1500° C above the room temperature.

The resistance R_t of a conductor at temperature t°C is given by,

$$R_t = R_0(1+\alpha t)$$

$$\text{or } R_t = R_0 + R_0\alpha t$$

$$\text{or } \alpha = \frac{R_t - R_0}{R_0 \times t} \quad ----=(2)$$

Where α is constant, it is known as tempreature coefficient of resistance from eq^n (2) we say.

$$\alpha = \frac{\text{Increase in resistance}}{\text{Original resistance} \times \text{rise of temperature.}}$$

"Thus temperature coeffiecient of resistance is defined as the increase in resistance per unit of original resistance per degree rise of tmeperature."

For Metals like Ag, Cu, etc. The value of α is positive because the resistance of metals increase with increase in temperature.

(ii) SEMICONDUCTOR :-

The resistance of semiconductors such as carbon, silicon and germanium, the resistance gradually decrease with increase in temperature as the value of α is -ve.

(iii) INSULATORS :-

The resistance of insulators such as rubber, mica etc decreases with increase in temperature and same is the case with the resistance of ELECTROLYTES. As they have negative temperature coefficient.

(iv) ALLOYS :-

In case of alloys, the rate at which, the resistance change with temperature is much less, as compared to metal e.g. maganin (an alloy of Cu, Ni, Fe, Maganese) has a very small temperature coefficient of resistance. Its value is near about $0.00001°C^{-1}$. For this reason, it is an excellent substance to be used for construction of a standered resistance coil.

ELECTROMOTIVE FORCE (E.M.F.) :-

"The Potential difference between the two poles of the cell in a open circuit (when no current is drawn from the cell) is called the electromotive force of the cell."

It is denoted by E.

In S.I., The unit od e.m.f. is volt (v) or joule per coulomb (JC^{-1})

"The e.m.f. of cell is called one Volt if I joule of work is performed by the cell to drive one coulomb of charge round the circuit."

TERMINAL POTENTIAL DIFFERENCE :-

"The Potential difference between the two poles of a cell in a closed circuit (when current is drawn from the cell) is called terminal potential difference of the cell."

It is denoted by V.

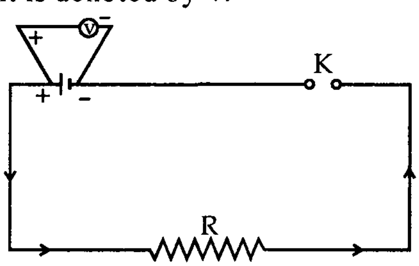


Fig. 5.4(a)

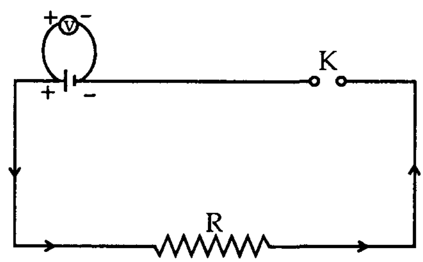


Fig. 5.4(b)

Figure 5.4 (a) shown for an e.m.f. of cell when key k is open.

Figure 5.4 (a) shown for an terminal difference when key k is closed an current is flow in circuit. When current flows through the circuit, there is a fall of potential across the internal resistance of the cell. The potential difference between the two poles of the cells is less than the e.m.f. of the cell by an amount equal to potential drop across the intenal resistance. Therefore, the terminal potential difference of a cell is always less than its e.m.f.

E.M.F.	POTENTIAL DIFFERENCE
1. The e.m.f. of a cell is maximum P.D. between the two electrodes of a cell in an open circuit.	1. The Potential difference b/w the two Points is the difference of P.D. between those two points in a closed circuit.
2. The term e.m.f. is used for the source of electric current.	2. The Potential difference is measured b/w any two points of electric charge.
3. It is a cause.	3. It is an effect.

4. It is measured in volt.	4. It is also measured in Volt.
5. It is independent of the resistance of circuit.	5. It is depend upon the resistance b/w two points of the circuit.
6. It is depend upon the nature of electrode and electrolyte of the cells.	6. It is depend upon the current flows through the circuit and also nature of electrode of cells.

KIRCHHOFF'S LAW :-

Ohm's Law is useful for analysing simple circuits in order to study complicated circuits containing more than one source of e.m.f., Ohm's Law fails to deliver. In 1842 Gustov Kirchhoff a Russian scientist put forward the following two laws to solve the problems related to complicated circuits. These laws are simply the expressions of conservation of electric charge and of energy. The Laws were stated as follows :-

I. KIRCHHOFF'S FIRST LAW (OR) KIRCHHOFF'S JUNCTION LAW (OR) KIRCHHOFF'S CURRENT LAW :-

"It states that the algebric sum of the currents meeting at a junction point in an electrical circuit is always Zero."

This law is based upon the fact that in an electrical circuit, a point can neither act as a source of charge nor the charge can accomulate at a point. It is also called Junction Rule.

Consider a point O in an electrical circuit at which currents $I_1, I_2, I_3 I_4$ and I_5 are following through the five conductors in the directions as shown in Figure (5.5).

Let us adopt the following sign convention :

The current following through a conductor towards the point O is positive and the current away from the point O is taken negative.

Therefore current I_1, I_4 flowing towards O are positive, while the current I_2, I_3, I_5 away from the centre O are taken negative.

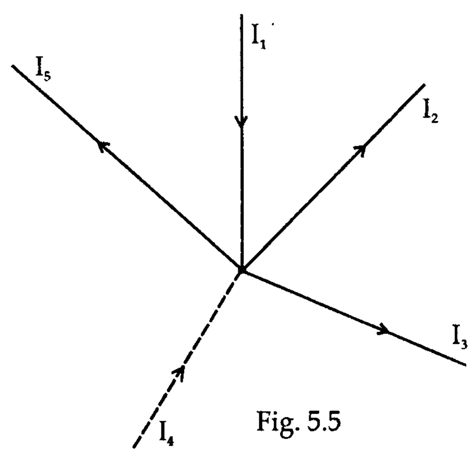


Fig. 5.5

SO ACCORDING TO KARCHHOFF'S LAW :

$\Sigma I = 0$

$\therefore$ from the figure (5.5) we have,

$I_1 + (-I_2) + (-I_3) + I_4 + (-I_5) = 0$

or $I_1 - I_2 - I_3 + I_4 - I_5 = 0$

or $I_1 + I_4 = I_2 + I_3 + I_5$

i.e sum of Incoming currents = sum of outgoing currents "Hence Kirchhoff's Ist Law can also be defined as the sum of incoming currents is equal to the sum of outgoing currents at any Juction Point in an electrical circuit."

2. KIRCHHOFF'S SECOND LAW (OR) KIRCHHOFF'S LOOP LAW (OR) KIRCHHOFF'S VOLTAGE LAW :-

"It states that in any closed part of an electrical circuit, the algebric sum of the e.m.f. is equal to the algebric sum of the products of the resistance and the curents flowing through them." It is also called loop rule.

Consider a closed electrical circuit ABCD containing two cells of e.m.f. E_1 and E_2 and five resistances R_1, R_2, R_3, R_4 and R_5 as shown in figure (5.6)

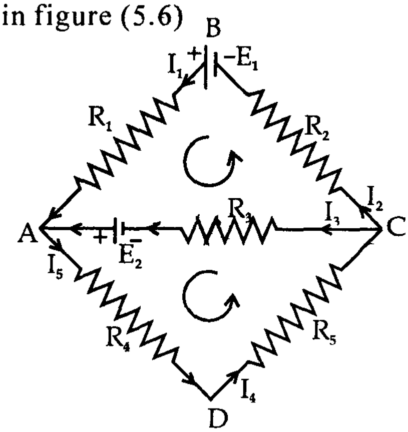


Fig. 5.6

Let us adopt the following sign conventions :-

(i) The current F flowing in anti-clock wise direction is positive otherwise take negative.

(ii) The e.m.f. of a cell is taken positive if the -ve pole of cells comes first or otherwise take negative.

Let us consider the closed part ABCD of the electrical circuit :-

The direction of e.m.f. of cell E_1 is anticlockwise and that of the cell of e.m.f. E_2 is closed. Therefore

The total e.m.f. of the closed part ABCD = $E_1 + (-E_2)$

$$= E_1 - E_2$$

Also in closed part ABCD, currents I_1 and I_2 flows in anticlockwise direction while the current I_3 flows in clockwise direction. Therefore in a closed part ABCD the algebric sum of the products of resistance and currents in them

$$= I_1 R_1 + I_2 R_2 + (-I_3 R_3)$$

$$= I_1 R_1 + I_2 R_2 - I_3 R_3$$

According to Kirchhoff's second Law, for closed part ABCD,

$$E_1 - E_2 = I_2 R_2 - I_3 R_3$$

Similarly it can be found that for closed part ADCA,

$$E_2 = -I_3 R_3 + I_4 R_4 + I_5 R_5$$

WHEATSTONE BRIDGE :-

"Wheatstone Bridge principle states that if four resistance P,Q,R and S are arranged to form a bridge as shown in figure (5.7) with a cell E and one way key K_1 between the point A and C and a galvanometer G and tapping key K_2 between the point B and D, on closing K_1 first and K_2 later on , if Galvanometer shows no deflection the Bridge is balanced." In that case

$$\frac{P}{Q}=\frac{R}{S} \quad \text{-------(1)}$$ C

Proof :-

Let I be the total current given out by the cell. On reaching the point A, It is divided into two parts:

It is flowing through P and $(I-I_1)$ through R. At point B current I_1 is divided into two parts, I_g through Glavanometer G and (I_1-I_g) through Q, The current I_g through the BD and $(I-I_1)$ through AD, combine to send a current $(I-I_1+I_g)$ through S.

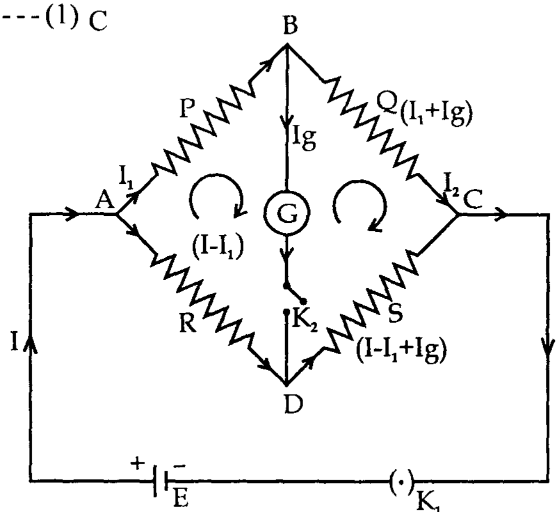


Fig. 5.7

On. reaching the point c the current (I_1-I_g) through BC and $(I-I_1+I_g)$ through DC combine to give total current I, thus compliting the circuit. The value of current at a junction can be verified by applying Kirchhoff's Ist Law at that junction.

Applying Kirchhoff-IInd Law to the closed loop ABCD, weget.

$$I_1P+I_gG-(I\ -I_1)R=0 \quad \text{------(1)}$$

from closed loop BDCB weget,

$$(I_1-I_g)-(I\ -I_1+I_g)S-I_gG=0 \quad \text{------(2)}$$

In eq^n (1) G is resistance of Galvanometer. If the value of R is adjusted in such a way that galvanometer shows no deflection, means when potential at point B and D are same, so that there is no current flowing through galvanometer. i.e. $I_g=0$. Now the bridge is called Balance. Putting $I_g=0$ in eq^n. (1) and (2) weget.

$$I_1P+0-(I_1-I_1)R=0 \quad \text{-----(3)}$$

$$(I_1-0)Q-(I-I_1+0)S-O\times G=0 \quad \text{-----(4)}$$

or $I_1P - (I - I_1) R$

or $I_1P = (I - I_1) R$ -----(5)

from eg^n (4),

$I_1S - (I - I_1) S = 0$

or $I_1Q = (I - I_1) S$ ------(6)

Divided equation (5) by (6) weget.

$$\frac{I_1P}{I_1Q} = \frac{(I - I_1) R}{(I - I_1) S}$$

or $\frac{P}{Q} = \frac{R}{S}$ Proof.

When P, Q and R are known resistance and S is unknown resistance and hence wheatstone bridge are used to find out the unknown resistance under Balanced condition.

EXAMPLE-5.15

In the circuit shown below find the voltage and current in each resistance.

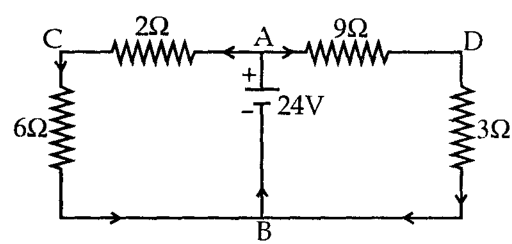


Fig. 5.8

SOLUTION :-

In figure 5.8, three are two parallel path between A and B one path is ACB and has a total resistance of 2+6 = 8Ω. The other path is ADB and has a total resistance of 9+3 = 12Ω. Both are connected in parallel and have a potential difference of 24 v across them.

Current through ACB = $\frac{24}{8} = 3A$

Voltage drop across 2Ω resistor = $3\times6 = 6V$

Voltage drop across 6Ω resistor = $3\times6 = 18V$

Voltage drop across 3Ω resistor = $3\times2 = 6V$

EXAMPLE 5.16

Two batteries of e.m.f. 6V and 12V and internal resistance 1Ω and 2Ω respectively are connected in Parallel with a resistance of 15Ω. Find the current through each branch of the circuit and potential difference across the resistance.

SOLUTION :-

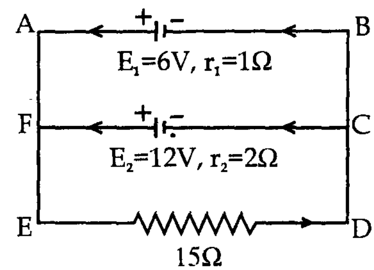


Fig. 5.9

Let the circuit due to the cells of e.m.f. E_1 and E_2, be I_1 and I_2 as shown in figure (5.9). Then according to the Ist Kirchhoff's Law.

The current through R = 15Ω will be $I_1 + I_2$

Applying Kirchhoff's IInd Law to closed part ABDEA, we have

$$E_1 = I_1 r_1 + (I_1 + I_2) R$$

$$\text{or } 6 = I_1 \times 1 + (I_1 + I_2)\ 15$$

$$\text{or } 16\ I_1 + 15\ I_2 = 6 \text{ ------(1)}$$

Applying Kirchhoff's 2nd Law to closed $I_1 = -1.66$ A

$$I_2 = 2.17 \text{ A}$$

Since I_1 is negative, the current of I_1 will be opposide to that shown in figure.

Now $I_1 + I_2 = -1.66 + 2.17 \Rightarrow 0.51$ A

$\therefore$ Potential difference across $R = (I_1 + I_2) R \Rightarrow 0.51 \times 15 \Rightarrow 7.65$ V.

EXAMPLE-5.17

Determine the current in branch of the following network.

SOLUTION :-

Suppose I be main current following from cell, at point A current I be divided in to two Parts I_1 through resistance $10\,\Omega$ and I − I_2 flows through resistance $5\,\Omega$. At point B I_1 divided in I_2 flows through $5\,\Omega$. $(I_1 - I_2)$ flows through BC, $I - I_1 + I_g$ flows through DC in $10\,\Omega$.

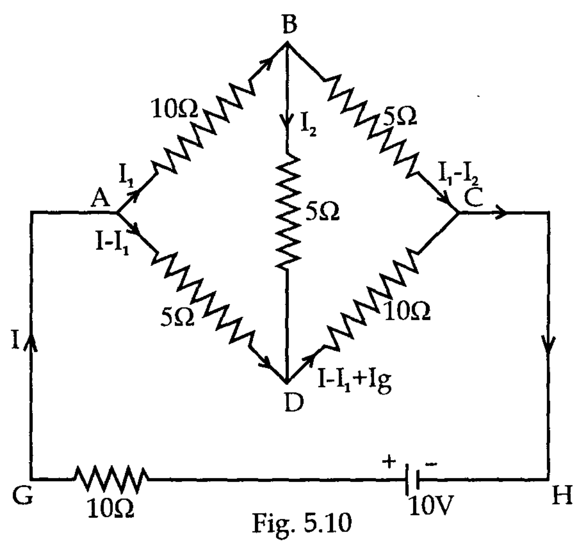


Fig. 5.10

Let us taking current flowing in clockwise direction as the +ve direction of current.

Applying Kirchhoff's IInd Law to closed part ABDA :-

$$10\,I_1 + 5\,I_2 - 5\,(I - I_2) = 0$$

$$3\,I_1 - \,I_2 - 1 = 0 \text{ -------(1)}$$

In closed loop BCDB,

$$5\,(I_1 - I_2) - 10\,(I - I_1 + I_2) - 5\,I_2 = 0$$

$$\text{or } 3\,I_1 - I_2 + 2\,I = 2 \text{ -----(3)}$$

In closed loop ABCHGA

$$10\,I + 10\,I_1 + 5(I_1 + I_2) - 5\,I_2 = 0$$

$$3\,I_1 - I_1 + 2\,I \;= 2 \text{ ------(3)}$$

Adclig eq^n (2) and (3) we get.

$$6\,I_1 - 5\,I_2 = 2 \text{ ------(4)}$$

Multiplying by 2 in both sides, of eg^n (1) we get.

$$6\,I_1 - 2\,I_2 = 2\,I = 0 \text{------(5)}$$

Adding eq^n (3) and (5) we get.

$$9\,I_1 - I_2 = 2$$

$$\text{or } I_1 = 2.9\,I_1 \text{ -------(6)}$$

Putting value of I_2 in eg^n (4) we get.

$$6\,I_1 - 5\,(2 - 9\,I_1) = 2$$

$$6\,I_1 - 10 + 45\,I_1 = 2$$

$$51\,I_1 - 12 = 0$$

$$17\,I_1 - 4 = 0$$

$$\therefore\; I_1 = \frac{4}{17}\text{A (Through Branch AB)}$$

Putting I_1 in eq^n (6) we get,

$$I_2 = 2 - \frac{4}{17} \times 9$$

$$= \frac{34 - 36}{17} \Rightarrow \frac{-2}{17}\text{ A (Through branch BD)}$$

The negative sign shows that current actually flows from D to B.

form eq^n. (1) we have,

$$I = 3 \quad I_1 + I_2 \Rightarrow 3 \times \frac{4}{17} + (\frac{-2}{17}) \Rightarrow \frac{10}{17} \text{ A (Through main circuit)}$$

Current in branch BC, $I_1 - I_2 = \frac{4}{17} - (\frac{-2}{17}) \Rightarrow \frac{16}{17}$ A

Current in branch AD, $I \ - I_1 = \frac{10}{17} - \frac{4}{17} \Rightarrow \frac{6}{17}$ A

Current in branch DC, $I \ - I_1 = \frac{10}{17} - \frac{4}{17} + (\frac{-2}{17}) \Rightarrow \frac{4}{17}$ A Answer.

EXAMPLE-5.18

A Wheatstone consist of the following $P = 10\ \Omega$, $Q = 3\ \Omega$, $R = 12\ \Omega$, $S = 6\ \Omega$ A 2 Volt of cell is connected between B and D and a galvanometer of resistance 20Ω between A and C. Find out current I_g through galvenometer.

SOLUTION :-

The current flowing through various brances is showns in figure (5.11) Applying Kirchhoff's 2nd Law in closed loop ABDA, we have

$$10\, I_1 + I_g\, G - (I - I_1)\ 12 = 0$$

$$10\, I_1 + I_g\, G - 12\, I_1 = 0$$

$$-12\, I \ + 22\, I_1 + \ I_g\, G = 0 \quad (\therefore\ G = 20\ \Omega)$$

$$-12\, I \ + 22\, I_1 + \ I_g\, G = 0$$

Applying Kifchhoff's 2nd Law in closed loop BCDB we get.

$$(I_1 - I_g) \times 3 \ - (I - I_1 + I_g) \times 6 - I_g \times 20 = 0$$

$$3\, I_1 - 3\, I_g - 6\, I + 6\, I_1 - 6\, I_g - 20\, I_g = 0$$

$$-6\, I + 9\, I_1 - 29\, I_g = 0$$

$$\text{or } 6\, I - 9\, I_1 + 29\, I_g = 0 \text{ -------(2)}$$

Also applying Kirchhoff'sf Law in closed loop ABCA, we get.

$$10\, I_1 + 3\, (I_1 - I_g) - 2 = 0$$

$$13\, I_1 - 3\, I_g = +2 \text{ -----(3)}$$

Multiplying eq^n (ii) by 2, $12\,I - 18\,I_1 + 58\,I_g = 0$ -----(4)

Sibtracted eq^n (1) and (4) we get,

$$-4\,I_1 - 78\,I_g = 0$$

$$4\,I_1 = -78\,I_g$$

$$I_1 = -\frac{78}{4}\,I_g \Rightarrow \frac{39}{2}\,I_g.$$

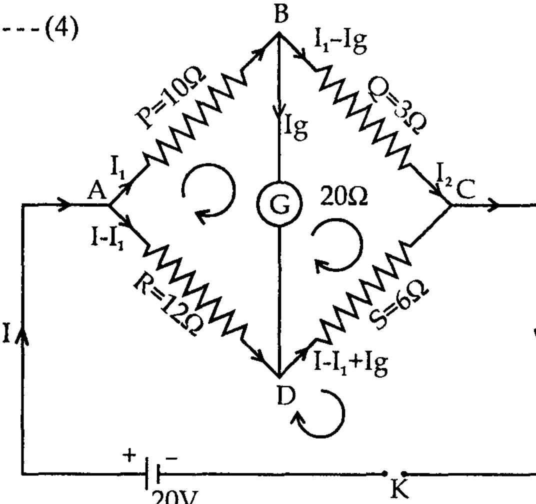


Fig. 5.11

Putting value of I_1 in eq^n (iii) we get,

$$13 \times (-39/_2)\,I_g - 3\,I_g = 2$$

$$-\frac{513}{2}\,I_g = 2$$

$$I_g = -\frac{4}{513}$$

$I_g = -0.0078$ A $\Rightarrow$ 7.8 mA   Answer.

Thus current through galvenometer is 7.8 mA from D to B.

HEATING EFFECT OF CURRENT :-

Whenever the electric current is passed through a conductor, it becomes hot after some time. This indicates that electrical energy is being converted into heat energy. This effect is known as Heating effect of current or Joule heating Effect.

This effect froms the basis of various electric appiliances such as electric bulb, electric furnance, heat. convetor. geyser etc.

Joule in 1941 studied experimentally the heating effect of current and came to the conclusion that amount of heat produced (H) when a current I flows through a conductor of resistance R for time t is given by

$$H \,\alpha\, I^2 R t \text{ -------(1)}$$

This equation (1) IS known as Joule's Law of heating effect.

CAUSE OF HEATING EFFECT OF CURRENT :-

When Potential difference is applied across the two ends of a conductor, an electric field is set up across its ends. Under the effect of electirc field, the electron gets accelerated and move in a direction opposite to the direction of the electric field. As they move, they collide against the ions and atoms in the conductor and in this process the electron transfer their K.E. to the atoms. As a result the average K.E. of the atoms increases and consquently the temperature of the condutor rises. It is termed as the heating effect of currents.

PROOF OF JOULE'S LAW OF HEATING :-

Considered a conductor AB of resistance R across the ends of AB. Let V = Pot. diff. applied across the ends (AB)

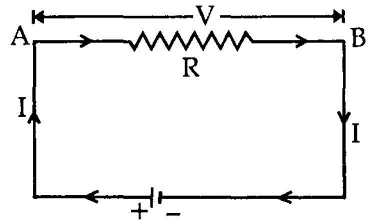


Fig. 5.12

I = Current flowing through AB

t = time for which current is flowing.

∴ Total charge flowinng from A to B in time τ is given by

$q = It$ -----(1) ($\therefore$ $I = q/t$)

By defination of Potential difference, work done in caring unit charge from A to B = V.

The total work done in carrying a charge q from A to B is given by.

$W = v \times q$

$W = vIt$ (By using eq^n 1)

$W = IR \times It$ ($\therefore$ $v = IR$)

$W = I^2Rt$ Joule --------(2)

This work done is called electric work done, if this workdone appears as heat, then amount of heat Produced (H) is given by.

$H = W\ I^2Rt$ Joule ------(3)

$$H = \frac{I^2Rt}{4.18} \text{ Joule } (\therefore 1 \text{ colorie } = 4.18J)$$

Equation (3) is Joule's Law of heating. It states that amount of heat Produced in a conductor, cwhen current flows through, it is directly proporational to

(i) square of current flowing through the conductor i.e. $H \alpha I^2$

(ii) resistance R of the conductor i.e. $H \alpha R$

(iii) time for which the current is passed for a conductor i.e $H \alpha t$

ELECTRIC POWER :-

The rate of dissipation of electrical energy across the resistance is called electric power.

(OR)

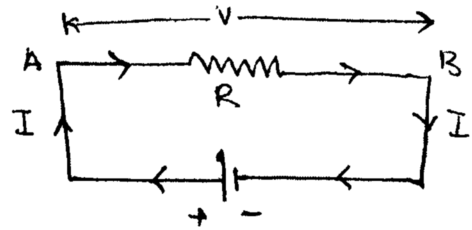
The rate at which electric work (w) is consumed in a electircal circuit is known as electric power.

It is denoted by P, and given by

$$P = \frac{W}{t} \text{ -------(1)}$$

$$P = \frac{V I t}{t} \quad (\because W = V I t)$$

$$P = V I \text{ --------(2)}$$



(FIG. 5.12)

From eq^n (2) we can also say that electric power is the product of voltage and current.

S. I. unit of electric power is Watt.

So 1 Watt = 1 Volt × 1 Ampere.

1 W = 1 V × 1 A

"The electric power of a circuit is said to be one Watt if one ampere of current flows through it, when a constant potential difference of one Volt is applied across it."

Biggest unit of Power are kilowatt (KW) and megawatt (MW)

Where 1 Kw = 10^3 W

1 Mw = 10^6 W

1 Kill watt - hour = 1 kill watt - 1 hour

= 1000 watt×3600 sec.

$= 36 \times 10^5$ W - sec.

1 Kw = hr $= 36 \times 10^5$ Joule ($\because$ 1 w - sec = 1 Joule)

The commercial unit of Power is horse Power (H.P)

Where 1 H.P. = 746 watt.

NUMERICAL PROBLEMS ON HEATING EFFECT OF CURRENT

Example (5.19) :

A 500 watt having unit is designed to operated from a 200 V line. By what percentage will its heat output drop if the line voltage drops to 160 Volt.

SOLUTION :-

Here, P = 500 W

V = 200 V

$$\text{Electric Power } P = V\,I \Rightarrow V \times \frac{V}{R} \Rightarrow \frac{V^2}{R} \;(\because\; V = I\,R)$$

$$\therefore P = \frac{V^2}{R}$$

$$\therefore R = \frac{V^2}{P} \Rightarrow \frac{(200)^2}{500} = 80\ \Omega$$

When voltage drops to 160 W, then heat produced Per second = $\frac{V^2}{R}$

$$= \frac{(160)^2}{80} \Rightarrow 320\ \text{W}$$

$\therefore$ Drop in heat Production - 500-320 $\Rightarrow$ 180 W

$\therefore$ % Drop in heat Production = $\frac{180}{500} \times 100 \Rightarrow 36\%$

EXAMPLE 5.20

A 100 W bulb and a 500 W bulb are joined in Parallel to the mains. Which bulb will draw move current.

SOLUTION :-

Here, $P_1 = 100$ W , $P_2 = 500$ W

Let V is voltage of the mains I_1 and I_2 are the current through the two bulbs. In Parallel combination of bulbs to the mains, V is some for the bulbs.

$\therefore P_1 = I_1 V_1$ and $P_2 = I_2 V_2$

(But $V_1 = V_2 = V$ say)

Divided both equation weget.

$$\frac{P_2}{P_1} = \frac{I_2 V}{I_1 V}$$

$$\therefore \frac{P_2}{P_1} = \frac{I_2}{I_1} \Rightarrow \frac{I_2}{I_1} = \frac{P_2}{P_1} \Rightarrow \frac{500}{100} \Rightarrow 5 \text{ i.e.}$$

$$I_2 = 5\,I_1 \text{ or } I_2 > I_1$$

It means 500 W bulb draws more current,

EXAMPLE 5.21

An electric bulb is marked 100 W, 230 V. If the supply voltage drops to 115 V, What is the heat and light energy produced by te bulb in 20 minutes ?

SOLUTION :-

Here, $P = 100\ W,\ V = 230\ V$

$t = 20 \times 60\ sec \Rightarrow 1200\ sec.$

$$\therefore P = VI \Rightarrow V \times \frac{V}{R} \Rightarrow \frac{V^2}{R}$$

$$\therefore R = \frac{V^2}{P}$$

$$R = \frac{(230)^2}{100} \Rightarrow 529\ \Omega$$

Supply Voltage $V^1 = 115\ V$

$$\therefore \text{Energy dissipated by the bulb} = \frac{V^{1^2}}{R} \times t$$

$$= \frac{(115)^2 \times 1200}{529}$$

$$= 30{,}000\ J \quad \text{Ans.}$$

EXAMPLE 5.22

A line having total resistance of 0.2Ω delievers 10 KW at 250 V to a factory. Waht is the efficiency of transmission ?

SOLUTION :-

Electric Power is given by $P = V\ I$ ----------(1)

$$P = I\ R \times I \qquad (\therefore\ V = I\ R)$$

$$\therefore P = I^2 R$$

So Power lost = $I^2 R$

$$= \left(\frac{P}{V}\right)^2 \times R \qquad (\text{By using eq}^n.\ (1)\ I = {}^P/_V)$$

Here, $P = 10\ KW \Rightarrow 10 \times 10^3\ W \Rightarrow 10{,}000\ W,\ V = 250\ V,\ R = 0.2\ \Omega$

$$\therefore \text{Power loss} = \left(\frac{10{,}000}{250}\right)^2 \times 0.2\ \Omega$$

$$\text{Efficiency} = \frac{\text{Power delieverd by the line}}{\text{Power supplied to the line}}$$

$$= \frac{10\ \text{KW}}{(10+0.32)\ \text{KW}} \Rightarrow 0.97 \Rightarrow 97\% \quad \text{Ans.}$$

EXAMPLE 5.23

A lamp of 100W works at 220V. What is its resistance and current capacity ?

SOLUTION :-

Here, P = 100 W

V = 220 V

Now P = V I

current capacity of the lamp $I = \frac{P}{V} = \frac{100}{220} \Rightarrow 0.455\ \text{A}$

Resistance of the lamp V = I R

$$\therefore R = \frac{V}{I} \Rightarrow \frac{220}{0.455} \Rightarrow 483.52\ \Omega$$

EXAMPLE 5.24

An electric motor operating on a 50 V d.c. supply draws a current of 12 V. If the effciency of motor is 30%, estimate the resistance of the windings of the motors.

SOLUTION :-

Here, V = 50 W

I = 12 V

Power of electic motor P = V× I

P = 50× 12 ⇒ 600 W

Since efficiency of the motor is 30%, It dissipate 70% of the Power across the resistance of windings of the motors.

$$\therefore \text{Power dissipate } = 600 \times \frac{70}{100} \Rightarrow 420\ \text{W}$$

If R is resistance of the windings of the motor

Then

$$I^2 R = P$$

$$I^2 R = 420$$

$$\text{or } R \frac{420}{I} \Rightarrow \frac{420}{(12)^2}$$

$$R = 2.92\ \Omega$$

OBJECTIVE TYPE QUESTIONS

Q. 1 Distinguish between static electricity and current electricity ?

Ans :- Static electricity deals with charge at rest and current electricity deals with charge in motion.

Q. 2 Waht do you understand by electromotive force ? State its S.I. unit.

Ans :- E.m.f. of a cell is maximum potential difference across the two electrodes of the cell when no current is drawn from the cell or cell in the open circuit. S.I. unit of e.m.f. of cell is Volt.

Q. 3 Explain the significance of direction of current in the circuit ?

Ans :- The conventional direction of current in the circuit gives the direction of flow of +ve charge. The direction of flow of e^- gives the direction of electronic current. Which is opposite to that of conventional current.

Q. 4 Why copper are used as connecting wires ?

Ans :- Because the conductivity of cu is high and its electrical resistivity is low.

Q. 5 Is Ohm's Law true for all the conductors ?

Ans :- No, It is true only for metallic conductors.

Q. 6 I the redius of cu wire is double, what will be the effect of specific resistance?

Ans :- Specific resistance will be uncharged.

Q. 7 Explain why resistance become more in series combination ?

Ans :- In series combination of resistance, the effective length of the conductor increase, hence resistance increase because $R \,\alpha\, \ell$.

Q. 8 Explain why resistance become less in parallel combination ?

Ans :- Because $R \,\alpha\, \frac{1}{A}$ and in Parallel combination the effective area of cross-section of conductor increase.

Q. 9 State the basic concept on which two Kirchhoff's Law are based ?

Ans :- It is based upon the fact that the charges not accumulated at Junction.

Q. 10 Kirchhoff's -Ist Law obey law of conservation of charge. Explain. ?

Ans :- A ccording to Kirchhoff's Law-Ist the current (I_2) entering a given juction of the circuit in a certain time (t) = current (I_2) = leaving the junction during the same time (t). So $I_1 t = I_2 t$ or $q_1 = q_2$

charges entering the junction is equal to the charge leaving that junction.

Q. 11 What is the merit of Wheatstone Bridge ?

Ans :- It is a null method, and the bridge can be sensitive by adjusting the resistance of all the four arms equal i.e. The balanced Point at the middle of bridge wire.

Q. 12 A current in a circuit having constant resistance is tripled. How does this affect the Power dissipation ?

Ans :- The Power dissipation in a circuit is $P = I^2 R$

Thus $P \alpha I^2$ where R is constant. When I becomes triple, Power becomes 9 times so that Power dissipation becomes 9 times.

Q. 13 A cwire connected to a bulb do not glow, whereas the filament of bulb glows when same current flows through them. Why ?

Ans :- Filament of the bulb and supply wires are connected in series so the same current flows through them. The resistance of connecting wires is negligible small as compared to resistance of filament and heat produced to given current is directly proportional to its resistance. The heat produced in the filament is very large. Hence the bulb glows.

Q. 14 Which lamp has greater resistance 60 W or 100 W lamp, When connected to the same supply ?

Ans :- Electric Power, $P = V I \Rightarrow \frac{V^2}{R}$

$$\therefore R = \frac{V^2}{P} \text{ or } R \alpha \frac{1}{P}$$

It means resistance of a lamp is inversly proportional to its Power. Thus a 60 W lamp has more resistance than 100 W lamp.

Q. 15 By what %age will the illumination of the lamp decrease if the current drops by 20% ?

Ans :- It R is resistance fo the lamp and I is current flowing in time τ, then heat produced is given by,

$$H = I^2 R t$$

when current drops by 20%, then the current in circuit = 80%

$$= \frac{80}{100} I \Rightarrow \frac{4}{5} I$$

Heat Produced $H^1 = \left(\frac{4}{5} I\right)^2 R t$

$$= \frac{16}{25} I^2 R t$$

so % decrease in heat Production $\left(\frac{H - H^1}{H}\right) \times 100$

$$\left(1 - \frac{H^1}{H}\right) \times 100$$

$$\left(1 - \frac{16}{25}\right) \times 100 = 36\%$$

Q. 16 Bulbs always fuse when they are switched on. Why ?

Ans :- As the bulb is switched on, it light up and temperature also increased and resistance of the filament of bulb is also increase. This action is happening very quickly. After many cycles the filament of bulb becomes thin and the bulb at the verge of burning out. When such a bulb is switched on , its initail resistance being low, there will be a sudden rush of current, as a result of which the filament burns off.

Q. 17 State the characterstics of fuse wire ?

Ans :- A fuse wire should be a meterail having

(i) High resistivity.

(ii) Low melting point.

(iii) Suitable current rating corresponding to the loads in a circuit.

MULTIPLE CHOICE QUESTIONS

1. Current flowing in a conductor due to
   (a) Motion of +ve ions (b) Motion of free electron in it
   (c) Motion of free electron and holes (d) Protons

2. The Electric Potential difference measured in
   (a) Killowatt (b) Joule (c) Volt (d) Watt

3. The S.I. Unit of electric current is
   (a) Volt (b) Killowatt (c) Ohm (d) Ampear

4. The charge on an electron is
   (a) 1.6×10^{19} C (b) 1.6×10^{20} C (c) 1.6×10^{-19} C (d) 1.6×10^{-20} C

5. Ohm's Law deals with the relation between,
   (a) Capacitor and charge (b) Current and Potential difference
   (c) Capacitor and resistance (d) None of these

6. The S.I. unit of resistance is
   (a) mho (b) Ohm (c) Ampear (d) Watt

7. Specific resistance of a wire depends upon
   (a) Its length (b) Cross-sectional area (c) material (d) Dimensions.

8. The S.I. unit of specific resistance is
   (a) Ohm (b) Watt (c) Ohm-m (d) Killowatt.

9. 1 Ohm-m is equal to
   (a) 1000 Ohm cm (b) 10 Ohm cm (c) 100 Ohm - cm (d) Zero.

10. The conductance of a condctor is equal to
    (a) equal to resistance (b) resiprocal to resistance
    (c) equal to Volt (d) None of these.

11. If a wire of the resistivity ρ is stretched double its length, then new resistivity will be
    (a) Half (b) double (c) Four times (d) Not change.

12. Specific resistance of a conductor increase with
    (a) Increase in temperature (b) Increase in cross-section area
    (c) descrease in cross-section area
    (d) Increase in cross-section and decrease in lenght.

13. Three resistance each of 4Ω are conneted to form a triangle. The resistance between any two terminals is
    (a) $12\ \Omega$ (b) $6\ \Omega$ (c) $8/3\ \Omega$ (d) $2\ \Omega$

14. As the temperature of conductor increase its resistivity and conductivity change. The ratio of resistivity to conductivity.
(a) Increase (b) Decrease (c) Constant
(d) Decrease or increase depending on temp.

15. If the temperature of metal is increase. Then its resistance will be
(a) Decrease (b) Decrease (c) Zero (d) Constant.

16. When a piece of $A\ell$ wire of finite length is drawn through a series of dies to reduce its diameter to half its original value, its resistance will be becomes.
(a) Two times (b) Four times (c) Eight time (d) Sixteen times.

17. When a body is earth connected electrons from the earth flow into the body. This means the body is
(a) Charged negatively (b) Insulator
(c) Uncharged (d) Charged positively

18. A wire has a resistance of 10Ω. It is streatched by one tength of its original length. Then its resistance will be
(a) 9 Ω (b) 10 Ω (c) 11 Ω (d) 12.1 Ω

19. A steady current is passing through a linear conductor of non-uniform cross-section. The net quantity of charge crossing any cross-section per second is.
(a) Inversly proportional to the length of conductor
(b) Directly proportional to area of cross-section
(c) Independent of area of cross-section
(d) None of these.

20. Kirchoff's Ist Law of a junction point deals with
(a) Law of momentum (b) Sum of mass and energy
(c) conservation of charge (d) Coscervation of angular momentum.

21. According to Kirchoff's 2nd Law, $\sum IR = ?$
(a) $\sum Q$ (b) $\sum M$ (c) $\sum E$ (d) None of these.

22. If Galvanometer shows no deflection in a wheatstone bridge, then bridge said to be.
(a) In unbalanced (b) In Balanced (c) In paralled (d) In series

23. According to Wheatstone bride, $\frac{P}{Q} = ?$
(a) $\frac{R}{S}$ (b) $\frac{S}{R}$ (c) $R \times S$ (d) None of these.

24. The equivalent resistance of resitors in Parallel is always :-

(a) Equal to sum of the resistors
(b) Less than the lowest of component resistors.
(c) Higher than the highest components of resistors
(d) None of these

25. When three resistors R_1, R_2, R_3 are connected in series then resultant R_s is given by

(a) $R_s = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ (b) $R_s = R_1, R_2, R_3$

(c) $R_s = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ (d) None of these.

26. Joule's Law equation H= ?
(a) $I R^2 t / 4.2$ (b) $4.2 / I R^2 t$ (c) $I Rt^2 / 4.2$ (d) $I^2 Rt / 4.2$

27. Electric Power in circuit is given by P = ?
(a) $\frac{V}{1}$ (b) $\frac{1}{V}$ (c) $V \times 1$ (d) $I^2 Rt$

28. 1 Killowatt hour is equal to --------- Joules
(a) 36×10^3 (b) 36×10^4 (c) 36×10^5 (d) 36×10^6

29. 1 horse power = --------- watt.
(a) 743 (b) 744 (c) 745 (d) 746

30. 1 Kw- hour is a unit of
(a) Electric Potential (b) Power (c) Work (d) Energy.

31. The specific resistance of all metals is most effected by
(a) Pressure (b) Dimensions (c) Temperature (d) Area

32. Heat Produced in a conductor is
(a) Directly proportional to resistance (b) Inversly proportion to resistence
(c) Both (a) & (b) (d) None of these

33. Two heater wires of equal length are first connected in series & then in parallel. The ratio of heat produced in the two cases is :
(a) 2:1 (b) 1:2 (c) 4:1 (d) 1:4

34. Two electrical lamps of 40 watt are connected in series. The power consumed by combination will be :
(a) 20 W (b) 60 W (c) 80 W (d) 100 W

35. In Joules law of heating effect of current, the electrical energy converts into :
(a) Mechanical Energy
(b) Chemical Energy
(c) Heat Energy
(d) None of these

VERY SHORT ANSWER QUESTIONS [2 MARKS]

1. What is current and its S.I. Unit ? [Imp.]
2. What is the number of electrons that consitutes a current of one ampere ?
3. Define electric potential and give its units [Imp.]
4. Define Potential difference.
5. State Ohm's Law. [Imp.]
6. Define resistance of a conductor and gives it unit.
7. Define specific resistance or resistivity. Give its unit. [Imp.]
8. Define conductance and give its unit.
9. What do u mean by conductivity also give its unit.
10. Write down the total equivalent resistance, when three resistance are connected in (i) series combination and (ii) Paralel combination.
11. Define temperature coefficient of resistance ? [Imp.]
12. What is the effect of temperature on resistance ? [V. Imp.]
13. Define E.M.F. (Electromotive Force) of a cell.
14. Give unit of E.M.F.
15. State Kirchhoff's -1st Law of an circuit.
16. State Kirchhoff's -IInd Law.
17. State principle of Wheatstone Bridge.
18. Draw a neat and clean circuit diagrom of Wheatstone Bridge.
19. Define Heating Effect of current. [Imp.]
20. What is the cause of Heating Effect of current.
21. State Joule's Law of Heating Effect of current. [Imp.]
22. Define electric Power and give its unit. [V. Imp.]
23. 1 H.P. = ----------------------Watt.
24. Convert 1 KWH into Joule.
25. What is electrical energy. Give its unit.
26. Define 1 Ampere and 1 Volt.

SHORT TYPE ANSWER QUESTIONS [6 MARKS]

1. Explain resistance, specific resistance and conductance, also their units.
2. Differeutiate between electromotive force (e.m.f.) and Potential difference of the cell.
3. Find out the equivalent resistance, when three or more resistance are connected in series combination. [V. Imp.]
4. Find out the equivalent resistance, when three of more resistance are connecting in Parallel combination. [V. Imp.]
5. Explain the effect of temperature of resistance. [Imp.]
6. State and explain Kirchhoff's Law. [M. Imp.]
7. State and explain Joule's Law of heating effect of current. [Imp.]
8. Define electric Power and its S.I. unit.

LONG ANSWER QUESTIONS [10 MARKS]

1. Define the terms - current, ampere, Ohm, resistivity and conductivity.
2. Define resistivity of a metarial. Does it depend upon the shape of the cross section of wire of metarial ? What are its S.I. and C.G. S. unit ?
3. State and explain Kirchhoff's Law. Describe their application to Wheatstone Bridge. [M. Imp.]
4. Find out the equivalent resistance three or more resistance are connecting in
   (i) Series Combination.
   (ii) Parallel Combination. [M. Imp.]
5. State Principle, construction and working of Wheat-stone Bridge. How will you determine unknown resistance with it ? [M. Imp.]

NUMERICAL PROBLEMS

1. How many electrons pass through a lamp in one minute if the current is 600 mA ? Given charges on electron is $1.6 \times 10^{-19} C$ [Ans. 2.25×10^{20}]
2. Find out the resistance of a hollow eylindrical pipe of length 1.0 m whose inner and outer radil are 10 cm and 20 cm respectivelly. The resistivity of materail is $2 \times 10^{8}\ \Omega\,m$ · [Ans. $2.1 \times 10^{-7} \Omega$]
3. A wire of resistance $R = 4\,\Omega$ is streatched, so that its reduis decrease to by a factor n = 5, calculate its new resistance. [Ans. 2.5 KΩ]
4. The copper coil of length 10 m has a resistance of $2\ \Omega\,m^{-1}$ at 20°C. Find its resistance at 50°C. The temperature coefficient of resistance for copper is $3.80 \times 10^{-4°} C^{-1}$
   [Ans. 20.2 Ω]

5. The specific resistance of the material of a wire is $44 \times 10^{-6}\ \Omega\,m$. If the resistance of wire is $14\ \Omega$ and its diameter is 1mm, calculated the length of wire.

[Ans. 0.25 m]

6. The resistance of a copper wire if length 1 m is $0.1\ \Omega$. The diameter of the wire is 0.045 cm. Find its resistivity. [Ans. $159.1 \times 10^{-10}\ \Omega$- m]

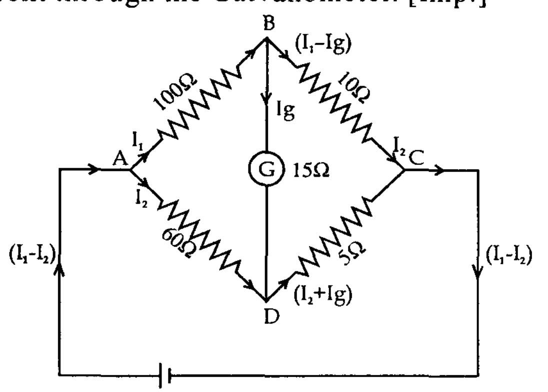
7. 1 m eureka wire has a resistance of $5\ \Omega$. It is streached to double its length without any change in the volume. What will be its new resistance. [Ans. $20\ \Omega$]

8. A Parallel combination of three resistors take a current 7.5 A from a 30 V supply. If the two resistors are $10\ \Omega$ & $12\ \Omega$. Find the third one. [Ans.= $15\ \Omega$]

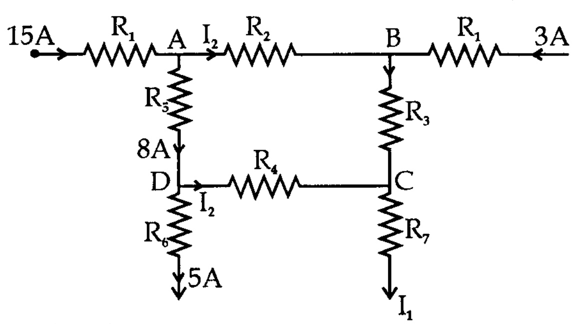
9. Given three $30\ \Omega$ resistance, How can they be connected to give a total resistance of (i) $90\ \Omega$ (ii) $10\ \Omega$ (iii) $45\ \Omega$?

[Ans. (i) in series (ii) in Parallel (iii) two in parallel and one in series]

10. Calculate the current through the Galvanometer. [Imp.]



11. Calculate the value of current in the various arms of network shown in figure.



12. A line having a total resistance of $0.2\ \Omega$ delievers 10 Kw at 250 V to a small factory. What is the efficiency of transmission ? [Ans.= 97%]

13. Two heater are marked 200 V, 300 W and 200 V, 600 W. If the neaters are combined in series and the combinatin connected to a 200 V d.c. supply, which heater will produce more heat ? [Ans. A heater marked 200 V, 300 W]

14. An elctric motor operates on a 50 V supply and draw a current of 12 A. If the motor yields a mechanical power of 150 W. What is the percentage efficiency of the motor?

[Ans. 25%]

15. Find the resistance of a conductor in which a current of 2 A is flowing for 20 S and producing a heat of 80 J. [Ans.1 Ω]

ANSWER KEY FOR MULTIPLE CHOICE QUESTIONS

(1)	b	(2)	c	(3)	d	(4)	c	(5)	b
(6)	b	(7)	c	(8)	c	(9)	c	(10)	b
(11)	d	(12)	a	(13)	c	(14)	a	(15)	b
(16)	d	(17)	d	(18)	d	(19)	c	(20)	c
(21)	c	(22)	b	(23)	a	(24)	b	(25)	b
(26)	d	(27)	c	(28)	c	(29)	d	(30)	b
(31)	c	(32)	b	(33)	d	(34)	a	(35)	c

UNIT - 6

SEMICONDUCTOR PHYSICS

INTRODUCTION :-

The branch of Physics which deals with the study of semiconductors is known as semiconductor Physics.

There are mainly three types of materials like :-

1. Conducting materials
2. Insulating materials and
3. Semiconductor materials.

As conducting materials are good conductors of electricity. e.g. Cu, Ag and Al etc. Insulating materials are bad conductors of electricity e.g glass, quartz and rubber etc. There is another group of materials such as germanium and silicon, these are neither good conductors nor bad insulators are known as semiconductor materials. At room temperature Ge and Si have conductivities considerably lower than that of conductors, but much higher than that of Insulators.

STRUCTURE OF AN ATOM :-

An atom consist of two parts. Ist is a central body called the nucleus and secondly Extra nuclear part. The electrons are revolving around the extra nuclear part.

The nuclear of all element (except hydrogen atom) contains two types of particles called protons and neutrons. The protons and neutrons have almost some mass, but the charge of a proton is positive whereas neutron has no charge, means it is a neutral particle. So whole mass of the atom is concentrated in its nucleus. And elelctrons are revoloving around the nucleus are very light in weight. An electron is about 1850 times lighter than the protons or neutrons.

An electron has the same amount of charge as in the protons. But the charge on an electron is negative, it means that in an atom (in normal site) the number of orbital electron must be the same as the number of protons in its nucleus.

The number of protons in an atom is called atomic number. All the electrons of an atom do not move in the same orbit. The electrons are arranged in different orbit or shells. The maximum number of electrons that can exist in first orbit is two, in second orbit it is eight, in third orbit it is exist eighteen. The fourth not more than thirty two and so on. In generally a shell can occupy a maximum number of electron is given by $2n^2$ electrons.

Where n= number of shells,

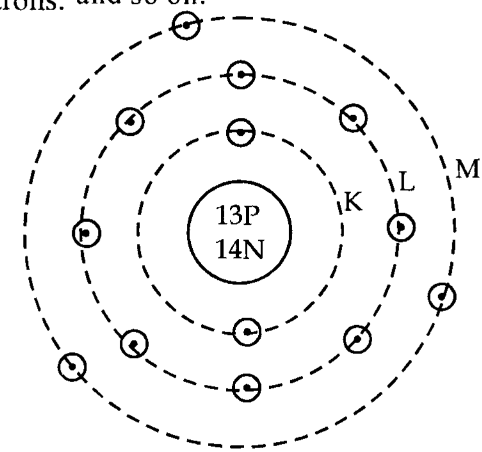
So for Ist (K) n=1, $\therefore e = 2n^2 \Rightarrow 2\times1^2 \Rightarrow$ 2 electrons.

IInd (K) n=2, $\therefore e = 2n^2 \Rightarrow 2\times2^2 \Rightarrow$ 8 electrons.

IIIrd (K) n=3, $\therefore e = 2n^2 \Rightarrow 2\times3^2 \Rightarrow$ 18 electrons.

IVth (K) n=4, $\therefore e = 2n^2 \Rightarrow 2\times4^2 \Rightarrow$ 32 electrons. and so on.

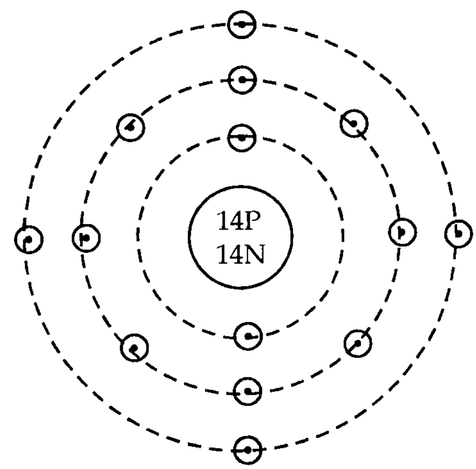
The outermost orbit in an atom cannot accomodate more than eight electrons. These electrons present in the outermost orbit are called valance electrons.



Aluminium. Atom
Fig. 6.1

Figure (6.1) shows the structure of an aluminium atom. The nucleus of $A\ell$ -atom contains 13 Proton (13 P) and 14 neutron (14 N). The 13 numbers of elelctrons rrevolving around the nucleus. The positive charge on 13 P are just balanced by negative charge on 13 e- rovoloving around the necleus in different shells or orbit. There are two electrons in first shell, eight electrons in second orbit and only three electrons in outermost orbit or say in third orbit. These three electrons are known as valance electrons.

The electrons in the inner shell do not normally leave the atom as they bound tightly with necleus. But the electrons which revolve at a great speed in the outermost orbit do not always remains confined to the some atom, and leave the atoms as they loosly bounded with necleus. These are free to move to another atom and are known as free electrons. Fig. (6.2) represents S*ι*-atom, in its necleus contains 14 P and 14 N. There are 14e revolving around the necleus. Two in Ist orbit, eight in 2nd orbit and four in third orbit. These four electrons are known as valance electrons.



S*ι*. Atom
Fig. 6.2

$A\ell$, Z=13, $1S^2\ 2S^2\ 1P^6\ 3S^2\ 3P^1$

$S\iota$, Z=12, $1S^2\ 2S^2\ 2P^6\ 3S^2$

SHELL	SUBSHELL					NO. OF ELECTRONS
	S	p	d	t	g	
n = 1, K	2					02
n = 2, L	2	6				08
n = 3, M	2	6	10			18
n = 4, N	2	6	10	14		32
n = 5, O	2	6	10	14	18	50

ENERGY BAND IN SOLIDS :-

In a solid, The orbit of electrons is influnced not only by the charges in its own atom but by nucler and electrons of every aoms in the solid. Since each electron occupies a different position inside the solid, no two electrons can have exactly the same pattern of surrounding charges. As a result the orbits of the electrons are different.

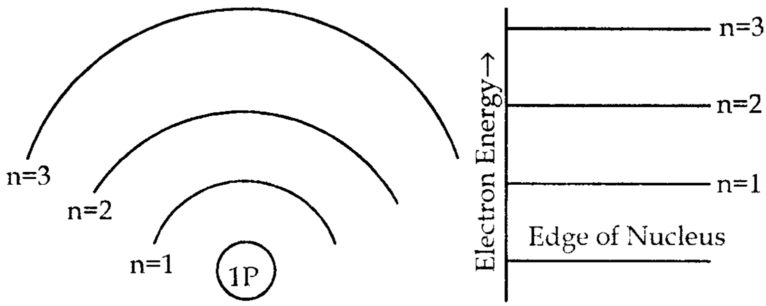


Fig. 6.3

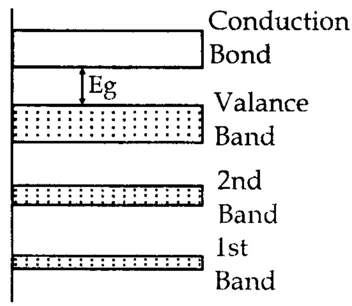


Fig. 6.4

In fig. (6.4) there are millions of electrons, belonging to the first orbit of atoms in the solids.Each orbit have different energy. Since there are millions of electrons in Ist orbit, they are closely spaced, differing very slightly in energy level and hence form a cluster or band. Similarly the IInd orbit and high orbit electrons also form band. These are known as first energy band, second energy band, third energy band and so on.

In fig. (6.4) the atomic number of silicon is 14, and each of its atoms has only four electrons in the third (outermost) orbit, the third band becomes known as valance band. An additional Band called conduction band, is shown above the valance band. All the three lower bands including valance band are completely filled. Although the third shell of an isolated atom of silicon is partly filled with four electrons and it occupies maximum eight number of electrons. The third energy band or valance band of solid solicon is completely filled because in solid silicon atom, each atoms positions itself between four other silicon atoms, and each of these neighbours share an electron with the central atoms. So now each atom has eight electrons filling the valance band completely. When the band is filled, it means that all the permissible energy levels, in the band are occupied by electrons. No electrons in a filled band can move, because there is no place to move. Thus an electron in a completely fulled band cannot contribute to electric current.

The conduction band represent the next higher group of permissible energy levels. There is an energy gap E_G between the valance band and conduction band known as the "forbidden energy gap."

for silicon, $E_g = 1.12ev$

for Germanium, $E_g = 0.72cv$

CONDUCTORS, INSULATORS AND SEMICONDUCTORS :-

(i) CONDUCTORS :-

There is a zero energy band gap between the valanced band and conduction band, it means that the two bands actually overlap as shown in fig 6.5 (a) called conductors. The valanced band energies are the same as conduction band energies in the metals. like copper and silver etc.

(ii) INSULATORS :-

The energy band gap (Eg) between the valance band and conduction band is very wide approxomately (5 ev or more) are known as Insulators. Due to large band gap there is no possibility of jumping of elelctron from valanced band to conduction band. At higher temperature electrons can jump only from valanced band to conduction band. At room temperature, an insulators does not conduct because there are no conduction of electrons. Fig. 6.5 (b)

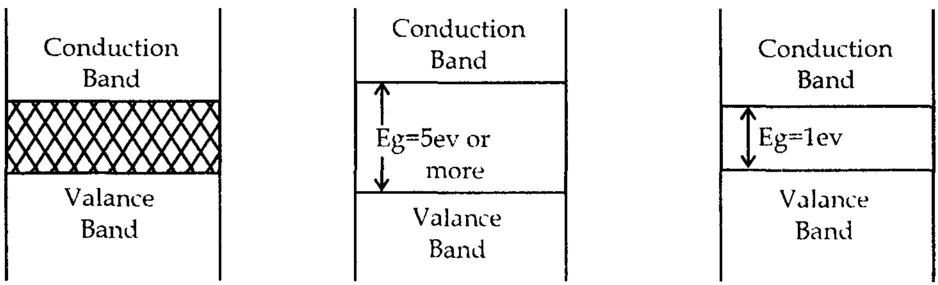


Fig. 6.5(a) Fig. 6.5(b) Fig. 6.5(c)

SEMICONDUCTOR :-

The forbidden energy gap between the valance band and condution band is not very wide. It is of the order of 1 ev.(For Ge, Eg = 0.72 ev and for silicon, Eg = 1.12ev) as shown in fig. 6.5 (c). The energy provided by the heat at the room temperature is sufficient to lift electrons from valance band to conduction band. Some electron do jump the gap and go into conduction band. Therefore at room temperature semiconductors are capable of conducting some electric current.

CURRENT CARRIERS (ELECTRONS AND HOLES) IN SEMICONDUCTORS :-

The energy band gap for Germanium is of 0.72 ev and for silicon it is of 1.1 ev. At zero kalvin, electrons are not able to cross even this small forbidden gap and hence the conduction band remains totally empty. Therefore at zero kelvin semiconductors behaves as insulators.

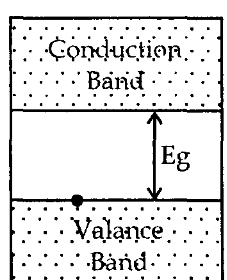


Fig. 6.6(a)

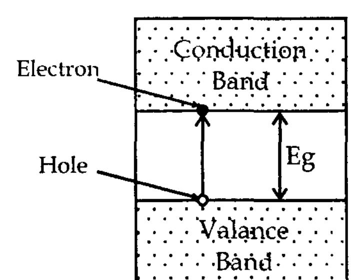


Fig. 6.6(b)

But at higher temperature some of the

electrons gain energy due to thermal iginiation and move from valance band to the conduction band. As a result of this a vacancy is created in the valance band at a place where the electrons were present before moving to the conduction band as shown in fig. 6.6 (a). This vacancy is called a hole. Since absence of a negatively charged electron is equivalent to the presence of an equivalent amount of positive charge, therefore a hole is considered as a seat of positive charge having charge equal to that of an electron.

The hole is considered as an active particle in the valance Band as an electron in the conduction band.

TYPES OF SEMICONDUCTORS :-

Semiconductors are of two types :-

(a) INTRINSIC SEMICONDUCTOR (OR) PURE SEMICONDUCTOR

(b) EXTRINSIC SEMICONDUCTOR (OR) IMPURE SEMICONDUCTOR

(a) INTRINSIC SEMICONDUCTOR :-

The semiconductors which are quite pure and free of impurities are called intrinsic semicondutor or pure semiconductors. Silicon (Si) and Germanium (Ge) are the two best examples of pure semiconductors, which are widly used in electronics and transistors manufacturing. The electronic configuration of Si and Ge are as given by

Silicon (14) $=1S^2, 2S^2, 2p^6, 3S^2, 4p^2$

Germanium (32) $=1S^2, 2S^2, 2p^6, 3S^2, 3p^6, 3d^{10}, 4S^2, 4p^2$

Both of them have four valance electrons. The crystal structure of Si in two dimensions as shown in fig. 6.7 . The four valance electron of a Si atom form four covlent bonds by sharing the electrons of neighbouring four Si atom.

Each covelent bond shares two electrons one from each atom. By forming such covalent bonds, each Si atom in the crystal behaves as if the outermost orbit of each atom is complete with eight electrons, having no free electron in the Si-structure.

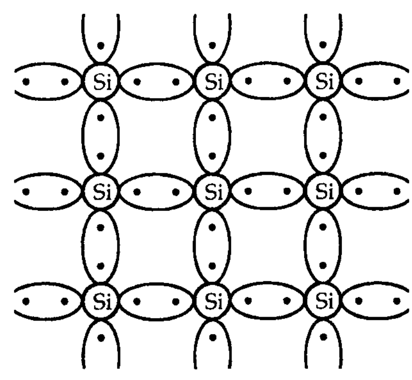


Fig. 6.7

At absolute zero temperature, the valance bond is cempletely filled and the conduction band is completely empty. So semiconductors behave like insulators. Even at room temperature, the electrons in valance bond cross the forbidden gap and enter into conduction bond as free electrons. Higher the temperature, larger will be the number of electrons crossing over to the conduction bond, leaving behind equal number of holes in the valance bond.

When an electron breaks away from a covalent bond. The empty place left in the bond is called a hole. When an external electric field is applied these free electrons and holes move in opposite directions and constitute a current flow through the silicon crystal. The number of free electron and holes are exactly equal in an intrinsic semiconductor. Thus in the intrinsic semiconductor

$$n_e = n_h = n_i$$

Where n_e, n_h are number density of electron in conduction band and number density of holes in valance band.

n_i = Number density of intrinsic carriers (holes or electrons) in a Pure semiconductor.

DOPING :-

The process of adding impurities to pure semiconductor is called doping. The impurity atoms are of two types :-

(a) Pentavalent impurity atoms i.e having five valance electrons in outermost orbit e.g. Arsenic (As), antimony (Sb).

(b) Trivalent impurity atoms i.e atoms having three valance electron in outermost orbit e.g Galium (Ga), Aluminium ($A\ell$), Boron (B) etc.

EXTRINSIC SEMICONDUCTORS :-

A semiconductor with suitable impurity atoms added to it, is called extrinsic semiconductor or Impure semiconductor. Extrinsic semiconductors are of two types :-

(i) N- type semiconductor.
(ii) P- type semiconductor.

(i) N-TYPE SEMICONDUCTOR :-

When a pentavalent impurities like arsenic Z = 33, Phasphorous (P), Z = 15, antimony (Sb) Z = 51 etc. are added to pure semiconductor silicon (Si) and Germanium (Ge), which have five valance electron, in which four electrons are formed covelent bond and one electron will be left free. Then the semicondctor is known as N=type semiconductor.

The four of the five electrons of the impurity atoms will form covlent bonds by sharing the electrons with the adjoining four atoms of silicon while the fifth electron is very loosely bound with the parent impurity atoms and is comparatively free to move. It is so because the force of attraction between electrons and nucleus of donor atom becomes very small due to high value of dielectric constant of Ge and Si. Thus each impurity atoms added donates one free electrons to crystal structure. These impurity atoms which donate free electrons for conduction are called donor atoms. Since the conduction of electricity is due to the motin of electrons i.e n-type carriers therefore semiconductor is called donor type semiconductor.

At room temperature, some of the covelent bonds may get reptured, producing thereby electron and an equal number of holes in the n-type semiconductor. But overall the total number of holes in n-type semiconductor is relatively low, hence in n-type semiconductors, electrons are majority carriers and hole are minority carriers.

On giving up their fifth electron, the donor atoms become positively charged. However the matter remains electrically neutral as a whole. the extra electron of the donor atom orbits around the donor necleus. It has been found that 0.045 ev energy is required to remove this electron from the impurity atom and makes it a free electron.

P-TYPE SEMICONDUCTORS :-

When a trivalent impurity such as boron, aluminium, indium and galluim etc. will be added to the pure semiconductor, the result is P-type semiconductor. Let us consider a sample of pure silicon to which a very small amount of boron is added. Since the impurity ratio is of order of one part in one part in one million each impurity atom is surrounded by silicon atoms. The valance electron in Boron are three electron in outermost orbit. These three valance electron form covalent bonds with three neighbouring silicon atom. The fourth electron of silicon is unable to form a covalent bond with the boron atom because boron atom does not have the fourth electron in its valance orbit.

There is a vacency of electron around the boron atom. So single electron in the incomplete bond has a greater tendency to attract an electron from the neighbouring atom. Hence a very small energy is required to fill up the vacanct bond from neighbouring atom. This electron then complete the covalent bond around boron atom. The additional energy is required for this is of the order of 0.01 ev.

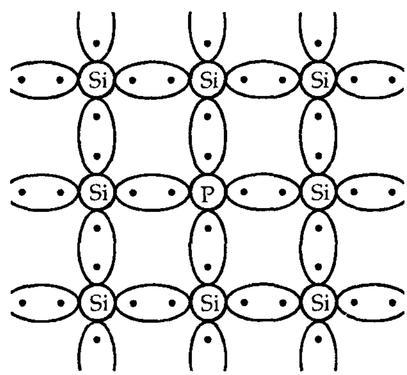


Fig. 6.8

When an electron from adjacent covalent bond jumps to fill the vacancy in the incomplete bond around the boron atom, Two things happen :-

(i) A vacancy is created in the adjacent bond from where the electron have jump. This vacancy has a positive charged associated with it hence it is a hole.

(ii) Due to filling of the incomplete bond now it is becomes negative ion.

Since Boron atom is fightly bounded by covalent bonds. The boron atoms becomes negative ions by accepting one electron from the neighbouring atoms. That is why this is called ACCEPTOR TYPE SEMICONDUCTOR.

Hence Holes are majority carriers and electrons are minority carriers.

DIFFERENCE BETWEEN INTRINSIC SEMICONDUCTOR & EXTRINSIC SEMICONDUCTOR :-

INTRINSIC SEMICONDUCTOR	EXTRINSIC SEMICONDUCTOR
1. It is pure semiconductor and no impurity atoms are added to it.	1. It is prepared by doping a small quantity of impurity atoms to the pure semiconductor.
2. Si and Ge are the example of Pure semiconductor.	2. Examples are Si, Ge atoms with impurity atoms of Boron, Phosphorous, antimony, indium, aluminium etc.
3. Its electrical conductivity is low.	3. Its electrical conductivity is high.
4. The number of electron in conduction bond and number of holes in valance bond are exactly same.	4. The number of electrons and holes is never same.
5. Its electrical conductivity is a function of temperature alone.	5. Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms dopes in the structure.

DIFFERENCE BETWEEN N-TYPE SEMICONDUCTOR & P-TYPE SEMICONDUCTOR :-

N-TYPE SEMICONDUCTOR	P-TYPE SEMICONDUCTOR
1. It is obtained by doping the impurity atoms of Pantavalent atoms like P, Bi, As into Si and Ge atom.	1. It is obtained by doping the impurity atoms of trivalent atoms like Boron, indium, alluminium into Si and Ge atom.
2. It is also known as Donor type semiconductor.	2. It is also known as acceptor type semiconductor.
3. Electrons are majority carrier and holes are minority carriers.	3. Holes are majority carriers and electron are minority carriers.
4. The electron density n_e is much greater than the hole density n_h i.e $n_e > n_h$	4. The hole density n_h is much greater than the electron density . n_e i.e $n_h > n_e$

PN JUNCTION

When a P-type semiconductor is placed in contact with N-type semiconductor in order to form one piece, the asembly so obtained is called PN Junction or Junction diode. The surface of contact of P-type and N-type crystals is called Juction. Holes and electrons are majority carriers in P-type and N-type semiconductor respectively. Due to high concentration of different types of charges carriers in two section, Holes from P-region deffuse into N-region and electrons diffuse into P-region. In both the case when an electron meets a holes, they cancel the effect of each other and result in a thin layer at the junction becomes devoid of charge carriers called deplection layer as shown in fig.(6.10). The thickness of depletion layer is of the order of 10^{-6}

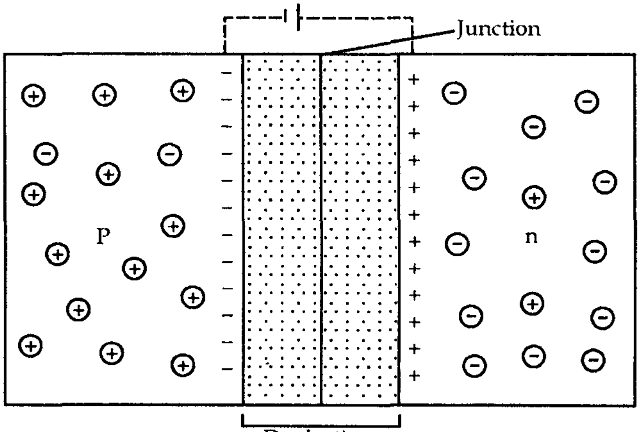


Fig. 6 10

Due to migration of charge carriers across the junction the n-region of the junction will have its electrons neutrallised by holes from P-regions leaving only positive charge which are bound and cannot move. Similarly the P-region of the junction will have negative charge which are immobile. Due to this there is a potential gradient in the deplection layer negative on the P-side and positive on the n-side. In other words, it appears as if some fictitious battery is connected across the junction with negative poles connected to P-region and positive Pole connected to n-region. The potential difference developed across the junction due to migration of majority carriers is called Potential Barriers, It opposes the further migration of charge carriers. The magnitude of Potential Barrier for Ge is about 0.3 Volt and for Si is of about 0.7 Volt. The value of Potential Barriers depends upon the amount of doping of the semiconductor crystal.

BIASING OF THE PN JUNCTION :-

There are two method of biasing the PN Junction.

(1) FORWARD BIASING :-

"A PN Junction is said to be forward biased if the positive terminal of the battary is connected to the P-side and the negative terminal to the n-side of PN Junction " as shown in fig. (6.11)

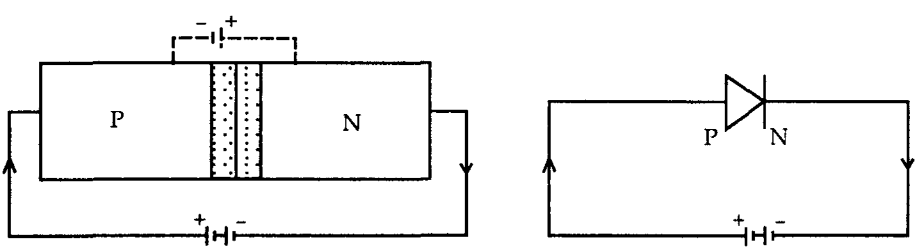


Fig. 6.11

As we connect the Battery with forward bias with PN Junction, The majority electrons from n-region are repelled by negative potential of the battery and move towards the junctions, similarly holes from P-region are repelled by positive potential of the battery and moves towards the junction. It is means that holes are attracted by n-region and electron are attracted by p-region. Hence more majority carriers cross the junction. The electrons and holes recombine to each other by crossing the juction and an electron from the negative terminal of battery entres the N-type, drifts towards the junction. Similarly in the P-type near the positive terminal of the battary an electron breaks a bond in the crystal and enters the positive terminal of the battary. For each electron that breaks its bond a hole is created. These holes drift towards the junctions. Hence Potential barrier will be reduced. The current in the N-region is due to the movement of holes. If the battery voltage is further increased the barrier potential is reduced. Hence current flowing in the forward biasing is due to flow of majority carriers and called forward current.

REVERSE BIASING :-

A PN Junction is said to be reverse biased if the positive terminal of battary connected to the N-type and negative terminal of battary to the P-type of PN Junction as shown in fig. (6.12)

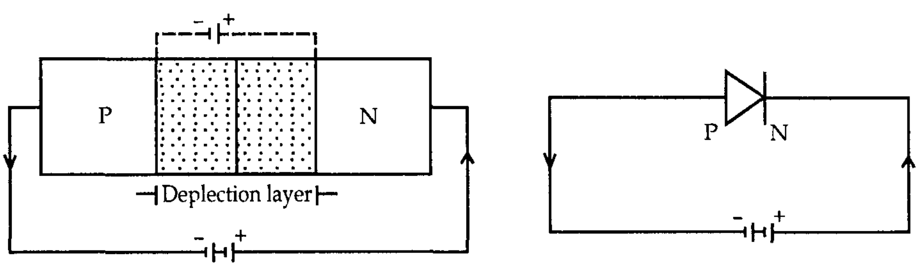


Fig. 6.12

When reverse bias is applied, the majority carriers are pulled away from the junction so that the depletion layer becomes thick. The resistance of junction diode becomes very high. The majority carriers do not cross the junction. However a little amount of current flows due to the motion of minority carriers. This current is called reverse current. Hence the potential barriers oppose the forward current, while it aids the reverse current.

CHARACTERISTICS OF P-N JUNCTION :-

There are two types of characteristics of PN Junction.

(i) Forward Characteristics.

(ii) Reverse Characteristics.

(i) Forward Characteristics.

The forward bias connections are shown in fig. (6.13) (a). Let us connect the battery in such a way that +ve terminal of battery to p-type and -ve terminal of battery to N-type to PN Junction. Holes from P type and elelctrons from N-type are repelled by Battery and cross the junction. Hence maximum majority carriers are crossing the juction and a maximum current will flow due to majority carriers called forward current and reduced the potential Barriers.

A maximum voltage of about 0.3 to 0.7 V is needed to overcome the potential at the junction. With the further increase of forward bias from this value, the current in the external circuit increase rapidly and for a voltage as little as 1V or so, the current reaches a value of about 8-10 mA. The graph showing the variation between and current is as given in fig. 6.13 (b). It is clear from the curve that before the forward conduction becomes fully operative, the barrier potential differnce must be overcome by applying a forward potential difference of about 0.3V for Ge diode, 0.7V for Si diode.

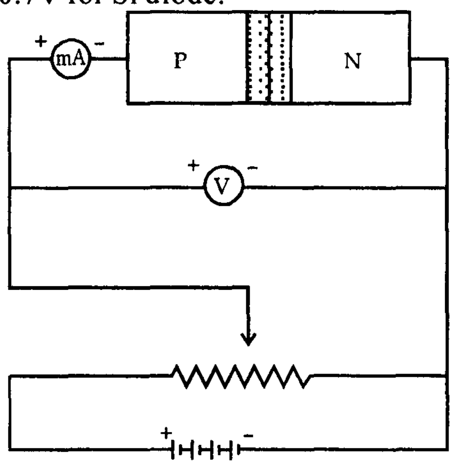


Fig. 6.13(a)

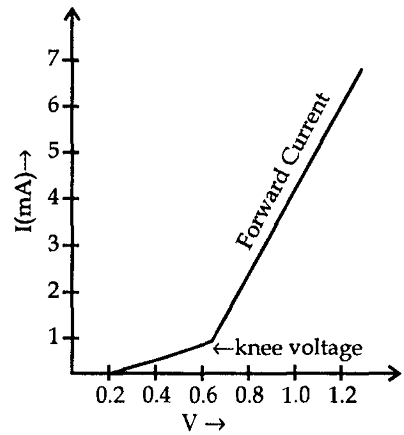


Fig. 6.13(b)

For this reason, Ge diodes are more acceptable. Once the potential barrier is overcome, the current increases rapidly to about 10 mA for a small potential difference of about one volt. The minimum value of applied potential difference required so that current starts flowing is known as knee voltage.

REVERSE BIAS CHARACTERISTICS :-

Let us connect the external Battery with potential dividing arrangement to P-N Junction as shown in fig. 6.14 (a) so that PN Junction is reverse biased.

For the given small reverse bias voltage applied to PN Junction, note down the reverse current from the microammeter (μA). The current flowing in the circuit is due to minority carriers across the PN Junction. On increasing the reverse bias voltage we can note down the reverse current. On plotting a graph between the reverse bias and reverse current, we get the reverse characteristics as shown in fig. 6.14 (b). From this graph we note that in reverse biasing PN Junction diode, the reverse current is very small and almost remains constant with reverse bias voltage. It is called reverse saturation current. If the reverse bias voltage equal to OB, the current flowing through PN Junction will increase abruptly. The reverse bias voltage is then known as

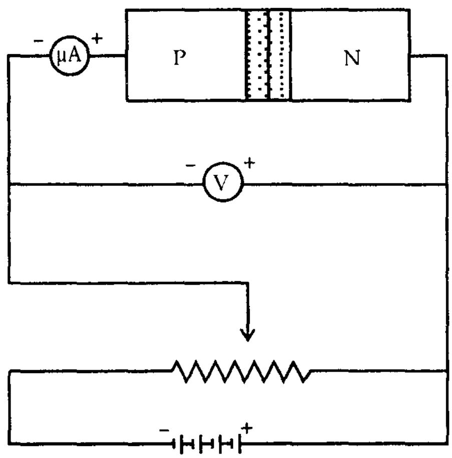


Fig. 6.14(a)

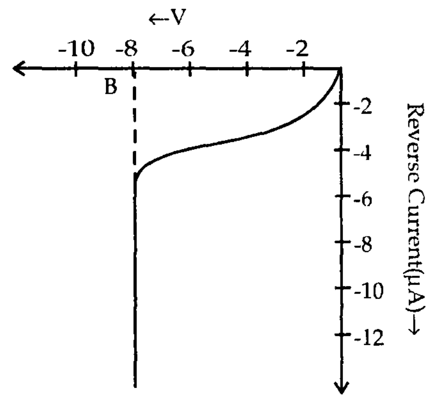


Fig. 6.14(b)

breakdown voltage ro Zener voltage.

JUNCTION DIODE AS RECTIFIER :-

Rectifier is an electronic device that converts a.c. (alternating current) voltage into d.c. (direct current) voltage is called a rectifier.

PRINCIPLE :-

The study of the junction diode characterstics, reveals that the junction diode offers a low resistance for forward biased and high resistance for reversed biased. The two half cycles of alternating input e.m.f. provide opposite kinds of bias to the junction diode. If the junction gets forward biased during first half cycle and reversed baised during second half cycle and viceversa.

In other words, we say that for an altenating e.m.f. signal is applied across a junction diode, it will conduct only during those alternate half cycle, that bias it in forward direction.

There are two types of rectifier as follows :-

(i) Half Wave Rectifier,

(ii) Full Wave Rectifier,

HALF WAVE RECTIFIER :-

A rectifier that rectifies only half of each a.c. supply cycle is called half wave rectifier.

CIRCUIT DIAGRAM

The a.c supply is fed across the primary coil P of a step down transformer. The secondry coil S of the transformer is connected to the junction diode with a load resistance R_L as shown in fig. (6.15). The output d.c voltage is obtained across the load resistance R_L.

WORKING :-

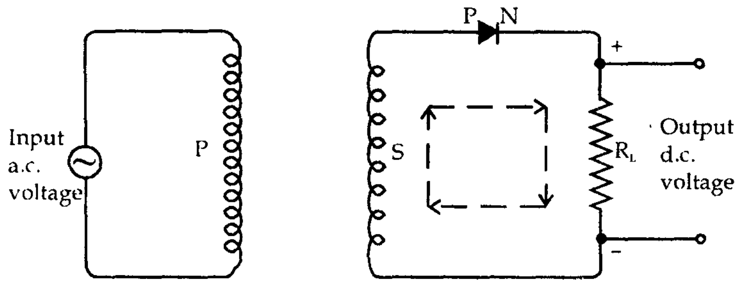


Fig. 6.15

Let us suppose that for Ist half input cycle the junction diode gets forward biased. The conventional current will flow in the direction of arrow heads. The upper end of R_L will be at positive potential w.r.t. the lower ends. The magnitude of output across R_L during Ist half cycles at any time will be proportional to the magnitude of current through R_L. Hence during Ist half cycle of input, the junction diode will be conduct and output across R_L will vary in accordance with a.c. input.

During 2nd half cycle, junction diode will get reverse biased and hence no output will be obtained across R_L. A small current will be flow due to minority carriers and a negligible output will be obtained during this half cycle. During the next half cycle, the junction diode will get forward biased and output will be obtained. Thus we shall get the discontinuous and pulsating d.c. output across the load resistance as shown in fig. (6.16)

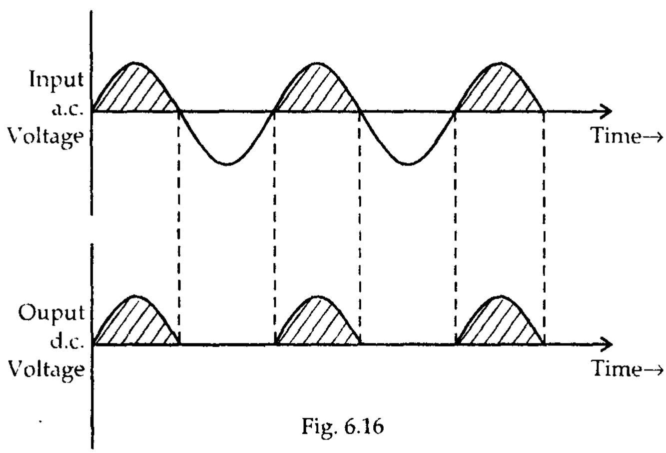


Fig. 6.16

Half wave rectifier involves a lot of wastage of energy and hence it is not preferred.

FULL WAVE RECTIFIER :-

A rectifier which rectifies both halves of the a.c. input is called a full wave rectifier. To make use of both the halves of input cycle, two junction diodes are used.

CIRCUIT DIAGRAM :-

The a.c supply is fed across the primary coil P of a step up transformer. The two ends of secondory coil S of the transformer are connected to P-region of the junction diode D_2 and D_2. A load resistance R_L is connected across the n-region of the two diodes and the central tapping of the secondary coil as shown in fig. (6.17). The d.c. output will be obtained across the R_L.

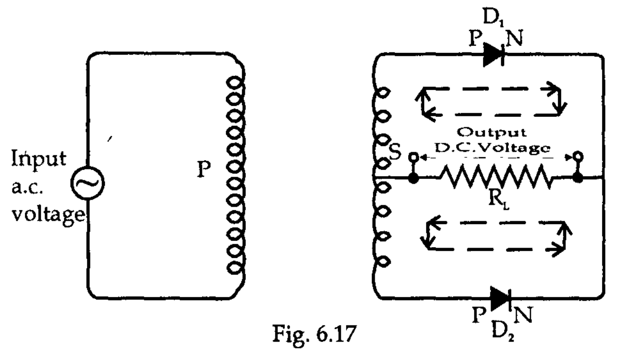


Fig. 6.17

WORKING :-

Let us suppose for Ist half cycle of a.c. voltage, the upper end of S coil is at positive terminal and lower end is at negative terminal. It means that junction Diode D_1 is in forward end D_2 is in reverse biased. Hence due to forward biasing of Diode D_1 the maximum current will be flowing through circuit along the path of full arrows. This means Junction diode D_1 conducts and D_2 does not conduct. So that we get same output as of a.c. input voltage due to junction diode D_1.

During the second half cycle, the upper end of S coil is at negative terminal and lower end is at positive terminal. It means junction diode D_1 is connected into reverse biased and D_2 in forward biased. Hence we say that D_1 donot conduct and D_2 conducts. So a maximum current will flow in circuit due to D_2 as shown by the path of dotted arrows. We get full output voltage as of input a.c. due to junction diode D_2. This procedure will be continue for alternate cycles as shown n fig. (6.16)

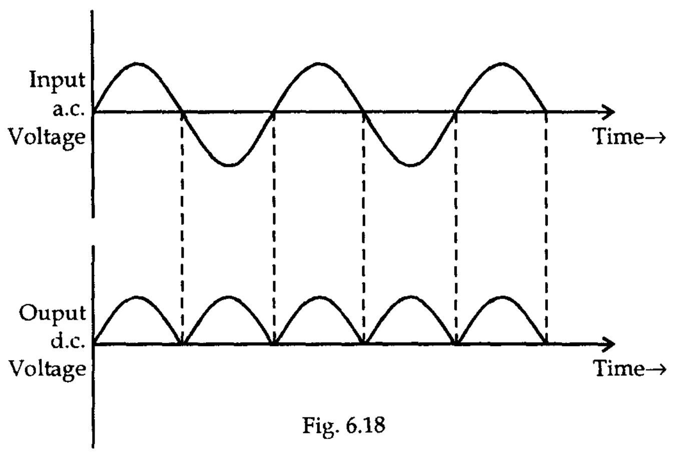


Fig. 6.18

Thus the full wave rectifier, pulsating voltage will be obtained. So that it can be made smooth by using a filter circuit.

JUNCTION TRANSISTOR :-

A junction diode can not be used for amplifying the signal. For amplification another type of semiconductor devices called TRANSISTORS are used.

A junction transistor is obtained by implanting a thin layer of one type semiconductor in between two thick layers of other similar type semiconductors. Thus a junction transistor is a semiconductor device having two junction and three terminals.

The junction transistors are mainly of two types namely :-

(i) NPN TRANSISTOR.

(ii) PNP TRANSISTOR.

A NPN transistor is obtained by implanting a thin layer of P-type semiconductor in between two similar thick layers of N-type semiconductors as shown in fig. (6.19). Also PNP transistor is obtained by implanting a thin layer of N-type semiconductor in between two similar thick layer of P-type semiconductors as shown in fig. (6.20).s

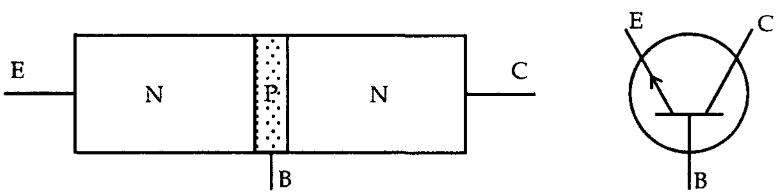


Fig. 6.19

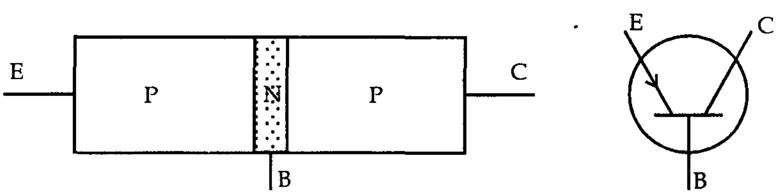


Fig. 6.20

The three sections of the transistor are called emitter (E), base (B) and collector (C). The base of transistor is thin and the number of majority carriers is always lesser as compared to that in emitter and collector. The doping of base is always light as compared to emitter and collector. The emitter supplies the majority carriers for current flows and collector collect them. The base provides the junctions for proper interaction between the emitter and collector.

When a transistor is used in a circuit, the base-emitter junction is always forward baised and the base-collector region is always reverse biased.

WORKING OF JUNCTION TRANSISTOR :-

(a) N-P-N TRANSISTOR :-

In a NPN transistor, the emitter base junction is made forward biased by connecting n-type semiconductor to negative pole of the battery and base collector junction is made reverse biased by connecting n-type semiconductor to positive pole of the battery as shown in fig. (6.21) (a) & (b).

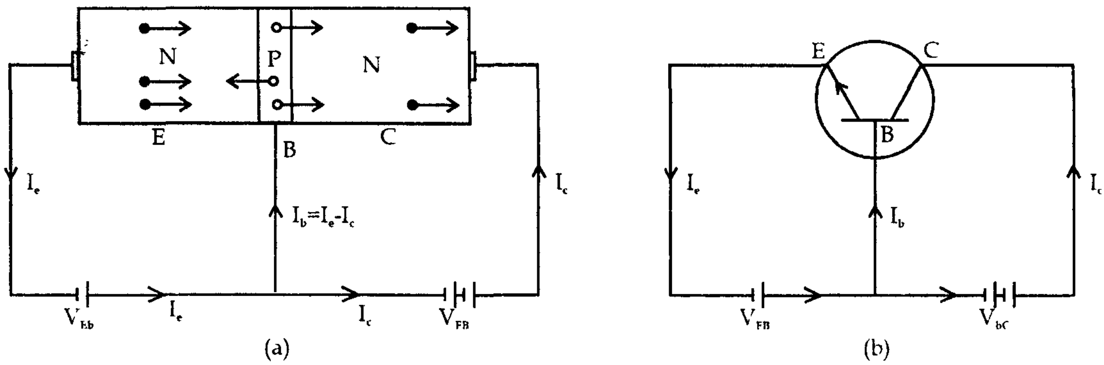


Fig. 6.21

The majority of carrier electrons in the emitter are repelled towards the base due to the forward bias. The base contains hole as majority carriers but their number density is small as it is doped lightly as compared to emitter and collector. Due to this the probability of electron hole combination in the base region is very low (≈ 95%) they cross into collector region, where they are swept away by the positive terminal of the battery EBC connected to the collector. Each electron that sweeps out by the collector and enters the emitter from the negative pole of the emitter base battery EBE. In NPN transistor the current is carried inside the transistor as well as external circuit by the electrons. If I_e, B_c and I_c are the emitter current, base current and collector current then, $I_e = b_c + I_c$

(B) PNP TRANSISTOR :-

In a PNP transistor emitter base junction is made forward biased by connected P-type emitted to positive terminal of battery V_{EB} and base collector junction will be reversed biased by,connecting P-type collector to the negative Pole of V_{CB} as shown in fig. (6.22) (a) & (B).

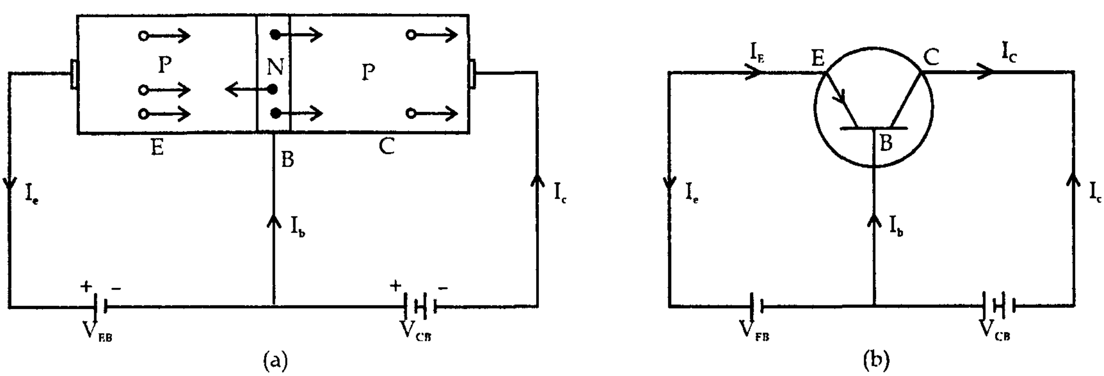


Fig. 6.22

In this case, the majority carriers in emitter are holes and they are repelled towards the base due to the forward bias. As the base is thin and lightly doped, it has a very low density of elelctrons. When holes enters the base region. Then only about 5% electron-holes combination takes place. Most of 95% reach the collector under the influence of reverese biased.

As one hole reches the collector an electron leaves the negative Pole of collector base battery V_{CB} and combine with it. At the same time an electron from emitter is released and create a hole in emitter and enters the positive Pole of the emitter base V_{EB}. Thus current in PNP transistor is carried by holes and at the same time their concentration is given by

$$I_e = I_b + I_c$$

Where I_b, I_e, I_c are the base current, emitter current and collector current.

ADVANTAGES OF TRANSISTORS :-

1. Transistors are shock Proof.
2. Transistors have almost unlimited life.
3. As transistors have no filament hence no power is needed to heat them.
4. As no heating is required, they are set into operation as soon as they are switched on.
5. They require low voltage to operate.
6. Transistors are small in size as the circuit involving transistors are very compact.
7. Transistors do not Produced any humming noise.

DISADVANTAGES :-

1. At high frequency transistors have Poor response.
2. At higher temperature transistors become conducting.

MULTIPLE CHOICE QUESTION

1. The material which do not allow the current to pass through is called
   a) Insulator b) Conductor c) Semiconductor d) Dielectric

2. The materials which allow the current to pass through are called
   a) Semiconductor b) Insulator c) Dielectric d) Conductor

3. The forbidden energy gap (Eg) in case of conductor is
   a) Negative b) Positive c) Zero d) Name of these

4. If the forbidden energy gap between the conduction band and valance band is approximately 5 ev then material is called.
   a) Conductor b) Insulator c) Semiconductor d) None of these.

5. Overlapping of conduction band and valance band means the material is
   a) Conductor b) Insulator c) Semiconductor d) None of these.

6. The electron in the outer most orbit of an atom is called.
   a) Primary Electron b) Secondry Electron
   c) Valance Electron d) Photo Electron

7. Si and Ge are best example of
   a) Conductor b) Insulator c) Dielectrics d) Semiconductor

8. The energy band gap for si-atom is
   a) 0.74 ev b) 1 ev c) 1.17 ev d) 1.20 ev.

9. At absolute zero, semiconductor behaves like
   a) Dielectrics b) Conductor c) Insulator d) Name of these

10. Intrinsic semiconductors are also known as
   a) Pure Semiconductor b) Impure Semiconductor
   c) Conductor d) Insulator

11 The majority carriers in the N-type semiconductor are
   a) Holes b) Electron
   c) Both holes & Electron d) None of these.

12. The minority carriers in the N-Type semicoductors are
   a) Holes b) Electron
   c) Both holes & Electron d) None of these.

13. In the N-Type of semiconductor, which type of impurity will be added.
   a) Trivalent Impurity b) Pentavalent Impurity
   c) Tetravalent Impurity d) None of these.

14. The majority carriers in the P-type semiconductor are
   a) Holes b) Electron
   c) Both holes & Electron d) None of these.

15. The minority carriers in the P-type semiconductor are
   a) Holes b) Electron
   c) Both holes & Electron d) None of these.

16. Aluminium is added to pure semiconductor to make it
   a) N-type b) P-type
   c) Both P and N-Type d) None of these

17. The width of the potential barrier for a PN Junction is of the order of
   a) 10^3m b) 10^6m c) 10^{-3}m d) 10^{-6}m

18. Conductivity of instrinsic semiconductor will be
   a) Decrease with rise in temperature
   b) Increase with decrease in temperature
   c) Increase with rise in temperature
   d) Decrease with decrease in temperature

19. The maximum current flowing inthe forward blased due to
   a) Majority Carriers b) Minority Carriers
   c) Diode d) None of these

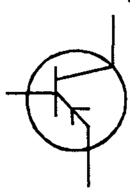
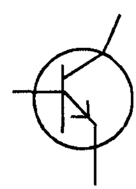
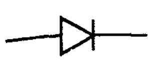
20. The current flowing in the reverse blased due to
   a) Majority Carriers b) Minority Carriers
   c) Diode d) None of these

21. The value of forward current for a diode is in
   a) A b) μA c) mA d) None of these.

22. An electronic device which converts A.C. Into D.C. is known as
   a) Oscillator b) Transformer c) Diode d) Rectifier

23. The frequency of A.C. is
   a) 40Hz b) 50Hz c) 60Hz d) 70Hz

24. The frequency of D.C. is
   a) Zero b) 10 Hz c) 50Hz d) None of these.

25. The following symble is the symbole of NPN Transistor.
   a) 
   b) 
   c) 
   d) 

26. For a transistor, the emitter base junction will be made
   a) Fowrard Biased b) Reversed Biased c) Diode d) Rectifier

27. The collector base junction will be made always.
   a) Fowrard Biased b) Reversed Biased
   c) Diode d) None of these

28. The temperature coefficient of resistance of semiconductor always
   a) Zero b) Positive c) Negative d) Infinity

VERY SHORT QUESTIONS ANSWER

1. What is semiconductor Physics ?
2. Define conductor.
3. Define Insulator.
4. Define semiconductor.
5. Define forbidden energy Gap.
6. What is the energy Gap in conductor, insulators and semiconductor ?
7. What is Pure and Impure semiconductor ?
8. Define Hole.
9. What is doping ?
10. Name the majority carriers and minority carriers in P-type and N-type semiconductor.
11. What is trivalent impurity ?
12. What is N-type semiconductor ?
13. What is P-type semiconductor ?
14. What is pentavalent impurity ?
15. What is PN Junction diode ?
16. What is depletion layer ?
17. How many types of blasing of a PN Junction diode ?
18. What is knee voltage ?
19. Define Rectifier ?
20. Name the two types of rectifier.
21. What is Half Wave and Full Wave rectifier ?
22 What is transistor ?
23. How many types of transistors ?
24. Why is the base lightly dopes ?
25. Name the three terminals of a transistors.

SHORT TYPE QUESTIONS

1. Differentiate conductors, Insulators and semiconductors on the bases of energy band gap.
2. Explain energy Band theory of solids.
3. Explaon Intrnsic Semiconductor.
4. Explain P-type and N-type semiconducotr.
5. Distinguish between Intrinsic and extrinsic semiconductor.
6. Distinguish between N-type and P-type semiconductor.

7. Explain PN Junction diode.
8. What do you mean by biasing of a diode. Explain forward biased and reverse biased of a diode.
9. Explain Characterstic of a PN Junction diode.
10. What is transistors ? Explain.
11. Explain the working of a PNP transistors with a lebelled circuit diagram.
12. Explain the working of a PNP transistor with a suitable circuit diagram.
13. What is the effect of temperature on semiconductors ?
14. What are advantage and disadvantage of a transistor ?

LONG TYPE QUESTIONS

1. Explain energy band of solids.
2. What are intrinsic and extrinsic semiconductors? Distinguish between N-type and P-type semiconductors.
3. Explain PN Junction diode and its V-I characterstics in forward biased and in reverse biased.
4. What is a rectifier? Explain Half wave and full wave rectifiers with input and output waveforms.
5. What is transistor? Explain the working of NPN and PNP transistors with suitable circuit diagram and also given theirs symboles.

ANSWER KEY FOR MULTIPLE CHOICE QUESTIONS

1.	a	2.	d	3.	c	4.	b	5.	a
6.	c	7.	d	8.	c	9.	c	10.	a
11.	b	12.	a	13.	b	14.	a	15.	b
16.	b	17.	c	18.	c	19.	a	20.	b
21.	c	22.	d	23	b	24.	a	25	b
26.	a	27.	b	28.	c				

UNIT - 7

MODERN PHYSICS

INTRODUCTION

Laser is an acronym that stands for a light amplification by stimulated emission of radiation.

Laser is one of the most important optical device to be developed in past 50 years. It is essentially an optical amplifier producing highly directional, monochromatic and coherent light.

Theortical idea of laser was first formulated in 1916 by Einstein when he predicted the existance of a new radiative process called stimulated emission of radiation. In 1954 charles Townes developed a microwave amplifier called MASER. Today laser and laser system find wide use in communication, computers, navigation, nolography, medicine, surgery, long distance measurements etc.

EXCITATION POTENTIAL :

It may be defined as the minimum energy required to raise an atom, from one energy level to another.

The energy of an atom is expressed in electron volt (ev) and hence

$1 \text{ ev} = 1.6\times10^{-19}$ J.

In ease of H-atom the energy of 1st level, we know that

$E = 13.6/n^2 = \text{ev}$

For 1st level, n = 1

$E_1 = -13.6$ ev

For 2nd level, n =2

$E_2 = -13.6/4 = -3.4$ ev

When an electron moves from 1st level to 2nd level, then it required energy.

$E = E_2 - E_1$

$E = -3.4 - (-13.6)$

$E = 10.2$ ev. is called excitation potential.

IONISATION POTENTIAL :

Ionisation is the process of removing an electron from the outer most orbit of an atom. The ionisation potential may be defined as the minimum accelerating potential that would remove an electron from outermost orbit.

In case of H-atom ionisation potential is 13.6 ev.

CHARACTERISTICS OF LASER :

Laser is an acronym that stands for light amplification by stimulated mission of radition. It is a device used for producing highly and strongly monochromatic, intense and cohrent, beam of light.

1. DIRECTIONALITY :

The convential light source emitts radiations in all the directions. Apertures are used to produce a narrow beam of light from such source, but laser emitts radiations only in one direction i.e. they have high degree of beam directionality.

The directionality of laser beam is usually expressed in terms of full angle beam divergence which is twice the angle that the outer edge of the beam makes with the axis of the beam. The outer edge of the beam is the point at which the strength of the beam drops to i.e. times its value at the centres.

2. MONOCHROMATICITY :

This is the most important property of laser light. A light of single wave length is called monochromaticity. So the light is more monochromatic source as compared to an ordinary souce.

3. COHERENCE :

A coherence is a measure of degree of phase correlation that exist in the radiation field of a light source at different location and different times. These are two types of coherence.

a) Longitudnal or Temporal Cohrence :

In which the field at a point and the field at the same point at a later time are correlated. A wave is said to be a temporal coherence if the phase difference between the two fields is constant during the period of observation of few micro seconds. If the phase difference changes frequently in an irregular fashion during the period of observation then the waves are called non-coherent.

b) Transeverse of Spatial Coherence :

Two fields at two different points on a wave front of a given electro-magnetic wave are said to be spatially cohrence. If a constant phase difference is maintained over any time t.

4. INTENSITY :

Light from a lamp almost uniformly spreads in all the directions. At a distance of 30cm. from a 100 watt filament lamp, power entering the eye is less than 10^{-3} watt. Laser gives out light into a narrow beam and its energy is concentrated in a small region and therefore its intensity is very high. Even a one watt laser appears many thousands time more intense than a 100 watt filament lamp.

Stimulated Absorption, Spontaneous Emission & Stimulated Emission :-

i. Stimulated Absorption :

When an electron in a atom is raised from its ground state (E_1) to higher state (E_2) by the absorption of a photon.

Then the phenormenon is known as stimulated absorption as shown in fig. 7.1 (a)

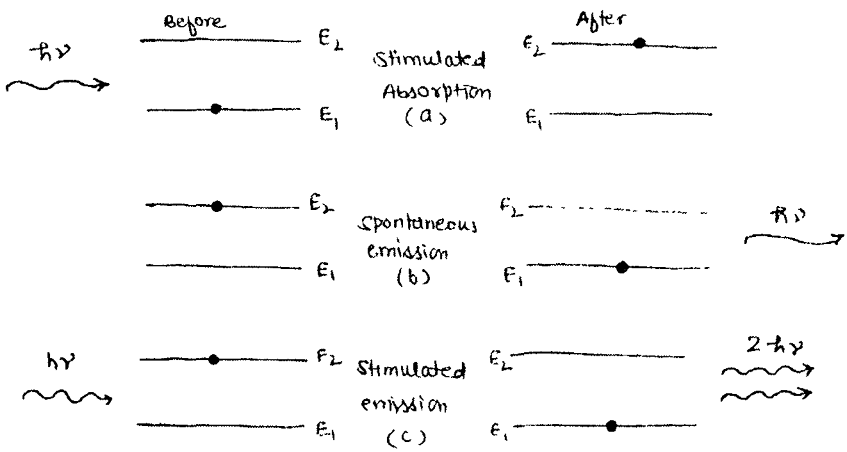


Fig.(7.1)

ii. Spontaneous Emission

When the atoms are already in a exicted state (E_2). No external radiation is required to start the emission process. An atom in an excited state (E_2) spontaneously gives up its energy and fall to E1 releasing a photon of energy $h\nu = E_2 - E_1$. This pnenomenon is known as spontaneous emission as shown in fig. 7.1. (b)

iii. Stimulated Emission

When an incident photon of energy (hr) passes by an atom in an excited state (E_2), it stimulates the atom to drop to the ground state (E_1) and the atom releases a photon of the same energy, direction, phase as that of passing by photon. This produced two identical photons in place of one. This pnenomena is known stimulated emission fig. 7.1 (c). By this process we increase the, intensity of incidence baem and make possible, the amplification of light in laser.

PRINCIPLE OF LASER :

The basic principle of the laser action is that of stimulated emission. Suppose a substance consists of a large number of excited atoms all in the same energy state.

When a photon of light frequency interacts with the atoms in the excited state. It may induce the election to make transition to the lower state. Hence a photon is emitted from the atom which agrees with the incident photon in phase, direction as shown in fig. 7.2. This is called stimulated emission.

These two identical photons cause stimulated emmission from the excited atoms. The process is repeated when these photons pass over excited atoms. The net result of stimulated emission becomes stranger and stronger. But on the other hand same unexcited atom in the ground atoms also gets the energy from photons and is raised to excited state. This process is known as stimulated absorption. Hence there are two process in progress, namely stimulated emission and stimulated absorption. But the principle of laser is based upon the stimulated emission so we dominate the stimulated emission over the stimulated absorption by population inversion.

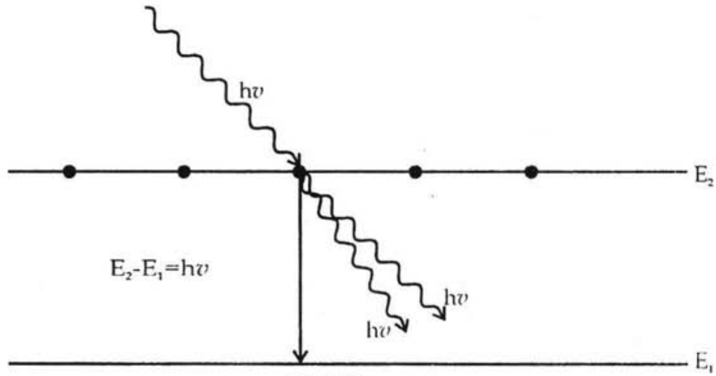


Fig. 7.2

Thus the process which dominates the stimulated emission over stimulated absorption is knwon as population inversion.

The population inversion is brought out by the process called optical pumping. Optical pumping means raising of all the atoms from ground state to excited state.

The excited incident photons raise the atoms from the lower energy level E_1 to the higher energy level E_2. Most of the electron reaching E_2 will make non-radiated emission to the metastable state E_3 as shown in fig. (7.3) metastable state is the stage between the ground state and excited state in which a atoms lies in the order of 10-6 sec. only.

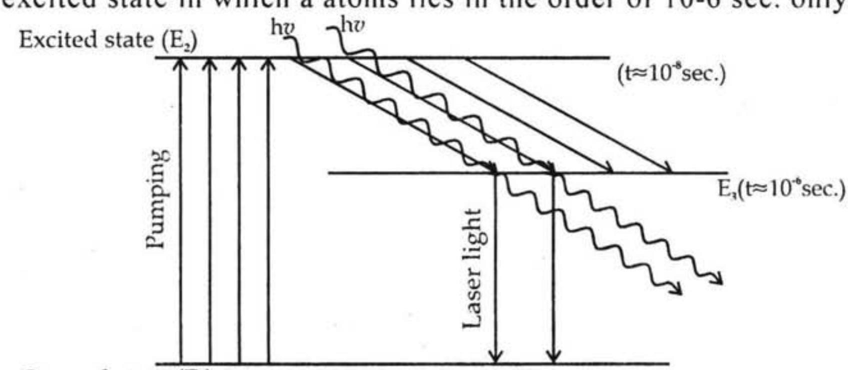


Fig. 7.3

The probabiltiy of transition (E_2-E_3) is much larger, than for the transition (E_2-E_1) and the ecess energy (E_2-E_3) is used to heating the substance. In this way the number of electrons in the metastable state E_3 are made to exceeds the number of lectrons in the state E_1. This is called population Inversion.

RUBY LASER :

It is a solid laser and first operating laser using three level scheme of population inversion. Its main part is a ruby rod called the laser rod. Ruby is a crystal of Aluminium oxide (Al_2O_3) with the addition of 0.03 to 0.05% of chromium oxide (Cr_2O_3) in which Cr ions replace some of a Al. ions in the crystal lattice. The ruby rod are 2 to 30cm in length and 0.5 to 2 cm in diameter. Flat end faces of the end arc made strictly parallel and are silvered so that the surfance of one face A becomes fully reflected and other face B partially reflected. The rod is surrounded by a cylindrical glass tube through liquid nitrogen circulates to keep the rod cool. The ruby rod is arranged along the axis of helical xenon-flash tube. The flash tube is provided with suitable power supply. The tube is made to flash for a few mili seconds. The diagram of ruby laser is shown in fig. (7.4).

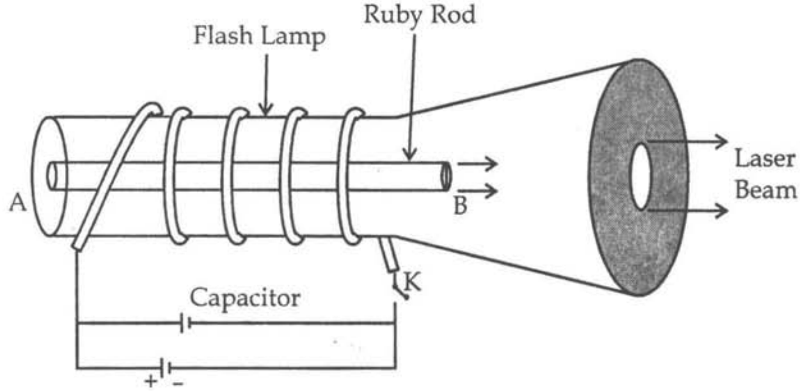


Fig. 7.4

WORKING :-

When light from the flash tube is made to fall upon the ruby rod. A major part of the energy emitted by the tube is used to heat the apparatus. Some energy in the form of blue and green radiations is absorbed by the ruby rod and used to excite chromium ions from ground state G to the level E_2. M is a metastable state of the system having a life time of about 3 milisecond at room temp. It has two sublevels of separation $29cm^{-1}$. From the level E_2 most of the atoms take non-radiative transitions to levels M. The probability of transition from E_2 to M is much higher than that from E_2 to G. As a result the level M becomes more populated than the ground state G. Population inversion thus takes place and proper condition for the induced emission are created. Such a system with population inversion in very unstable. So the propability of spontanceaus emission may be very high.

The chromium ions consists of two bands E_2 and E_1 respectively centred at λ = 4200Å and λ = 5500Å and are called Blue Band and Green Band. The emitted photons from M to G corresponding to red light of wavelength $\lambda_1 = 6943Å$ and $\lambda_2 = 6928Å$. But λ_1 attains laser thresold much before λ_2 so that laser action takes place for λ_1 only. The energy level diagram is shown in fig. (7.5)

The function of a mirror at the end faces is to make stimulated emission dominant over the spontaneaus emission by reflecting the photons back and forth form the ends of the rod. A narrow intense flash emerges from the partially silvered end which lasts for about a micro second.

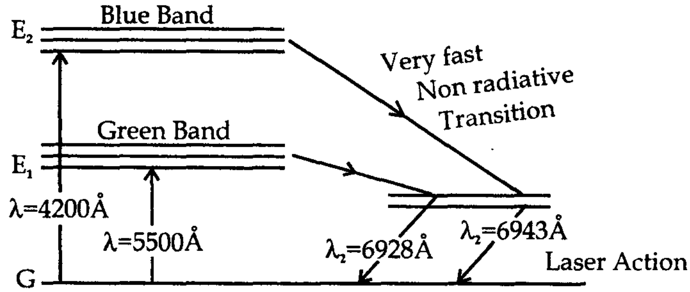


Fig. 7.5

APPLICATIONS OF LASER :

The Laser is of high application in several fields like industry, communication, medicine etc. The most important application of laser are given below :

i. The Measuring of Distance :

Lasers are used for measurement of large distances i.e. The distance between the moon and earth. By measuring the time between sending and receiving back by the laser beam, the distance between the earth and moon can be determined.

ii. Laser Welding :

Laser lights are used for both types of welding i.e. in spot welding and in seam welding. Spot welding means a joint only at a spot in one operation and seam welding means we required a heavy job like joining the tips of blades of a gas turbine.

iii. Cutting :

Hard metal can be cut by the laser light with a jet of oxygen. So that the cutting products are side by side removed. A gas laser is shown in fig. (7.6) Gas commonly used in laser cutting are air organ and oxygen. But oxygen gas are most commonly used for cutting the metal. Air has 20% oxygen and if air is used in placed of oxygen then the speed of cutting the metal beams is slow as compared in case of oxygen.

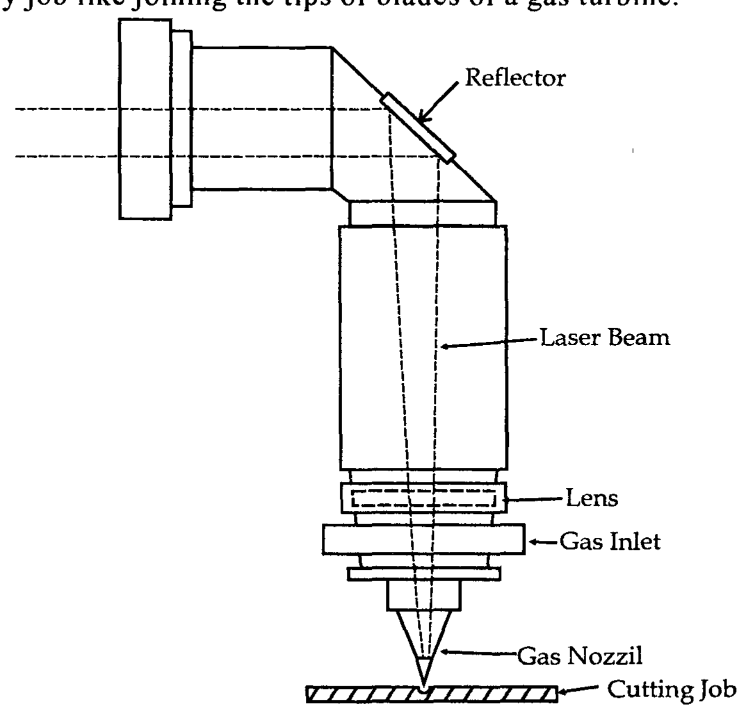


Fig. 7.6

iv. Drilling :

Hard materials can be easily drilled by laser light. The drilling in the material made of range from 0.1mm to 1.2mm with the length to diameter ratio of 100:1

v. Communication :

The laser lights are also used for communication i.e. in optical fitures. Optical fibre can be used for input and output such as link between the two telephone exchange. Also television programmes can be transmitted by laser light.

vi. In Medical :

Laser lights can be also useful in medical field. e.g. in operation theater of eye, to see the inner parts of the body by using the optical fibres. It can be often used for control the internal bleeding, treatment of king and to remove the tumors.

vii. Scientific Research :

Lasers are used to study the chemical reaction. Many chemical reactions are accelerated by exposing them to a laser beam. This is used in chemistry.

viii. Allignments :

Because the laser lights are highly unidirectionality, so the laser light can be used for testing alignment for a layer distance.

ix. Entertainment :

The vedio compact discs (VCD) are operated with the help of laser in the CD player or DVD player. In computers also we use the VCD by the laser light.

OPTICAL FIBRE :

Optical fibre is based on the phenomenon of the total internal reflection.

Optical fibres consist of thousands of very long fine quality of glass or quartz of refractive index about 1.7 or so. The diameter of each fibre is of the order of 10^{-4}cm. The fibres are coated with a thin layer of material of lower refractive index of the order of 1.48.

Light incident on one end of the fibre at a small angle passes inside and undergoes repeated total internal reflections inside the fibres. It finally comes out from the other end, even if the fibre is bent or twist in any form as shown in fig. (7.7) There is almost no loss of light though the sides of the fibres.

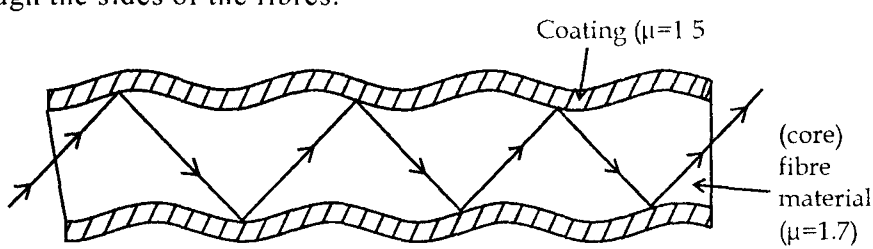


Fig. 7.7

The condition is that the angle of incidence of light must be greater than the critical angle for the fibre material w.r.t. its coating.

OPTICAL FIBRE MATERIAL :

The material required for optical fibre arelisted below.

1. It can be made of long, thin and flexible fibre.
2. It can be of particular wavelength in order of the optical fibre.
3. The refractive index of core and cladding be slightly different to each other.

The plastic fibre material are not often used because they have high attenuation than the glass.

TYPES OF OPTICAL FIBRES :

The optical fibres are divided pn to two types :

i. Step Index Optical Fibre :

Such type of optical fibre are made by core of inform refractive index surrouded by cladding of other material that have lower refractive index as compared to the core. The incident ray incidences at different angle and travels in different directions and emerge from the optical fibre at a different time at different direction as shown pn fig. (7.8)

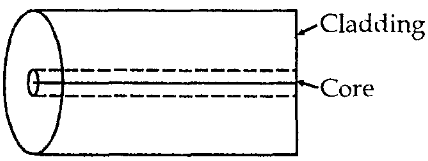


Fig. 7.8

ii. Graded Index Optical Fibre :

In this types of optical fibres the core is made of non uniform refractive index and cladding have uniform refractive index. The incidence ray entering at different angles, travels with a periodic path with same period in rase and time as shown in fig. (7.9)

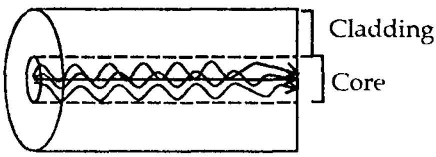


Fig. 7.9

LIGHT PROPAGATION :

The light propagation in step-index option fibre are known as single mode fibre because they have narrow core, allow only one wave to pass through them ,such types of fibres are called single mode option fibres.

The light propagation pn graded index optical fibre are multi mode because core of that fibre is widely used and allows different waves to passes through them, such fibres are called multimode optical fibre.

APPLICATIONS OF OPTICAL FIBRES ;

1. A bundle of optical fibre is called light pipe and this pipe can transmit on image. It is flexible and can be twisted in a desired manner so it can be used in medical and optical examination of inaccessible parts of an human body. Example a patient's stomach can be viewed by inserting one end of the light pipe into the stomach through mouth.
2. Optical fibres are used Pn transmission and reception of electrical signals by converting them first into light signals.
3. These are used in telephone and other transmitting cables. Each fibre can carry upto 2000 telephone messages.
4. These are used for local area network (LAN), network wire to computers etc.

SUPER CONDUCTIVITY :

Prof. K. Onnes in 1911 discovered certain metals and alloys which at very low temperatures lost their resistance considerably. This pnenomenon is known is SUPER CONDUCTIVITY.

As the temperature decrease the resistance of the material also decrease but when the temperature reaches a certain critical value means at critical temperature, the resitance of the material becomes zero. Then materials behaves as a superconductor. The critcal temperature for different materials will be different. In case of Hg the critical temperature will be 4 2 k.

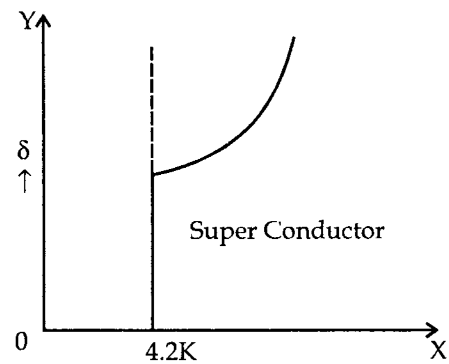


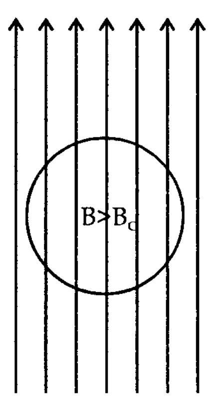
Fig. 7.10

MEISSNER EFFECT :

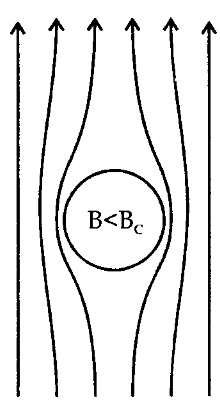
Supperconductors are perfectly diamagnetic means there are no magnetic field inside them under any circumstances. A applied magnetic field at which a superconductor becomes a normal conductor is called critical field.

In fig. (7.11), Bc shows that the critical magnetic field at which superconductor becomes a normal conductor.

Now if we put a sample of super conductor in a magnetic field (B) stronger, than critical magnetic field i.e. (B>BC) and take temperarature of the material T above the



$T>T_c$
Fig. 7.12



$T<T_c$
Fig. 7.13

critical temperature means (T>Tc). Then the magnetic lines of force crosses the sample of super conductor means there will be some magnetic field inside the super conductor as shown in fig. (7.12)

Now if we put the sample in magnetic field B weaker than critical magnetic field (Bc) and temperature of sample T less than the critical temperature (Tc) mean T<Tc then the magnetic lines of force does not cross the sample, but expelled from the interior part of the sampel as shown in fig. (7.13). Thenthis pnenomenon is known as meishner effect.

TYPES OF SUPER CODUCTORS :

The superconductors are divided into tow types :

1. Type - I Super Conductor
2. Type - II Super Conductor

1. Type-I Super Conductor :

Type - I superconductor are also known as soft super conductors. This is existing into two states only namely normal state and super conducting as shown in fig. (714). Type 1st super conductor are follow the meissner effect means they have diamagnetic, therefore magnetic flex do not pass through them. Type-I superconductor are usually pure specimen of elements like Al, Hg, In, Ga, Zn, Pb, etc. having very low critical magnetic field, so that it can not be used for the coirs of strong electro magnets. Type-I super conductor change from super conductor into normal state when the critical field is crossed.

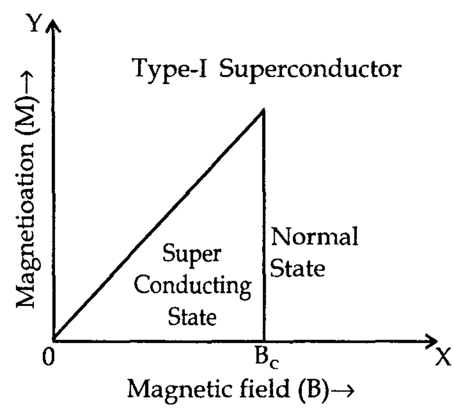


Fig. 7.14

2. Type-II Superconductor :

Type-II superconductor are also known as hard superconductor and existing mixed state in between of superconducting state and normal state as shown in fig. (7.15).

These conductors have two critical magnetic B and B . The mixed state is also known as vortex state and it is lies in between two critical field B , and B . If the applied

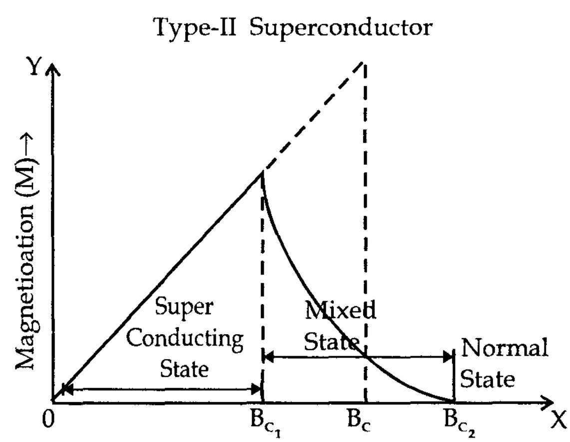


Fig. 7.15

magnetic field is less than B , then type-II super conductor behaves as a type-I superconductor. For these type of super conductor the speciman is perfectly diamagnetic below B and hence magnetic flux can not the speciman.

Then B is called lower critical magnetic field and B is called upper critical magnetic field. It is produced of magnetic field of order of Tedia.

APPLICATIONS OF SUPERCONDUCTORS :

1. Superconductors are used for making very strong electromagnets.
2. It plays an important role in material science and in high energy particle physics.
3. It is used for producing very high speed computers.
4. It is used for transmission of electric power.
5. Electrical machines and transformers developed using super conductor will have small size and high frequency.
6. These are used to generators and fusion device where large field of about 5T or more is needed.
7. These are used for super magnetic energy storage units (SMES)

ENERGY SOURCE :

Energy sources are divided into two parts :

1. Conventional Energy Source
2. Non Conventional Energy Source

1. CONVENTIONAL ENERGY SOURCE :

The source of energy which are exhaustible and have been accumulated in the nature over a long time are known as conventional energy sources.

These sources of energy are found on the earth in limiting amount and after their use we cannot use these resources again e.g.

i. Coas ii. Petrolium

iii. Natural Gas Etc.

2. NON CONVENTIONAL ENERGY SOUCE :

These are inexhaustible and are being produced continuous in nature are known as non -convensional energy souce e.g.

i. Biogas ii. Solar Energy

iii. Wind Energy iv. Water Energy

v. Nuclear Energy etc.

i. **BIOGAS :**

It is a mixture of methane, CO2, Hydrogen and Hydrogen Sulphide.

ii. **SOLAR ENERGY :**

The radiation comes from the sun warm the environment. Thus we get the energy from the sun. This type of energy is called solar energy.

iii. **WIND ENERGY :**

A moving body passes a kinetic energy. Thus air is moving and called wind. So the kinetic energy of the wind is called wind energy.

iv. **WATER ENERGY :**

The energy obtained from the flowing water in the rivers, sea, is called Hydro energy or water enrgy.

v. **NUCLEAR ENERGY :**

The energy obtained by a nuclear reaction is called nuclear energy for example in process of nuclear fussion and nuclear fission a large amount of energy is released, This is energy is called nuclear energy.

MULTIPLE CHOICE QUESTION

1. The basic principle of the LASER is
   a) Stimulated emission b) Stimulated Absorption
   c) Spontaneoves Emission d) None of these

2. In the following given which is not property of the lasor :
   a) Directionality b) Coherence c) Musical Sound d) Intensity

3. The velocity of light is .... m/sec.
   a) $3x10^6$ m/sec. b) $3x10^5$ m/sec. c) $3x10^7$ m/sec. d) $3x10^8$ m/sec

4. The value of 1 electron volt = ------------J.
   a) $1.6x10^{19}$ J b) $1.6x10^{20}$ J c) $1.6x10^{-19}$ J d) $1.6x10^{-20}$ J

5. The time occupy by an atom in a metastable is
   a) 10^5 sec. b) 10^6 sec. c) 10^{-5} sec d) 10^{-6} sec

6. The stimulated emission is dominent over stimulated absorption by the process is called.
   a) Population Inversion b) Optical Pumping
   c) Nuclear Energy d) None of these

7. Light emitted by ordinary source of light is
   a) Conereut b) Monochromaticity
   c) Non-coherent d) None of these

8. An electron can remain in excited state is
   a) 10^8 sec. b) 10^{-8} sec c) 10^7 sec d) 10^{-7} sec

9. The ruby laser compositionof
   a) Al_2O_3+0.03 to 0.05% of Cr_2O_3
   b) Al_2O_3+0.01% of Cr_2O_3
   c) Al_2O_3+10% of Cr_2O_3
   d) None of these

10. The output of Ruby laser is
    a) A pulsed ware
    b) A saw tooth wave
    c) Continuous ware
    d) None of these

11. The basic principle of optical fibre is
    a) Stimulated emission
    b) Stimulated absorption
    c) Spontaneous emission
    d) Total internal Reflection

12. The refractive index of care is
    a) Equal to that of cladding
    b) Less than that of cladding
    c) Greater to that of cladding
    d) None of thes above

13. The angle of incidence for a total internal reflection pnenomenon is always
    a) Less than the critical angle
    b) Greater than critical angle
    c) Equal to critical angle
    d) Zero

14. Who is the best optical fibre materials in the following :
    a) Glass b) Plastic c) Quartz d) Iron

15. For a superconductor at lower temperature, the resistance will be
    a) Increase
    b) Infinity
    c) Suddenly fall to zero
    d) None of these

16. Type-I superconductor is also known as:
    a) Soft supercondcutor
    b) Hard superconductor
    c) Mixed superconductor
    d) None of these

17. Type-II superconductor also known as :
    a) Soft supercondcutor
    b) Hard superconductor
    c) Mixed superconductor
    d) None of these

18. Type-II superconductors can produced magnetic field of the order or
    a) 1 Tesla b) 10 Tesla c) 100 Tesla d) None of these

19. Solar energy is the example of
    a) Convensional source of energy
    b) Non-convensional source of enrgy
    c) Mechanical energy
    d) None of these

20. Superconductors are perfectly
    a) Paramagnetic b) Diamagnetic c) ferromagnetic d) None of these

21. The temperature at which value of resistance fall to zero is known as

a) Kelvin Temperature
b) Critical Temperature
c) Zero Temperature
d) None of these

22. The value of the magnetic field at which a superconductor change into normal conductor is called.
a) Magnetic Field b) Meissner Effect c) Critical Field d) Electric Field

23. The wavelength of red light is
a) 6942Å b) 6943Å c) 6944Å d) 6945 Å

24. When an electron gets energy from the photon and more to excited state then the process is called.
a) Stimulated Absorption
b) Stimulated Emission
c) Spontaneous Emission
d) None of these

25. The energy of an photon is
a) $E = h\nu$ b) $E = mc^2$ c) $E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$ d) None of these.

VERY SHORT ANSWER QUESTION

1. What do you understand for LASER ?
2. What is the basic principle of LASER ?
3. Define Ionisation potential.
4. Define Excitation Potential.
5. Define stimulated emission.
6. What is population inversion?
7. What is the basic principle of optical fibres?
8. What is cladding?
9. What is superconductor?
10. Define critical magnetic field.
1. Define Meissner effect.
12. Give the name of two, type I and type II superconductor.
13. What do you mean by convensional source of energy?
14. What do you mean by non convensional source of energy?

SHORT ANSWER QUESTION

1. Explain the pnenomenon, stimulated emission, stimulated absorption and sponstaneous emission.
2. What do you stands for laser? Explain the principle of laser.
3. Explain population inversion and optical pumping.

4. Explain the application of laser./
5. Write a short note an optical fibre. Explain optical fibre materilas.
6. Explain the application of optical fibres.
7. Explain superconductivity.
8. Explain Type-I and Type-II superconductivity
9. Write down the application of super conductors
10. Explain the convensional and non convensional source of energy.
11. Explain meissner effect.

LONG ANSWER QUESTIONS

1. What is laser? Explain its basic principle and its application.
2. Describe the construction of working of Ruby Laser with a energy level diagram.
3. What is optical fibre? What are the optical fibres materials? Explain their application.
4. What is superconductor? What is the effect of magnetic field on superconductor. Also discuss its application.
5. Explain Type-I and Type-II superconductors also its applications.

ANSWER KEY FOR MULTIPLE CHOICE QUESTIONS

1.	a	2.	c	3.	d	4.	c	5.	d
6.	a	7.	c	8.	b	9.	a	10.	c
11.	d	12	c	13	b	14	a	15	c
16.	a	17.	b	18.	b	19.	b	20.	b
21.	b	22.	c	23.	a	24.	a	25	a

EXPERIMENTAL PHYSICS - II

LIST OF PRACTICALS

1. To determine and verify the time period of cantilever by drawing graph between Load (w) and Depression (p)
2. To determine the Magnifying Power of Compound Microscope.
3. To determine the magnifying powerof astronomical telescope.
4. To verify Ohm's law.
5. To verify of resistance in series.
6. To verify of resistance in parallel.
7. To convert a galvanometer into an ammeter of a given range.
8. To convert a galvanometer into an voltmeter of a given range.

Manoj kumar

EXPERIMENT No.1

AIM :

To determine and verify the time period of a cantilever by plotting graph between land (W) and depression (D).

APPARATUS REQUIRED :

Cantilever (Fixed horizontally at one end), Stop Watch, Weight Box, Meter Rod and Clamp.

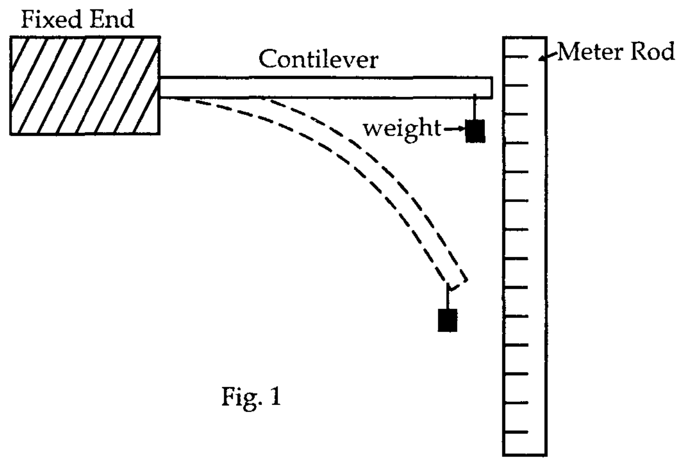


Fig. 1

THEORY :

A cantilever is simply, a metallic rod of about 1 meter length fixed at the one end and free at the other end. If the free end of the cantilever is loaded with the help of weights, a depression (D) is produced upon the length of the lever. The depression (D) in the cantilever depends upon the weight hung. and when the weight is released the free end of cantilever begins vibrate. The time of vibration is given by the formula.

$$t = 2n\sqrt{\frac{D}{g}}$$

Where

t = Time period of vibration

D = Depression produced by suspended load.

I = Accelration due to gravity.

So the time period of vibration varies with variation of load suspended. This time period can be verified by actual measurement by finding the time period for 20 vibrations with the help of stop watch and calculating that for one vibration.

PROCEDURE :

1. Fix one end of the cantilever at the end of laboratory table with the help of clamp.
2. Place a meter rod in vertical position near the free end of cantilever and note the reading of unloaded cantilever.
3. Hang a weight of 20gm near the free end of beam and note the depression (D) with the help of meter rod.

4. Repeat procedure 3 for the weight 40 gm., 60gm., 80gm., and 100gm. and note the depression in each case with the help f meter rod.
5. Now plot a graph between load (W) and depression (D).
6. Now place a weight of say 100gm. at the end of beam and let it vibrate note the time taken for 20 vibration with the help of stop watch.
7. Note two more readings with the same weight and find the mean time period for 20 vibration.
8. For verification the time period use the relation

$$t = 2n\sqrt{\frac{\text{depression}}{g}}$$

OBSERVATION :

a) Table for Depression (D) versus Load (W)

No. of Observation	Load (W) in gm.	Depression in cm.
1.	20	
2.	40	
3.	60	
4.	80	
5.	100	

b) Table for time period of vibration least count of stopwatch = s

Length of Cantilever = cm

Load of free end of Cantilever = 100 gm.

No. of observations	Load (W) in gm.	Length of Cantilever in cm.	No. of vibrations	Time taken for 20 Vibrations
1.	100		20	
2.	100		20	
3.	100		20	

Mean time T = ... S

CALCULATION :

Time taken for one Vibration = $\frac{T}{20}$ = -------S

Verification of the time period :-

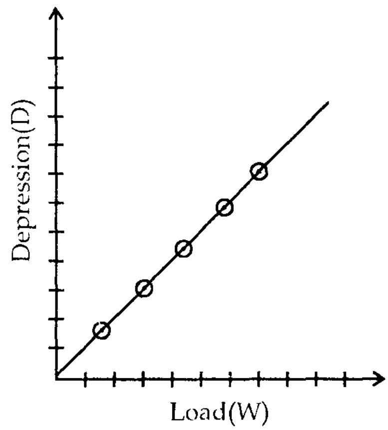
Depression D for 100 gm. Load = ... cm

Time period T = $t = 2n\sqrt{\frac{D}{g}}$

RESULT :

Thus with experimental error time period of cantilever is nearly equal to observed value of time period.

Graph between Depression (D) and Load (W)



PRECAUTIONS :

1. Length of the cantilever shold remain unchanged.
2. One end of the cantilever should be tightly clamped.
3. Meter rod used for recording depression should be vertical.
4. Weight should be hanged at the same place at the free end of cantilever.

VIVA-VOCE

Q. 1 What do you mean by a Cantilever?

Ans. Cantilever is a beam fixed at one end and another end kept free to vibrate.

Q. 2 What is the nature of vibration of a Cantilever?

Ans. Vibration of Cantilever is simple harmonic.

Q.3 Why the vibration of cantilever is SHM.

Ans. Because accelration of vibration is proportional to displacement and always directed towards fixed mean position.

Q. 4 What is the Time period of vibration?

Ans. The time taken by a body to complete one vibration in SHM is called time period.

Q. 5 What do you mean by vibration?

Ans. The to and for motion of a body about its mean position is called vibration.

Q. 6 Does the time period of cantilever depends upon its lenght?

Ans. No, time period is independent of lenght.

Q. 7 How does time period depends upon depression?

Ans. Time period T is directly proportional to the depression.

EXPERIMENT No.2

AIM :

To set up two lenses to form a model of Compound Microscope and calculate its magnifying power.

APPARATUS REQUIRED :

An optical bench, a convex lens of short focal length (5cm) with apperture, a convex lens of large focal length (15cm) with large aperture, two optical needlles (One thick and one thin), screen, uprights, knitting needle with the half meter rod.

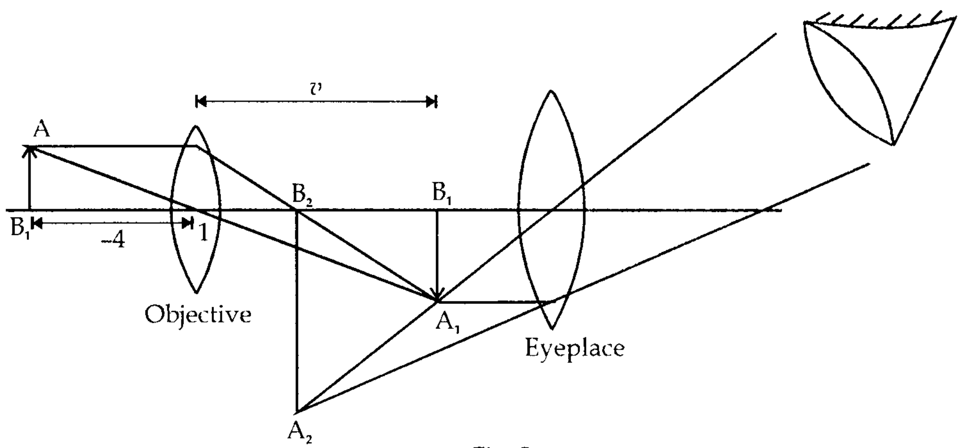


Fig. 2

THEORY :

The magnified image is formed beyond 2F when object is placed between F and 2F of a convex lens and another convex lens is placed in such a way that this image formed in first lens is between F and optical centre of second lens. Then a magnified virtual image of this image is again formed. Ist lens forwards small objects and is called objective and 2nd lens near which eye is kept to see final image is called eye piece. This set up of two lenses with the objective of smaller focal length of eye piece of larger focal length to see the magnified image of a small object is called Compound Microscope.

Its magnified power is given by

$$M.P = \frac{v}{u}\left(1+\frac{D}{fe}\right)$$

Where

v and u are for objective,
D is least distance of distinct
Vision and fe is focal length of eye piece.

PROCEDURE :

1. First find a rough focal length of two convex lenses i.e. objective and eye piece.
2. Find actual focal length of two lenses by u-v method.
3. Place the actual object in the form of a small narrow head in the hole of the card-board screen at a distance u slightly greater than the focal length of the objective infront of it.
4. See inverted image of the object in the objective, and with the help of a needle remove parallax set the image and needle.
5. Measure u and v for the objective lens.
6. Now take eye piece and place it at a distance little less from the focal length of the eye piece on the outer side of the image needle.
7. Remove the needle and place your eye close of this lens and look through this magnified image of the arrow head.
8. Make adjustment for final image at least distance vision.

   Calculate M.P. by formula, $MP = \frac{v}{u}\left(1+\frac{D}{fe}\right)$
9. Now in place of cardboard place a mm scale vertically.
10. Place the other mm scale vertically at a distance of 25cm. from the eye piece.
11. Look at the image of the first, through the microscope with one eye, keeping the other eye closed. When the image is clearly visible in the other eye, look directly on the second scale and adjust the microscope so that the images lie side by side.
12. Count the no of divisions (N) of the second scale (see directly) that coincide with the no. of divisions (n) of the first as (seen through the microscope) calculate the

    M.P. by relation $M.P = \frac{N}{n}$.

OBSERVATION :

Focal length of objective lens Fo = ...cm
Focal length of the eye piece Fe = ...cm
Distance of object from objective u = ...cm
Distance of image from objective v = ...cm
Least distance of distinct vision D = 25cm.

S. No.	No. of Division Seen	No. of division see through Microscope n	M =N/n
1.			
2.			
3.			

CALCULATION :

$$M.P. = \frac{v}{u}\left(1+\frac{D}{fe}\right)$$

Magnifying power by measurement $M = \frac{N}{n}$

RESULT :

Magnifying power by formula is .... and by measurement is ....

PRECAUTIONS :

1. Distance between scale and Telescope should be as large as possible.
2. Find magnifying powers by both the methods.
3. Eye should be very close to the eye piece while seeing through it.
4. Keep the scale vertical.
5. Principle axis of the two lenses should be in the same line.
6. Use objective and eye piece of proper focal length.

VIVA-VOCE

Q.1 What is meant by a Microscope?
Ans. It is a device used to see small and nearer objects in a clean and magnified form.

Q. 2 Name the types of microscopes?
Ans. i. Simple Microscope
ii. Compound Microscope

Q.3 Define a lens.
Ans. It is a piece of transparent medium bourded by at least one spherical surface.

Q. 4 What is the different set simple and compound Microscope?
Ans. A simple Microscope is a simple convex lens but a Compound Microscope consists of two convex lenses at a suitable distance.

Q. 5 What do you mean by magnifying power of a Microscope?
Ans. It is defined as the ratio of size of image to the size of object.

Q. 6 What is the nature of image formed by the Compound Microscope?
Ans. The image formed by compound microscope is virtual, inverted and magnified in nature.

Q. 7 What is object distanced (u) and image distance (v)?
Ans. The distance of object from the optical centre is called object distance (u) and distance of image normed by lens from the optical centre is called image distance (v).

Q. 8 What is least distance by distinct vision for a normal eye?
Ans. The least distance of distinct vision for normal eye is 25cm and 18 denoted by D.

EXPERIMENT No.3

AIM :

To set up a model of Astronomical Telescope by selecting suitable lenses and determine its magnifying power.

APPARATUS REQUIRED :

Optical Bench, Convex Lens, used as objective of focal length (40-50cm), Convex Lens used as eye-piece of focal length (10cm). A needle uprights for lenses and needle, a screen, long vertical scale.

a. When final image is formed at the distance of distinct vision (D)

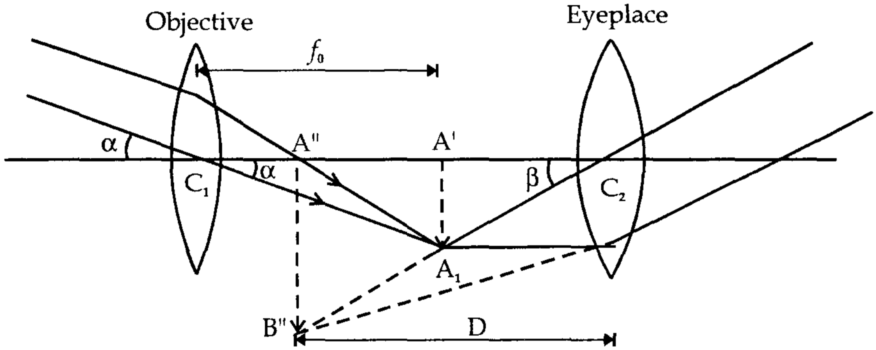
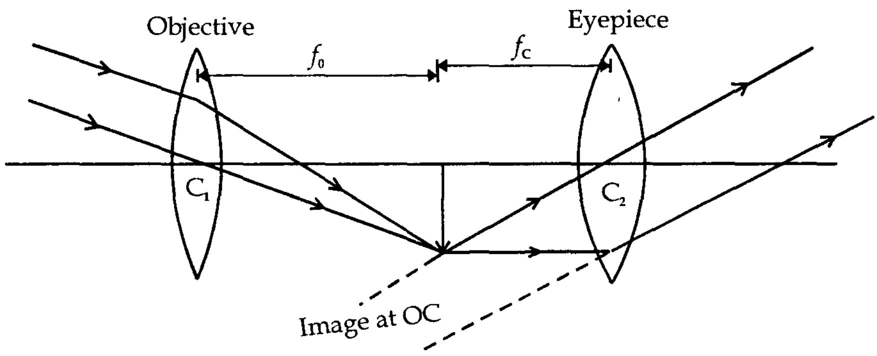


Fig. 3(a)

b. When final image is formed at infinity objective.



THEORY :

The lens facing the objective is called objective and the lens nearer to the eye is called eye piece. The objective forms the real and inverted image 'A B' of the astronomical object. The eye piece acts like a simple microscope, for the image A' B'. There ar two type of adjustments when final image is at the least distance of distinct vision (D). Fig. 3 (a) And 2nd when the image is act infinity. It is called normal adjustment. Fig. (3 b)

Magnifying Power (M.P.) = $\frac{F_o}{F_e}$ for normal adjustment

Magnifying Power (M.P.) = $\frac{F_o}{F_e}\left(1+\frac{F_e}{D}\right)$

for when image is at least distance of distinct vision.

Where F_O = Focal length of objective lens
F_e = Focal length of eye piece.

PROCEDURE :

1. Measure rough focal length of the objective and eye-piece by making a sharp image of the distant object on the screen or wall.
2. Objective lens is set up on the upright on the optical bench.
3. Mount a needle on the upright and place it on the other side and locate the position of image of distant object by removing the parallax between the needle, the inverted image and needle placed on optical bench.
4. Adjust second lens (small focal length) on the optical bench at a distance nearly equal to its focal length from the needle on the eye side.
5. Adjust the position of eye piece such that a clear image is formed at infinity keeping eye very close to the eye piece.
6. Measure the distance between the two lenses. It is equal to Fo + Fe.
7. Repeat the experiment changing distance between the scale and telescope.
8. Find magnifying power (M.P.) = $\frac{F_o}{F_e}$.

OBSERVATION :

Focal length of the Objective Lens (F_O) = ... cm

Focal length of the Eye Lens (f_e) = ... cm

Distance between the two lens L = ... cm

CALCULATION :

Magnifying power of the telescope M = $\frac{F_o}{F_e}$

PRECAUTIONS :

1. The principle axis of the two lenses should have in same line.
2. For viewing the final image the eye should be kept close to the eye piece.
3. The large focal length of the lens used as objective lens and small focal length used as eye lens.
4. In normal mode, the distance between the two lenses is equal to the sum of their focal length.

RESULT :

Magnifying power of an astronomical telescope = ... cm.

VIVA -VOCE

Q. 1 What is a Telescope?

Ans. An optical isntrument used for seeing distance for objects clearly.

Q.2 How many lenses are required for an Astronomical Telescope?

Ans. There are two convex lenses used. One of large focal length called objective lens and another of small focal length called eye piece.

Q. 3 Why objective lens is called objective lens?

Ans. As this lens is placed in front of the object so it is called objective lens.

Q.4 Define magnifying power of a Telescope?

Ans. It may be defined as the ratio of the angle substended by the image when seen through the telescope to the angle substended by the object at the eye when seen directly with both being at infinity.

Q. 5 Why a Telescope is called Astronomical Telescope?

Ans. As it is used to see distinct heavenly bodies clearly like moon, planets etc.

EXPERIMENT No.4

AIM :

To verify Ohm's Law and to measure the unknown resistance

APPARATUS REQUIRED :

Unknown Resistance, D.C. Source, Voltmeter, Ammeter, Rheostat, Key Connecting wires etc.

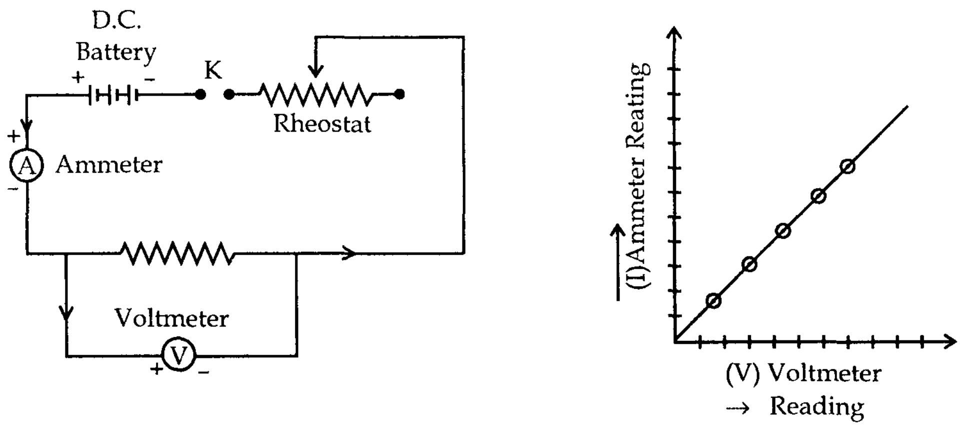


Fig. 4

THEORY :

Physical conditons of a conductor remaining same. The current passing through it is proportional to the voltage applied across its terminals. This is Ohm's Law i.e. I × V

or $V \propto I$

or $V = I R$

$\therefore \frac{v}{I} = R$ [Where R is constant called resistance of the conductor].

R is measured in ohm (Ω).

Here Rheostat is used as potential divider. For this terminals of D.C. source are used with fixed points of the rheostat. Then one fixed and one variable point of the rheostat are taken as source of variable potential.

PROCEDURE :

1. Make connections as show in circuit diagram.
2. For variable potential take one fixed terminal and one variable terminal as source.
3. Note readings of voltmeter and corresponding readings of ammeter.
4. Take more than 5 sets of reading for V and I by changing value of V with the help of slide on the rheostat.

5. For these sets draw points on the graph i.e. plot a graph between V and I show in diagram.
6. We will see that graph is a straight line.
7. From this we conclude that V and I i.e. Ohm's Law is verified.
8. Ratio of V to I gives resistance of the unknown resistance.

OBSERVATIONS :

Least count of Voltmeter = V
Least count of Ammeter = A
Zero error in Voltmeter = V
Zero error in Ammeter = V

Sr. No.	Voltmeter Reading (V)	Ammeter Reading Ω	$R = \frac{V}{I}\ \Omega$
1.	V_1 =	I_1 =	$R_1 = \frac{V_1}{I_1}$
2.	V_2 =	I_2 =	$R_2 = \frac{V_2}{I_2}$
3.	V_3 =	I_3 =	$R_3 = \frac{V_3}{I_3}$
4.	V_4 =	I_4 =	$R_4 = \frac{V_4}{I_4}$
5.	V_5 =	I_5 =	$R_5 = \frac{V_5}{I_5}$

Mean Resistance $R = \frac{R_1+R_2+R_3+R_4+R_5}{5}$

RESULT

Unknown resistance of the given resistor is Ω between V and I is a straight line which verifies Ohm's Law.

PRECAUTIONS :

1. Voltmeter and Ammeter should be of propergange.
2. The connecting wire must be clean.
3. Connections should be tight and clean.

4. Keys or switches should be properly used.
5. Reading for zero errors must be corrected.
6. Graph should be a straight line. Point which do nto coincide with this line due to some experimental errors must be avoided.
7. Rheostat should have low resistance.

VIVA-VOCE

Q.1 State Ohm's Law.

Ans. Ohm's Law states that the electric current I flowing through a conductor is directly proportional to the potential difference. Voltage (V) across its ends (Provided that the physical conditions temperature etc., of the conductor remain same.)

Q. 2 Give Mathematical form of the Ohm's Law.

Ans. Mathematical form of ohm's law is V = RI

Q. 3 Define resistance.

Ans. The constant ratio of potential difference V across the ends of a conductor to the current I flowing through it is called resistance of the conductor. Its symbol is R

i.e. $R \frac{V}{I}$

Q.4 What is ohm's and non-ohmic resistances.

Ans. Resistances whch obey ohm's law are called ohmic resistance. Resistance which do not obey ohm's law are called non-ohmic resistance.

Q.5 Give common examples of non-ohmic resistance.

Ans. Vaccum tube diodes and semi-conductor diodes are non-ohmic resistance.

Q. 6 What is the effect of temperature on the resistance of a conductor?

Ans. The resistance of most of the conductors increases with increase in temperature.

Q. 7 Name some of the substances whose resistance decreases with increase in temperature?

Ans. Resistance of semi conductors (Si, Ge) decreases with increase in temperature.

Q. 8 How do you conclude that the conductor used in experiment obeyed ohm's law?

Ans. It is done b with the help of two results :

i. The ratio of voltmeter reading (V) and the corresponding ammeter reading (I) comes to be constant.

ii. A graph between V and I comes to be a straight line.

Q. 9 Why do we use thick connecting wires?

Ans. Thick connecting wires offer neegligibel resistance.

EXPERIMENT No. 5

AIM :

To verify laws of resistance of series

APPARATUS REQUIRED :

Two resistance coils, a voltmeter, an ammeter, a rheostat, a battery, one way key, connecting wire etc.

CIRCUIT DIAGRAM :

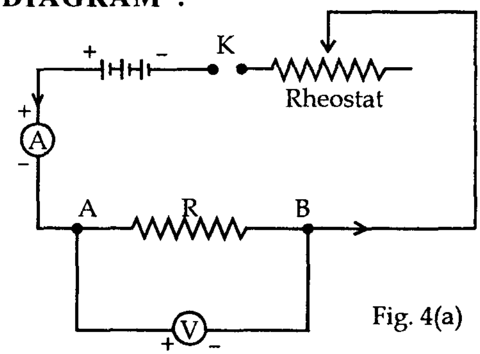


Fig. 4(a)

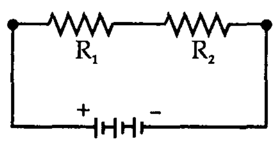


Fig. 4(b)

THEORY :

According to ohm's law $V = IR$

or $R = \frac{V}{I}$ .... (1)

When two resistance R_1 and R_2 are connected in series combination as shown in fig. 4 (b). Then current I will be same but potential difference full across R_1 and R_2 are V_1 and V_2 hence

$V = V_1 + V_2$ .... (2)

By using $V = IR$, $IR = IR_1 + IR_2$

So $R_S = R_1 + R_2$

PROCEDURE :

1. Connect the two resistance R_1 and R_2 in series as shown in fig. 4 (b)
2. Make the connections of various instruments as shown in fig. 4 (a)
3. Find out the least count of ammeter and voltmeter.
4. Switch on the D.C. Supply.
5. Adjust the rheostat for minimum current to pass through the circuit.

6. Note down the value of V and I from voltmeter and ammeter.
7. Then calculate the value of Rs which is equal to $\frac{V}{I}$.
8. Repeat this procedure so that a set a readings can be obtained.

OBSERVATION :

Least count of the voltmeter = ... V
Least count of the Ammeter = ... Amp
Zero error of Voltmeter = ... V
Zero error of Ammeter = ... A

OBSERVATION TABLE

Sr. No	Resistance	Voltmeter Reading	Ammeter Reading	$R=\frac{V}{I}$	Mean Resistance
1. 2. 3.	R_1				R_1 = ...
1. 2. 3.	R_2				R_2 = ...
1. 2. 3.	R_1 & R_2 are in series				R_3 = ...

CALCULATION :

$Rs = R_1 + R_2$
Rs = ... OHMS

RESULT :

Since $R_1 + R_2 = V/I$ therefore law of resistance in series is verified.

PRECAUTIONS :

1. Make sure all the connections are neat and clean and tight.
2. Note down the readings from voltmeter and ammeter carefully
3. Rheostat should be at 100 resistance.
4. Key should be taken when circuit is not in used.

EXPERIMENT No. 6

AIM :

To verify the law of resistance in parallel

APPARATUS REQUIRED :

Two resistance coils, a voltmeter, an ammeter, a rheostat, a battery, one way key, connecting wire etc.

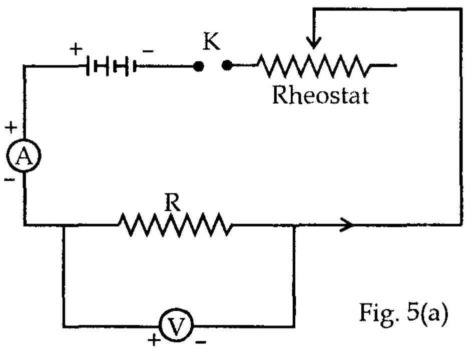


Fig. 5(a)

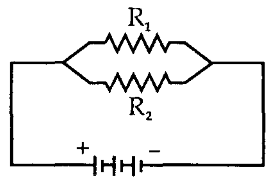


Fig. 5(b)

THEORY :

When two resistors R_1 and R_2 are connected in parallel combination then the potential difference will be same in both resistance. But current will be divided in to I_1 and I_2 so,

$I = I_1 + I_2$

By using V = IR, $\therefore \frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2}$

PROCEDURE :

1. Connect the two resistance R1 and R2 in series as shown in fig. 4 (b)
2. Make the connections of various instruments as shown in fig. 4 (a)
3. Find out the least count of ammeter and voltmeter.
4. Switch on the D.C. Supply.
5. Adjust the rheostat for minimum current to pass through the circuit.
6. Note down the value of V and I from voltmeter and ammeter.
7. Then calculate R_P which is equal to $\frac{V}{I}$
8. Repeate this procedure at least three set of reading.

OBSERVATION :

Least count of the voltmeter = ... V

Least count of the Ammeter = ... A

OBSERVATION TABLE:

Resistance	S. No.	Voltmeter Raeding	Ammeter Reading	$R=\frac{V}{I}$	Mean Resistance
R_1	1 2 3				R_1 = ...
R_2	1 2 3				R_2 = ...
$R_p = \frac{R_1+R_2}{R_1+R_2}$	1 2 3				R_p = ...

CALCULATION :

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

or $$R_P = R_P \frac{R_1+R_2}{R_1+R_2}$$

$$R_P = \text{.................}\ \Omega$$

RESULT :

Since $\frac{1}{R_1} + \frac{1}{R_2} = \frac{V}{I}$, therefore, lao fo resistance in parallel is veried.

VIVA-VOCE

Q. 1 What is Resistance?

Ans. Resistance is an electrical instrument which opposes the flow of the current.

Q. 2 What is the equivalent resistance when three resistance connected in series and parallel?

Ans. When three resistors R_1, R_2 and R_3 are connected in series and parallel are :

$$R_S = R_1+R_2+R_3$$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Q. 3 Define specific resistance of a conductor

Ans. We know that $\rho\ R\frac{A}{\ell}$

When $\ell = 1$, $A = 1$, then $\rho = R$

Hence resistivity is the resistance of a conductor of unti length and unit cross sectional area.

Q. 4 What is the unit of resistance?

Ans. Ohm

Q. 5 State Ohm's Law.

Ans. It states that, the current flowing through a conductor is directly proportional to the potential differnce across its two ends.

Q. 6 What is current?

Ans. It is the rate of flow of charge $I = \frac{dq}{dt}$

Q.7 What is the unit of current?

Ans. Ampear.

Q.8 Give S.I. unit of resistivity?

Ans. Ohm meter

Q. 9 At what resistancewill the current be maximum when three resistance through connected in parallel?

Ans. Current follows the least resistance path, so the current flowing through resistance are maximum.

Q.10 What do you mean by a parallel combination of resistance ?

Ans. Two or more resistance are connected in parallel if they have some potential difference.

EXPERIMENT No. 7

AIM :

To convert a galvanometer into an ammeter of given range.

APPARATUS USED :

Galvanometer, Voltmeter, A battery of two cells, a high resistance box, one way key, connecting wire and sand paper etc.

CIRCUIT DIAGRAM :

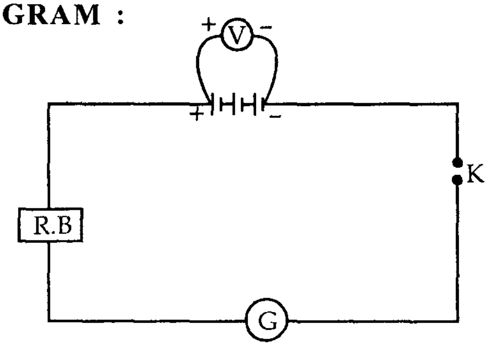


Fig. 6(a)

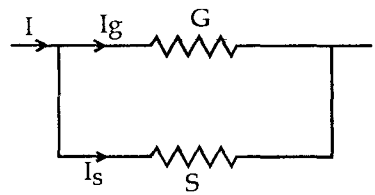


Fig. 6(b)

THEORY :

Let us assume a galvanometer of resistance G in which a maximum current Ig will be passed. Let S be shunt resisntace connected in the parallel with Galvanometer as shown in fig. 6 (b). The total current I will be given by

$$I = I_g + I_S \quad => \quad = I_S = I\text{-}Ig$$

Because G and S are the same potential

So $\quad IgG = IgS$

or $\quad S = \dfrac{Ig\,G}{Is}$

or $\quad S = \dfrac{Ig\,G}{I - Ig}$

PROCEDURE :

1. By taking out the one cell from battery find out its EMF.
2. Connect all the connections according to circuit diagram.
3. Now adjust the value from resistance box and close the key.
4. As the current flow in the circuit, open an resistance that shows a deflection say = 30 divsions.
5. Note down the value of resistance and deflection.
6. Now note down the galvanometer deflection by changing the value of R.

7. Repeat steps 1 to 6 with both cells of the battery.
8. Calculate figure of merit K by using the formula.
9. Note down the total division an Galvanometer in left and right sides.
10. Calculate Ig and S by using formula and connected in parallel with G.

OBSERVATION :

Resistance of Galvanometer G .... Ohm

OBSERVATION TABLE :

S. No.	e.m.f. of the cells (volt)	Resistance from resistance box	Deflection θ	Figure of merits $K = \frac{E}{(R=G)\theta}$ (amp/div)
1.				
2.				
3.				
4.				
5.				

Mean K = ... amp/div.

CALCULATION :

Number of division an Galvanometer scale n =

Current for full scale deflection of the Galvanometer

Ig = nk = ... ampears

Range of conversion I = ...amp.

Current through the shunt I - Ig .... = amp.

Since $\frac{Ig\ G}{I - Ig} = S$

Shunt S = ... ohm's

RESULT :

The given Galvanometer can be converted into an ammeter of range. .... ampere if a shunt resistance of .... ohm is connected in its parallel.

PRECAUTIONS :

1. The cells used should have constant EMF.
2. All the connections made sould be neat, clean and tight.
3. The ammeter should always be connected in a series.
4. All the plugs of the resistance box should be tight.

EXPERIMENT No. 8

AIM :

To convert a galvanometer into an Voltmeter of given range.

APPARATUS REQUIRED :

Galvanometer, Voltmeter, A battery of two cells, a high resistance box, one way key, connecting wire and sand paper etc.

CIRCUIT DIAGRAM :

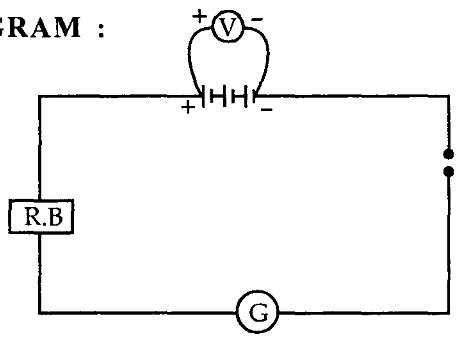


Fig. 7(a)

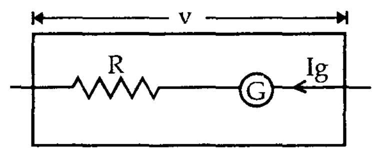


Fig. 7(b)

THEORY :

For convert a Galvanometer into a voltmeter we used a high value of resistance R which is connected in series with G as shown in fig. 7 (b) If ig will be current flowing in Galvanometer and V is the potential difference between Galvanometer and resistance then,

according to ohm's law

$$V = IR$$

or $$V = Ig\,(G + R)$$

or $$G + R = \frac{V}{Ig}$$

or $$R = \frac{V}{Ig} - G$$

PROCEDURE :

1. By taking out the one cell from battery find out its EMF.
2. Connect all the connection according to circuit diagram.
3. Now adjust the value from resistance box and closed the key.
4. As the current flow i nthe circuit, open an resistance shows a deflection say = 30 divsions.

5. Note down the value of resistance and deflection.
6. Now note down the galvanometer deflection by changing the value of R.
7. Repeat steps 1 to 6 with both cells of the battery.
8. Calculate figure of merit K by using the formula.
9. Note down the total division an Galvanometer in left and right sides.
10. Calculating the value of Ig and R to be connected in series with G.

OBSERVATION :

Resistance of Galvanometer G .... Ohms.

OBSERVATION TABLE :

S.No.	E.M. F. of cell volt (v)	Resistance from R.B. (Ω)	Deflection θ (div.)	Figure of merrite $K = \frac{E}{(R+G)\theta}$ amp/div
1				
2				
3				
4				
5				

Mean K = ... A/Div.

CALCULATION :

No. of division of Galvanometer scale (n) = ...
Figure of merrite (k) .... A/div.
Current in full scale deflection ig = nxk
Range of conversion V = ... volt

Hence, $R = \frac{V}{Ig} - G$ = ... ohms

RESULT :

The given galvanometer can be converted into avoltmeter of range ....V if a resistance of .... is connected in series with it.

PRECAUTIONS :

1. The cells used should be constant EMF.
2. The voltmeter always be connected in parallel to the cuircuit across which potentiol difference is to be measured.

VIVA-VOCE

Q.1 What is a Galvanometer?
Ans. It is a instruments which is used for detection of small current.

Q. 2 What is an ammeter?
Ans. It is a device which measures a large electric current in circuit.

Q. 3 What is a Voltmeter?
Ans. A device which measures P.D. between the two points of the circuits.

Q. 4 What is a shunt Resistance?
Ans. It is a low resistance connected in parallel with the galvanometer.

Q. 5 How is an ammeter used in a circuit?
Ans. Ammeter be used in series in a circuit.

Q. 6 Why an ammeter is always connected in a series.
Ans. An ammeter is so connected as it has low resistance and cross the large current in the circuit.

Q. 7 How is a voltmeter used in a circuit?
Ans. Voltmeter is always connected in parallel combination in a circuit.

Q. 8 Why anvoltmeter used in parallel in a circuit?
Ans. As it has large resistance and a very small current carrying capacity.

Q. 9 Can we increase or decrease the range of a given ammeter?
Ans. Range of an ammeter can't be decreases but can be increased by selection of shunt resistance.

Q. 10 What is the full name of an Ammeter?
Ans. Full name of Ammeter is Ampere-meter.

Q.11 1 milli-ampere = ... ampere.
Ans. 1 mA = 10^{-3} Amp.

Q. 12 Can we change the range of a given voltmeter?
Ans. yes by connecting a suitable high resitance in series with a given voltmeter.

Q. 13 Why a Galvanometer is not suitable to work as an Ammeter?
Ans. Because Galvanometer has more resistance and less current capacity those required by an ammeter.

Q.14 Why a Galvanometer is not suitable to work as a voltmeter?
Ans. Because Galvanometer has low resistance and more current carrying capacity from those requires by a voltmeter.

Q. 15 What is the relation between galvanometer current (Ig) potential difference (v) Galvanometer resistance G and high resistance R.

Ans. $Ig = \frac{V}{R+G}$

"This page is Intentionally Left Blank"