SBM

Toppers

+2

PHYSICS

VOL - II

AUTHOR

R.SRIDHARAN, M.Sc.,M.Phil.,B.Ed.,HDSE.,
Post Graduate Teacher (PHYSICS),
Govt. Boys Hr. Sec. School,
Melpallipattu - 606 703.
Tiruvannamalai Dt.

6. Ray Optics

1. What is reflection?

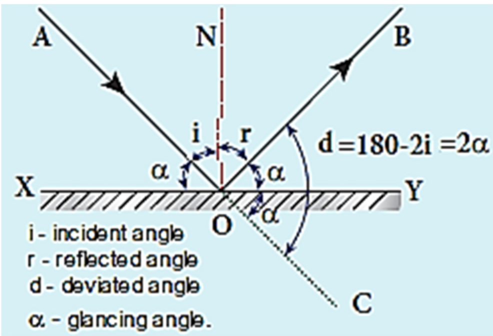
The bouncing back of light into the same medium when it encounters a reflecting surface is called reflection of light.

2. State the law of reflection.

- The incident ray, reflected ray and normal to the reflecting surface all are coplanar (i.e. lie in the same plane).
- The angle of incidence i is equal to the angle of reflection r.

3. What is angle of deviation due to reflection?

The angle between the incident and deviated light ray in reflection is called angle of deviation due to reflection.



4. What are the two types of images?

- Real image.
- Virtual image.

5. What is real image?

The type of image which can be formed on the screen but can also be seen with the eyes is called virtual image.

6. What is virtual image?

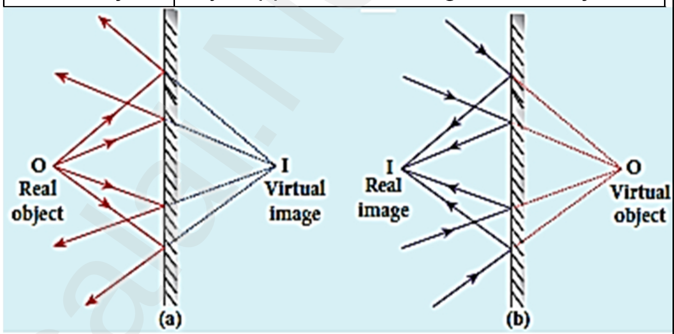
The type of image which cannot be formed on a screen and can only be seen with the eyes is called real image.

7. Give the characteristics of the image formed by a plane mirror?

- The image formed by a plane mirror is virtual, erect, and laterally inverted.
- The size of the image is equal to the size of the object.
- The image distance far behind the mirror is equal to the object distance in front of it.
- If an object is placed between two plane mirrors inclined at an angle θ, then the number of images n formed is as,
  - If $\left(\frac{360}{\theta}\right)$ is even then, $n = \left(\frac{360}{\theta} - 1\right)$ for objects placed symmetrically or unsymmetrically,
  - If $\left(\frac{360}{\theta}\right)$ is odd then, $n = \left(\frac{360}{\theta} - 1\right)$ for objects placed symmetrically,
  - If $\left(\frac{360}{\theta}\right)$ is odd then, $n = \left(\frac{360}{\theta}\right)$ for objects placed unsymmetrically.

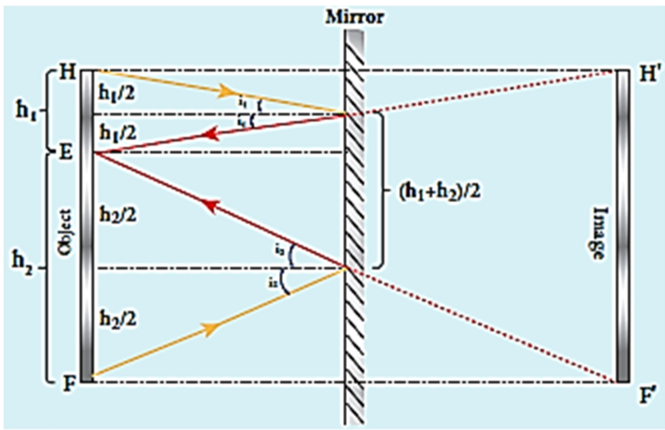
8. Tabulate the condition for nature of objects and images.

Nature of object/image	Condition
Real image	Rays actually converge at the image
Virtual image	Rays appear to diverge from the image
Real object	Rays actually diverge from the object
Virtual object	Rays appear to converge at the object



9. What is the height of the mirror needed to see the image of a person fully on the mirror? Does the height of the mirror depend on the distance between the person and the mirror?

- Let h_1 be the distance between head H and eye E and h_2 be distance between his feet F and eye E.



- The person's total height h is, $h = h_1 + h_2$
- By the law of reflection, the angle of incidence and angle of reflection are the same in the two extreme reflections.
- The normals are now the bisectors of angles between incident and reflected rays in the two reflections.

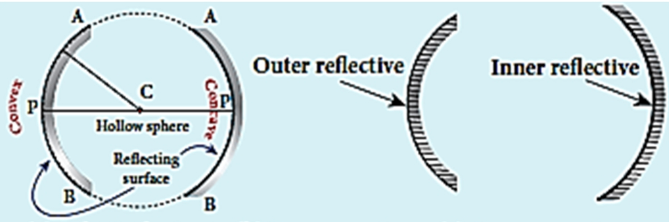
- By geometry, the height of the mirror needed is only half of the height of the person.

$$i.e.\ \frac{h_1 + h_2}{2} = \frac{h}{2}$$

- From the above equation, we conclude that the height of the mirror does not depend on the distance between the person and the mirror.

10. What is convex mirror?

If the reflection takes place at the convex surface, it is called a convex mirror.



(a) Spherical mirrors (b) A convex mirrors (c) A concave mirrors

11. What is concave mirror?

If the reflection takes place at the concave surface, it is called a concave mirror.

12. What is centre of curvature?

The centre of the sphere of which the mirror is a part is called the center of curvature (C) of the mirror.

13. What is radius of curvature?

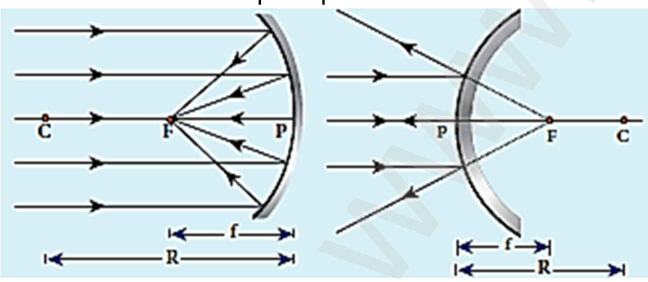
The radius of the sphere of which the spherical mirror is a part is called the radius of curvature (R) of the mirror.

14. What is pole?

The middle point on the spherical surface of the mirror (or) the geometrical center of the mirror is called pole (P) of the mirror.

15. What is principal axis or optical axis?

The line joining the pole and the centre of curvature is called the principal axis of the mirror.



16. What is focus or focal point?

Light rays travelling parallel and close to the principal axis when incident on a spherical mirror, converge at a point for concave mirror or appear to diverge from a point for convex mirror on the principal axis. This point is called the focus or focal point (F) of the mirror.

17. What is focal length?

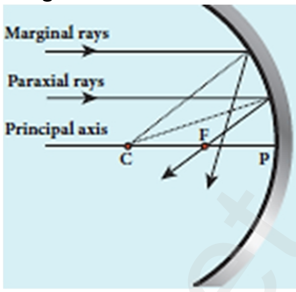
The distance between the pole and the focus is called the focal length (f) of the mirror.

18. What is focal plane?

The plane through the focus and perpendicular to the principal axis is called the focal plane of the mirror.

19. What is paraxial rays?

The rays travelling very close to the principal axis and make small angles with it are called paraxial rays.

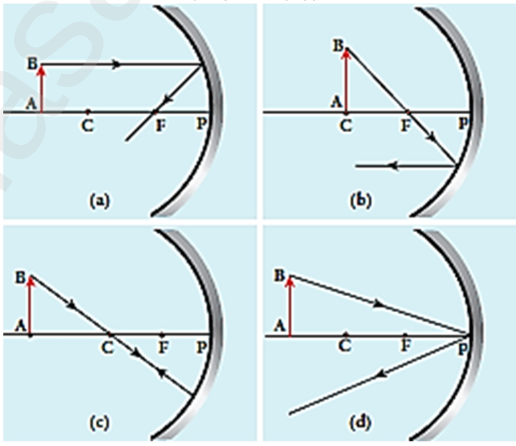


20. What is marginal rays?

The rays travelling far away from the principal axis and fall on the mirror far away from the pole are called as marginal rays.

21. Discuss about the image formation in spherical mirrors.

- A ray parallel to the principal axis after reflection will pass through or appear to pass through the principal focus. (Figure (a))

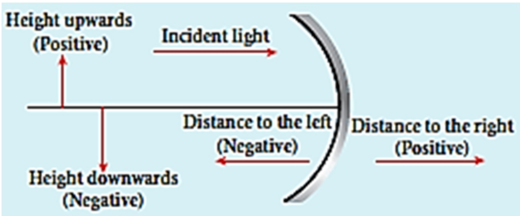


- A ray passing through or appear to pass through the principal focus, after reflection will travel parallel to the principal axis. (Figure (b))
- A ray passing through the centre of curvature retraces its path after reflection as it is a case of normal incidence.(Figure (c))
- A ray falling on the pole will get reflected as per law of reflection keeping principal axis as the normal. (Figure (d))

22. What are the Cartesian sign conventions for a spherical mirror?

- The Incident light is taken from left to right (i.e. object on the left of mirror).
- All the distances are measured from the pole of the mirror (pole is taken as origin).

- The distances measured to the right of pole along the principal axis are taken as positive.



- The distances measured to the left of pole along the principal axis are taken as negative.
- Heights measured in the upward perpendicular direction to the principal axis are taken as positive.
- Heights measured in the downward perpendicular direction to the principal axis, are taken as negative.

23. What is mirror equation?

The equation which establishes a relation among object distance u, image distance v and focal length f for a spherical mirror is called mirror equation.

24. Define lateral or transverse magnification.

The lateral or transverse magnification is defined as the ratio of the height of the image to the height of the object.

$$i.e.\quad m = \frac{h'}{h}$$

25. Define refractive index.

Refractive index of a transparent medium is defined as the ratio of speed of light in vacuum (or air) to the speed of light in that medium.

$$i.e.\quad n = \frac{c}{v}$$

26. Define optical path.

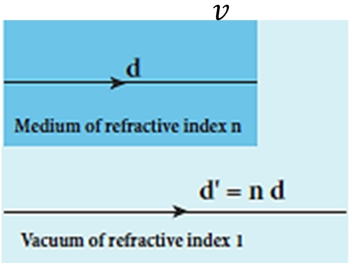
Optical path of a medium is defined as the distance d' travelled by the light in vacuum in the same time it travels a distance d in the medium.

27. Obtain the equation for optical path.

- Let us consider a medium of refractive index n and thickness d. Light travels with a speed v through the medium in a time t. Then we can write,

$$v = \frac{d}{t}$$

$$or \quad t = \frac{d}{v}$$



- In the same time, light can cover a greater distance d' in vacuum as it travels with greater speed c in vacuum as shown in figure. Then we have,

$$c = \frac{d'}{t}$$

$$or \quad t = \frac{d'}{v}$$

- As the time taken in both the cases is the same, we can equate the time t as,

$$t = \frac{d'}{v} = \frac{d}{v}$$

$$or \quad d' = \frac{c}{v} d$$

- As $\frac{c}{v} = n$, the optical path d' is,

$$d' = nd$$

- As n is always greater than 1, the optical path d' of the medium is always greater than d.

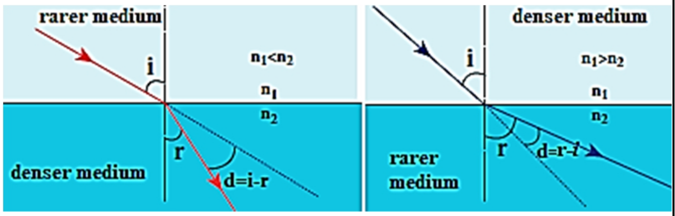
28. State the laws of refraction or State snell's law.

- The incident ray, refracted ray and normal to the refracting surface are all coplanar (*i.e.* lie in the same plane).
- The ratio of sine of angle of incident i in the first medium to the sine of angle of reflection r in the second medium is equal to the ratio of refractive index of the second medium n_2 to that of the refractive index of the first medium n_1.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

29. What is angle of deviation due to refraction?

The angle between the incident and deviated light ray in refraction is called angle of deviation due to refraction.



$$d = i - r \quad (rarer\ to\ denser)$$
$$d = r - i \quad (denser\ to\ rarer)$$

30. What is simultaneous reflection or refraction?

The phenomenon in which a part of light from a source undergoing reflection and another part of light from same source undergoing refraction is known as simultaneous reflection or simultaneous refraction.

31. What is principle of reversibility?

The principle of reversibility states that light will follow exactly the same path if its direction of travel is reversed.

32. What is relative refractive index?

- The comparison ratio of refractive index of one medium with respect to other medium is called relative refractive index.
- In snell's law, $\frac{n_2}{n_1} = n_{21}$ is the relative refractive index of the second medium with respect to first medium.

33. Write the relations of inverse rule and chain rule using relative refractive index.

- According to inverse rule,

$$n_{12} = \frac{1}{n_{21}} \quad or \quad \frac{n_1}{n_2} = \frac{1}{\left({}^{n_2}/{}_{n_1}\right)}$$

- According to chain rule,

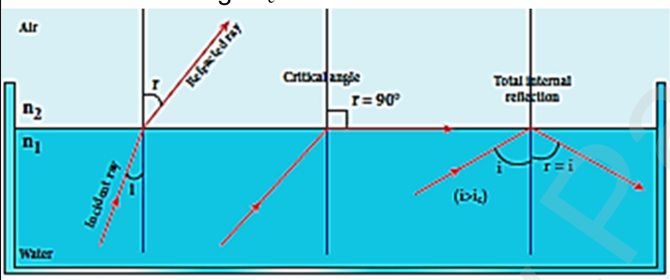
$$n_{32} = n_{31} \times n_{12}$$
$$or \qquad \frac{n_3}{n_2} = \frac{n_3}{n_1} \times \frac{n_1}{n_2}$$

34. Why do stars twinkle?

The stars actually do not twinkle. They appear twinkling because of the movement of the atmospheric layers with varying refractive indices, which is clearly seen in the night sky.

35. What is critical angle?

The angle of incidence in the denser medium for which the refracted ray graces the boundary(i.e. r = 90^0) is called critical angle i_c.



36. Obtain the equation for critical angle.

- Let n_1 and n_2 be the refractive index of the denser and rarer medium repectively and i_c is the crtical angle.
- According to Snell's law,

$$n_1 sin i_c = n_2 sin 90^0$$
$$sin i_c = \frac{n_2}{n_1} \quad ; \ Here \ n_1 > n_2$$

- If n_2 = 1 for air medium and n_1 = n,

$$sin i_c = \frac{1}{n} \quad (or) \ i_c = sin^{-1}\left(\frac{1}{n}\right)$$

37. What is total internal refraction?

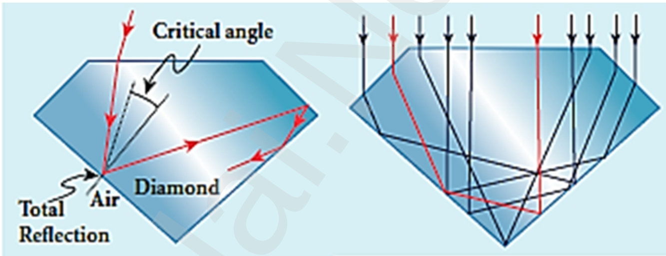
When the angle of incidence is above the criticle angle(i.e. $i > i_c$) , the entire light is reflected back into the denser medium itself. This phenomenon is called total internal reflection.

38. What are the two conditions for total internal refraction?

- Light must travel from denser to rarer medium,
- The angle of incidence in the denser medium must be greater than critical angle (i.e. $i > i_c$).

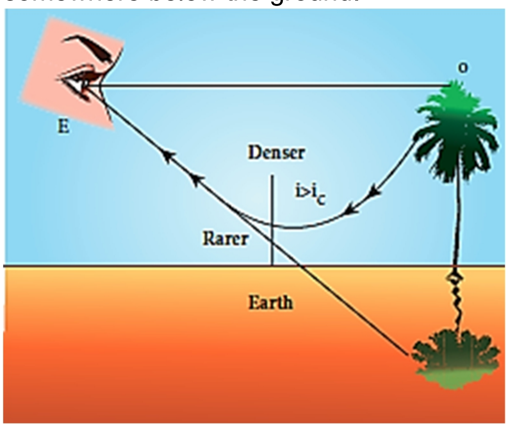
39. Explain the reason for glittering of diamond.

- The critical angle of diamond is about 24.4^0.
- A skilled diamond cutter makes use of this larger range of angle of incidence (24.4^0 to 90^0 inside the diamond), to ensure that light entering the diamond is total internally reflected from the many cut faces before getting out.
- This gives a sparkling effect for diamond.



40. Write a short note on mirage.

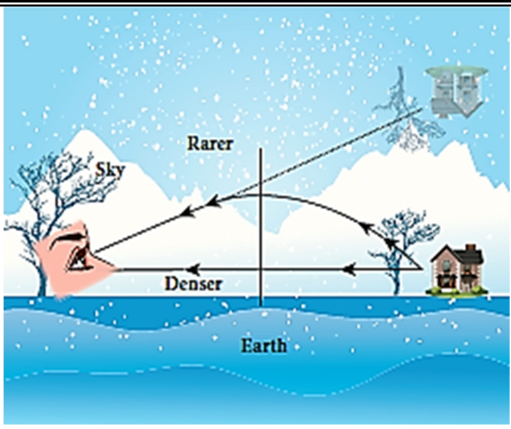
- In hot places, when move from ground to a height, the density and hence the refractive index of the air increases due to temperature variation.
- Such that the reflected light from the object travel towards the ground successively deviated above and it gets total internal reflection near the ground where $i > i_c$.
- This gives an illusion as if the light comes from somewhere below the ground.



- Due to the shaky nature of air layers, it appears like pool water or wet surface reflection. This phenomenon is called mirage.

41. Write a short n ote on looming.

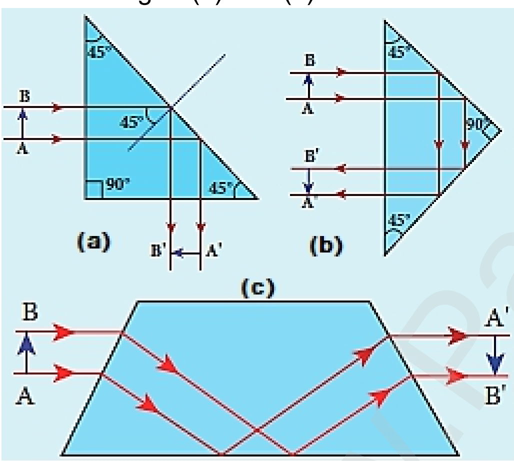
- In cold places, when move from ground to a height, the density and hence the refractive index of the air decreases due to temperature variation.



- Such that the reflected light from the object travel towards the sky successively deviated below and it gets total internal reflection near the sky where $i > i_c$.
- This gives the reverse effect of mirage. Hence, an inverted image is formed little above the surface. This phenomenon is called looming.

42. Write a short notes on the prisms making use of total internal reflection.

- Prisms can be designed to reflect light by 90^0 or by 180^0 by making use of total internal reflection as shown in Figure(a) and (b).



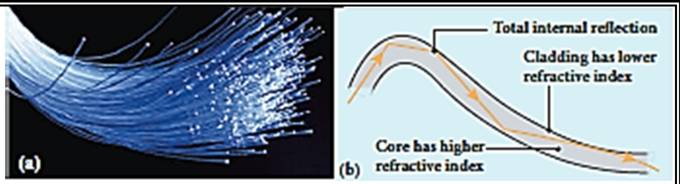
- In these cases, the critical angle i_c for the material of the prism must be less than 45^0 (For both crown glass and flint glass.
- Prisms are also used to invert images without changing their size as shown in Figure(c).

43. What is Snell's window?

When light entering the water from outside is seen from inside the water, the view is restricted to a particular angle equal to the critical angle i_c. The restricted illuminated circular area is called Snell's window.

44. Write a note on optical fibre.

- Transmitting signals through optical fibres is possible due to the phenomenon of total internal reflection.
- Optical fibres consists of inner part called core and outer part called cladding (or) sleeving.



- The refractive index of the material of the core must be higher than that of the cladding for total internal reflection to happen.
- Signal in the form of light is made to incident inside the core-cladding boundary at an angle greater than the critical angle.
- Hence, it undergoes repeated total internal reflections along the length of the fibre without undergoing any refraction.
- The light travels inside the core with no appreciable loss in the intensity of the light.

45. What is acceptance angle?

To ensure the critical angle incidence in the core-cladding boundary inside the optical fibre, the light should be incident at a certain angle at the end of the optical fiber while entering in to it. This angle is called acceptance angle.

46. What is acceptance cone?

A cone, which has acceptance angle is called acceptance cone.

47. Explain the working of an endoscope.

- An endoscope is an instrument used by doctors which has a bundle of optical fibres that are used to see inside a patient's body.

- Endoscopes work on the phenomenon of total internal reflection.
- The optical fibres are inserted in to the body through mouth, nose or a special hole made in the body.
- Even operations could be carried out with the endoscope cable, which has the necessary instruments attached at their ends.

48. What are the assumptions made while considering refraction at spherical surfaces?

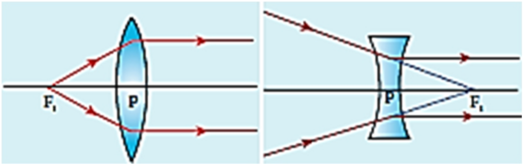
- The incident light is assumed to be monochromatic (single colour)
- The incident ray of light is very close to the principal axis (paraxial rays)

49. What is thin lens?

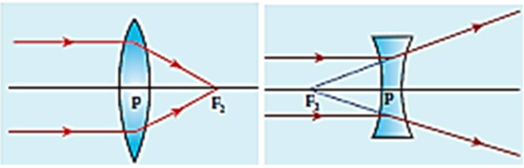
A lens which is formed by a transparent material bounded between two spherical surfaces or one plane and another spherical surface is called thin lens.

50. Define primary focus and secondary focus.

- The primary focus F_1 is defined as a point where an object should be placed to give parallel emergent rays to the principal axis.



- The secondary focus F_2 is defined as a point where all the parallel rays travelling close to the principal axis converge to form an image on the principal axis.



51. What are the sign conventions followed for lenses?

- The sign of focal length is not decided on the direction of measurement of the focal length from the pole of the lens as they have two focal lengths, one to the left and another to the right (primary and secondary focal lengths on either side of the lens).
- The focal length of the thin lens is taken as positive for a converging lens and negative for a diverging lens.
- The other sign conventions for object distance, image distance, radius of curvature, object height and image height remain the same for thin lenses as that of spherical mirrors.

52. Arrive at lens equation from lens maker's formula.

- According to lens maker's formula,

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \longrightarrow (1)$$

- From the general equation of spherical refraction,

$$\frac{1}{v} - \frac{1}{u} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \longrightarrow (2)$$

- Comparing the equations (1) and (2), we have,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \longrightarrow (3)$$

- The equation(3) is called len's equation.

53. What is p ower of a lens? Give its unit.

Power of lens is the degree of deviation of incident ray on a lens. It is defined as reciprocal of focal length of a lens. Its unit is diopter(D).

$$i.e.\ \ P = \frac{1}{f}$$

54. What is angle of deviation by a prism?

The angle between the direction of the incident ray and the emergent ray is called the angle of deviation(d) of a prism.

$$i.e.\ \ d = i_1 + i_2 - A$$

55. What are the factors affecting the angle of deviation by a prism?

- The angle of incidence(i_1)
- The angle of the prism(A)
- The refractive index of the material of the prism, which decides the angle of emergency(i_2).

56. What is angle of minimum deviation by a prism?

The minimum value of angle of deviation is called angle of minimum deviation(D) of a prism.

57. What are all the conditions at angle of minimum deviation by a prism?

- The angle of incidence is equal to the angle of emergence (i.e. $i_1 = i_2$).
- The angle of refraction at the face one and face two are equal (i.e. $r_1 = r_2$).
- The incident ray and emergent ray are symmetrical with respect to the prism.
- The refracted ray inside the prism is parallel to its base of the prism.

58. What is dispersion?

Dispersion is splitting of white light into its constituent colours.

59. What is spectrum?

The band of colours of light is called spectrum.

60. What is angular dispersion?

The angular separation between the two extreme colours (violet and red) in the spectrum is called the angular dispersion.

$$i.e.\ \ \delta_V - \delta_R = (n_V - n_R)A$$

61. What are the factors affecting the angular dispersion?

- Angle of the prism
- Nature of the material of the prism.

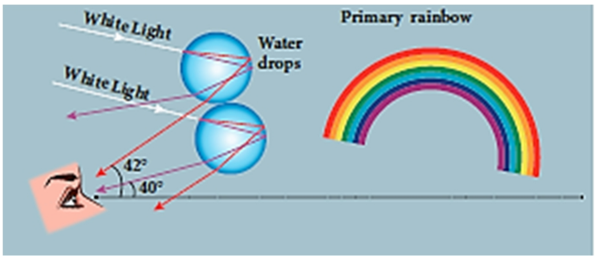
62. Define dispersive power.

Dispersive power is defined as the ratio of the angular dispersion for the extreme colours to the deviation for any mean colour.

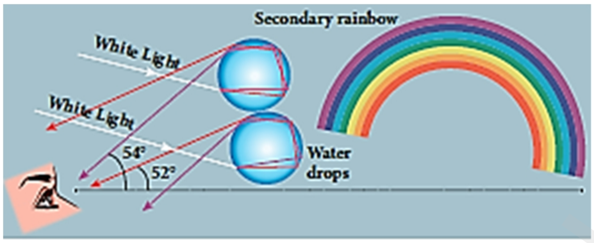
$$i.e.\ \ \omega = \frac{Angular\ dispersion}{Mean\ deviation} = \frac{\delta_V - \delta_R}{\delta}$$

63. How are rainbows formed?

- When sunlight falls on the water drop suspended in air , splits into its constituent seven colours. This forms a rainbow.
- Primary rainbow is formed when light entering the drop undergoes one total internal reflection inside the drop before coming out from the drop. The angle of view for violet to red in primary rainbow is 40^0 to 42^0.



- A secondary rainbow appears outside of a primary rainbow and develops when light entering a raindrop undergoes two internal reflections. The angle of view for red to violet in a secondary rainbow is, 52^0 to 54^0.



64. What is scattering of light?

When sunlight enters the atmosphere of the earth, the atmospheric particles present in the atmosphere change the direction of the light. This process is known as scattering of light.

65. What is Rayleigh's scattering?

If the scattering of light is by atoms and molecules which have size a very less than that of the wave length λ of light a<<λ, the scattering is called Rayleigh's scattering.

66. State the law of Rayleigh's scattering.

The intensity of Rayleigh's scattering is inversely proportional to fourth power of wavelength.

$$i.e.\ I \propto \frac{1}{\lambda^4}$$

67. Why does sky appear blue?

- According to the law of Rayleigh's scattering, violet colour which has the shortest wavelength gets much scattered during day time.
- The next scattered colour is blue. As our eyes are more sensitive to blue colour than violet colour the sky appears blue during day time

68. What is the reason for reddish appearance of sky during sunset and sunrise?

- During sunrise and sunset, the light from sun travels a greater distance through the atmosphere.
- Hence, the blue light which has shorter wavelength is scattered away and the less-scattered red light of longer wavelength manages to reach our eye.
- This is the reason for the reddish appearance of sky during sunrise and sunset.

69. Why do clouds appear white?

Usually clouds contains large amount of dust and water droplets whose size a >> λ. Thus, in clouds all the colours get equally scattered irrespective of wavelength. This is the reason for the whitish appearance of cloud.

Conceptual Questions:

70. Why are dish antennas curved?

The curved dish antennas act like concave mirrors and are used to get focussed signals of broadcasting.

71. What type of lens is formed by a bubble inside water?

Biconvex lens is formed when an air bubble is inside the water.

72. It is possible for two lenses to produce zero power?

Yes. It is possible when the combination of convex and concave lenses of same focal length is used.

73. A biconvex lens has focal length f and intensity of light I passing through it. What will be the focal length and intensity for portions of lenses obtained by cutting it vertically and horizontally as shown in figure?

- According to lens maker's formula, focal length of the lens(f) is directly proportional to radius of curvature(R) of the lens. Further, intensity of the light is directly proportional to area of aperture of the lens.
- **For vertical cut:**

  - Since radius of curvature of the lens is increased to double, focal length is also be increased to double.
  - As the area of the aperture is not changed, intensity of the light is also not be changed.
- **For horizontal cut:**

  - As the radius of curvature of the lens is not changed, focal length is also not be changed.
  - Since the area of the aperture is decreased, intensity of the light is also be decreased.

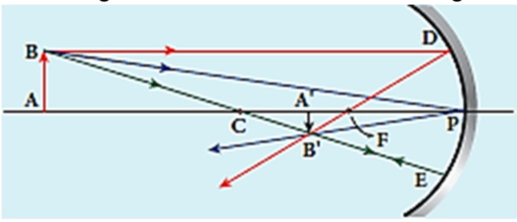
74. Why is yellow light preferred during fog?

When light pass through fog, Rayleigh's scattering happens where longer wavelength of light like yellow, orange and red are scattered less than other colours. Among these yellow is more sensitive to our eyes. Hence, the yellow light is preferred during fog.

5 Marks Q & A:

1. Derive the mirror equation and the equation for lateral magnification.

- The mirror equation establishes a relation among object distance u, image distance v and focal length f for a spherical mirror.
- An object AB is considered on the principal axis of a concave mirror beyond the center of curvature C. The image formation is shown in the figure.



- Let us consider three paraxial rays from point B on the object. The first paraxial ray BD travelling parallel to principal axis is incident on the concave mirror at D, close to the pole P.
- After reflection the ray passes through the focus F. The second paraxial ray BP incidentat the pole P is reflected along PB'.
- The third paraxial ray BC passing through centre of curvature C, falls normally on the mirror at E is reflected back along the same path.
- The three reflected rays intersect at the point A′ B′. A perpendicular drawn as A′ B′ to the principal axis is the real, inverted image of the object AB.
- As per law of reflection, the angle of incidence ∠BPA is equal to the angle of reflection ∠ B′PA′ .
- The triangles ΔBPA and ΔB′PA′ are similar. Thus, from the rule of similar triangles,

$$\frac{A'B'}{AB}=\frac{PA'}{PA} \longrightarrow (1)$$

- The other set of similar triangles are, ΔDPF and Δ B′A′ F. (PD is almost a straight vertical line)

$$\frac{A'B'}{PD}=\frac{A'F}{PF}$$

- As, the distances PD = AB the above equation becomes,

$$\frac{A'B'}{AB}=\frac{A'F}{PF} \longrightarrow (2)$$

- From equations (1) and (2) we can write,

$$\frac{PA'}{PA}=\frac{A'F}{PF}$$

- As, A′ F=PA′ - PF , the above equation becomes,

$$\frac{PA'}{PA}=\frac{PA'-PF}{PF} \longrightarrow (3)$$

- We can apply the sign conventions for the various distances in the above equation.

$$PA=-u, \quad PA'=-v, \quad PF=-f$$

- All the three distances are negative as per sign convention, because they are measured to the left of the pole. Now, the equation (3) becomes,

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

- On further simplification,

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

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

- Dividing either side with v,

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

- After rearranging,

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f} \longrightarrow (4)$$

- The above equation(4) is called mirror equation.

Lateral magnification in spherical mirrors:

- The lateral or transverse magnification is defined as,

$$magnification(m)=\frac{Height\ of\ the\ image(h')}{Height\ of\ the\ object(h)}$$

$$m=\frac{h'}{h}$$

- Applying proper sign conventions for equation (1),

$$\frac{A'B'}{AB}=\frac{PA'}{PA}$$

- Here, A'B'=–h, AB=h, PA'=–v, PA=–u

$$\frac{-h'}{h}=\frac{-v}{-u}$$

$$\frac{h'}{h}=-\frac{v}{u}$$

- On simplifying we get,

$$m=\frac{h'}{h}=-\frac{v}{u}$$

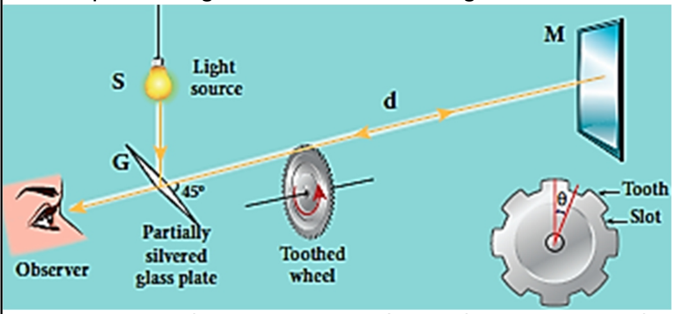
- Using mirror equation(4), we can further write the magnification as,

$$m=\frac{h'}{h}=\frac{f-v}{f}=\frac{f}{f-u}$$

2. **Describe the Fizeau's method to determine speed of light.**

Apparatus:

- The apparatus used by Fizeau for determining speed of light in air is shown in figure.



- The light from the source S was first allowed to fall on a partially silvered glass plate G kept at an angle of 45^0 to the incident light from the source.
- The light then was allowed to pass through a rotating toothed-wheel with N teeth and N cuts of equal widths whose speed of rotation could be varied through an external mechanism.
- The light passing through one cut in the wheel will get reflected by a mirror M kept at a long distance d, about 8 km from the toothed wheel.
- If the toothed wheel was not rotating, the reflected light from the mirror would again pass through the same cut and reach the eyes of the observer through the partially silvered glass plate.

Working:

- The angular speed of rotation of the toothed wheel was increased from zero to a value ω until light passing through one cut would completely be blocked by the adjacent tooth.
- This is ensured by the disappearance of light while looking through the partially silvered glass plate.

Expression for speed of light:

- The speed of light in air v is equal to the ratio of the distance the light travelled from the toothed wheel to the mirror and back 2d to the time taken t.

$$v = \frac{2d}{t} \dashrightarrow (1)$$

- The distance d is a known value from the arrangement.
- The time taken t for the light to travel the distance to and fro is calculated from the angular speed ω of the toothed wheel.
- The angular speed ω of the toothed wheel when the light disappeared for the first time is,

$$\omega = \frac{\theta}{t} \dashrightarrow (2)$$

- Here, θ is the angle between the tooth and the slot which is rotated by the toothed wheel within that time t.

$$\theta = \frac{Total\ angle\ of\ the\ circle\ in\ radian}{Number\ of\ teeth + number\ of\ cuts}$$

$$\theta = \frac{2\pi}{2N} = \frac{\pi}{N}$$

- Substituting the θ value in the equation(2), we get,

$$\omega = \frac{\pi/N}{t} = \frac{\pi}{Nt}$$

- Rewriting the above equation for t,

$$t = \frac{\pi}{N\omega} \dashrightarrow (3)$$

- Substituting t from equation (3) in equation (1),

$$v = \frac{2d}{\pi/N\omega}$$

- After rearranging,

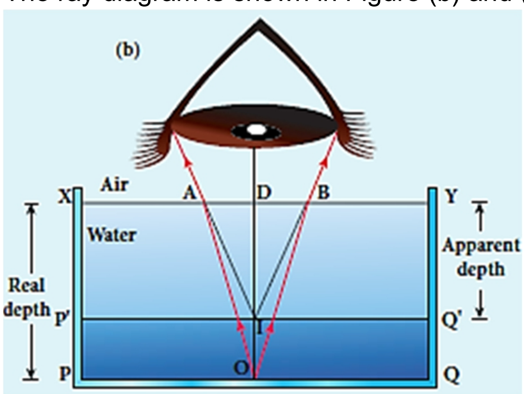
$$v = \frac{2dN\omega}{\pi}$$

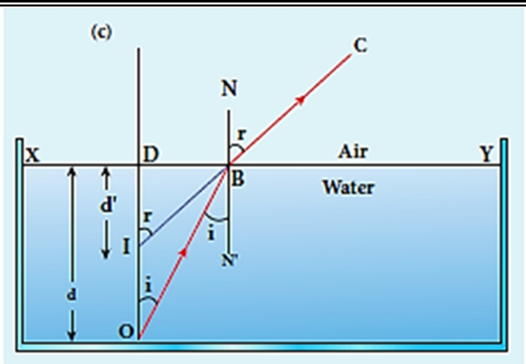
- From this method, the speed of light in air was determined as, $v = 2.99792 \times 10^8\ m\ s^{-1}$.

3. **Derive an expression for apparent depth for normal viewing.**

- It is a common observation that the bottom of a tank filled with water appears raised as shown in Figure (a).

- An equation could be derived for the apparent depth for viewing in the near normal direction.
- The ray diagram is shown in Figure (b) and (c).





- Light from the object O at the bottom of the tank passes from denser medium (water) to rarer medium (air) to reach our eyes.
- It deviates away from the normal in the rarer medium at the point of incidence B.
- The refractive index of the denser medium is n_1 and rarer medium is n_2. Here, $n_1 > n_2$.
- The angle of incidence in the denser medium is i and the angle of refraction in the rarer medium is r.
- The lines NN′ and OD are parallel. Thus angle ∠DIB is also r.
- The angles i and r are very small as the diverging light from O entering the eye is very narrow.
- The Snell's law in product form for this refraction is,

$$n_1 \sin i = n_2 \sin r$$

- As the angles i and r are small, we can approximate, $\sin i \approx \tan i$;

$$n_1 \tan i = n_2 \tan r$$

- In triangles ΔDOB and ΔDIB,

$$\tan i = \frac{DB}{DO} \text{ and } \tan r = \frac{DB}{DI}$$

$$n_1 \frac{DB}{DO} = n_2 \frac{DB}{DI}$$

- DB is cancelled on both sides, DO is the actual depth d and DI is the apparent depth d'.

$$n_1 \frac{1}{d} = n_2 \frac{1}{d'}$$

$$\frac{d'}{d} = \frac{n_2}{n_1}$$

- Rearranging the above equation for the apparent depth d',

$$d' = \frac{n_2}{n_1} d$$

- As the rarer medium is air and its refractive index n_2 can be taken as 1, ($n_2 = 1$). And the refractive index n_1 of denser medium could then be taken as n, ($n_1 = n$).
- In that case, the equation for apparent depth becomes,

$$d' = \frac{d}{n}$$

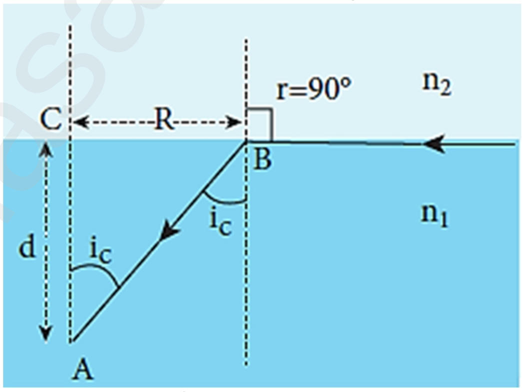
- The bottom appears to be elevated by d-d',

$$d - d' = d - \frac{d}{n}$$

$$d - d' = d\left(1 - \frac{1}{n}\right)$$

✓ **Obtain the equation for radius of illumination (or) Snell's window.**

- When light entering the water from outside is seen from inside the water, the view is restricted to a particular angle equal to the critical angle i_c. The restricted illuminated circular area is called Snell's window.
- The radius R of the circular area depends on the depth d from which it is seen and also the refractive indices of the media.
- The radius of Snell's window can be deduced with the illustration as shown in Figure.



- Light is seen from a point A at a depth d. The Snell's law in product form for the refraction happening at the point B on the boundary between the two media is,

$$n_1 \sin i_c = n_2 \sin 90^0$$

$$n_1 \sin i_c = n_2 \quad [\because \sin 90^0 = 1]$$

$$\sin i_c = \frac{n_2}{n_1} \longrightarrow (1)$$

- From the right angle triangle ΔABC,

$$\sin i_c = \frac{CB}{AB} = \frac{R}{\sqrt{d^2 + R^2}} \longrightarrow (2)$$

- Equating equations(1) and (2), we have,

$$\frac{R}{\sqrt{d^2 + R^2}} = \frac{n_2}{n_1}$$

- Squaring on both sides,

$$\frac{R^2}{d^2 + R^2} = \left(\frac{n_2}{n_1}\right)^2$$

- Taking reciprocal,

$$\frac{d^2 + R^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2$$

- On further simplifying,

$$1 + \frac{d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2$$

$$\frac{d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2 - 1$$

$$\frac{d^2}{R^2} = \frac{n_1^2}{n_2^2} - 1 = \frac{n_1^2 - n_2^2}{n_2^2}$$

- Again taking reciprocal and rearranging,

$$\frac{R^2}{d^2} = \frac{n_2^2}{n_1^2 - n_2^2}$$

$$R^2 = d^2\left(\frac{n_2^2}{n_1^2 - n_2^2}\right)$$

- The radius of illumination is,

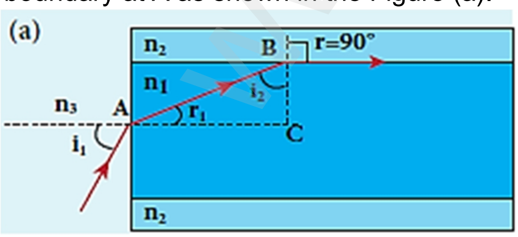
$$R = d\sqrt{\frac{n_2^2}{n_1^2 - n_2^2}}$$

- If the rarer medium outside is air, then, $n_2 = 1$, and we can take $n_1 = n$.

$$R = d\left(\frac{1}{\sqrt{n^2 - 1}}\right) = \frac{d}{\sqrt{n^2 - 1}}$$

5. Derive the equation for acceptance angle and numerical aperture of optical fiber.

- To ensure the critical angle of incidence in the core-cladding boundary inside the optical fibre, the light should be incident at a certain angle at the end of the optical fiber while entering in to it. This angle is called acceptance angle.
- It depends on the refractive indices of the core n_1, cladding n_2 and the outer medium n_3.
- Assume the light is incident at an angle called acceptance angle i_a at the outer medium and core boundary at A as shown in the Figure (a).



- The Snell's law in the product form for this refraction at the point A is,

$$n_3 \sin i_a = n_1 \sin r_a \longrightarrow (1)$$

- To have the total internal reflection inside optical fibre, the angle of incidence at the core-cladding interface at B should be atleast critical angle i_c.
- Snell's law in the product form for the refraction at point B is,

$$n_1 \sin i_c = n_2 \sin 90^0$$

$$n_1 \sin i_c = n_2 \quad [\because \sin 90^0 = 1]$$

$$\sin i_c = \frac{n_2}{n_1} \longrightarrow (2)$$

- From the right angle triangle ΔABC,

$$i_c = 90^0 - r_a$$

- Now, equation(2) becomes,

$$\sin(90^0 - r_a) = \frac{n_2}{n_1}$$

- Using trigonometry,

$$\cos r_a = \frac{n_2}{n_1}$$

$$\sin r_a = \sqrt{1 - \cos^2 r_a}$$

- Substituting for $\cos r_a$,

$$\sin r_a = \sqrt{1 - \left(\frac{n_2}{n_1}\right)^2} = \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}}$$

- Substituting this in equation(1),

$$n_3 \sin i_a = n_1\sqrt{\frac{n_1^2 - n_2^2}{n_1^2}} = \sqrt{n_1^2 - n_2^2} \longrightarrow (3)$$

- On further simplification,

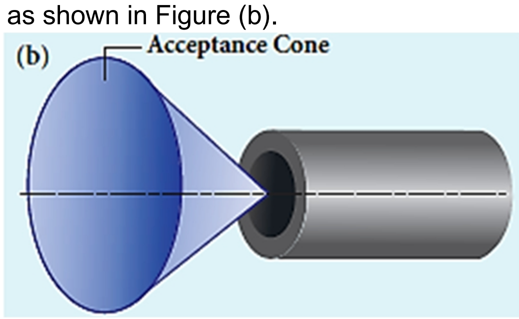
$$\sin i_a = \frac{\sqrt{n_1^2 - n_2^2}}{n_3}$$

$$\sin i_a = \sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}$$

- If outer medium is air, then $n_3 = 1$. The acceptance angle i_a becomes,

$$i_a = sin^{-1}\sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}$$

- Light can have any angle of incidence from 0 to i_a with the normal at the end of the optical fibre forming a conical shape called acceptance cone as shown in Figure (b).



- In the equation (3), the term $(n_3 \sin i_a)$ is called numerical aperture NA of the optical fibre.

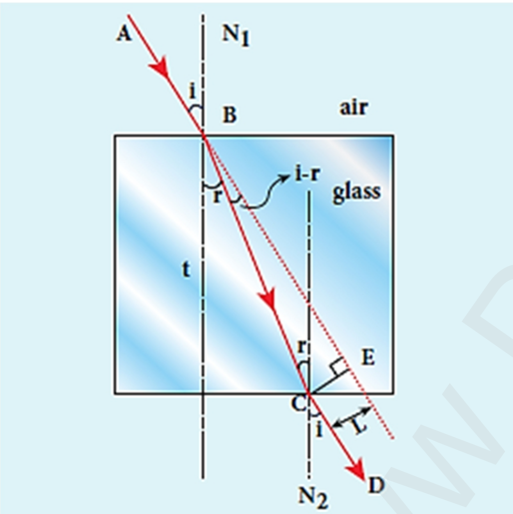
$$NA = n_3 \sin i_a = \sqrt{n_1^2 - n_2^2}$$

- If outer medium is air, then n_3 = 1. The numerical aperture NA becomes,

$$NA = \sin i_a = \sqrt{n_1^2 - n_2^2}$$

6. Obtain the equation for lateral displacement of light passing through a glass slab.

- When a ray of light passes through a glass slab it refracts at two refracting surfaces.
- After the two refractions, the emerging ray has the same direction as that of the incident ray on the slab with a lateral displacement or shift L.
- There is no change in the direction of ray but the path of the incident ray and refracted ray are different and parallel to each other.
- To calculate the lateral displacement, a perpendicular is drawn in between the paths of incident ray and refracted ray as shown in Figure.



- Consider a glass slab of thickness t and refractive index n is kept in air medium.
- The path of the light is ABCD and the refractions occur at two points B and C in the glass slab.
- The angles of incidence i and refraction r are measured with respect to the normal N_1 and N_2 at the two points B and C respectively.
- The lateral displacement L is the perpendicular distance CE drawn between the path of light and the undeviated path of light at point C.
- In the right angle triangle ΔBCE,

$$\sin(i-r) = \frac{L}{BC}$$

$$BC = \frac{L}{\sin(i-r)} \longrightarrow (1)$$

- In the right angle triangle ΔBCF,

$$\cos r = \frac{t}{BC}$$

$$BC = \frac{t}{\cos r} \longrightarrow (2)$$

- Equating equations(1) and (2),

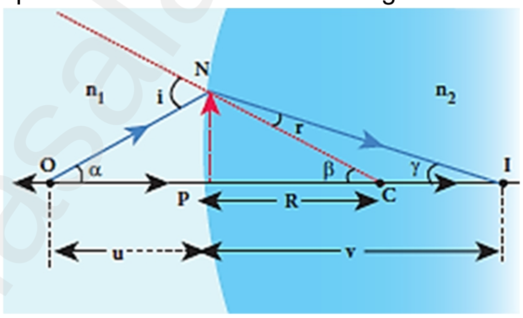
$$\frac{L}{\sin(i-r)} = \frac{t}{\cos r}$$

- After rearranging,

$$L = t\left(\frac{\sin(i-r)}{\cos r}\right)$$

7. Derive the equation for refraction at single spherical surface.

- Let us consider two transparent media having refractive indices n_1 and n_2 are separated by a spherical surface as shown in Figure.



- Let C be the centre of curvature of the spherical surface.
- Let a point object O be in the medium n_1. The line OC cuts the spherical surface at the pole P of the surface.
- As the rays considered are paraxial rays, the perpendicular dropped for the point of incidence to the principal axis is very close to the pole or passes through the pole itself.
- Light from O falls on the refracting surface at N. The normal drawn at the point of incidence passes through the centre of curvature C.
- As $n_2 > n_1$, light in the denser medium deviates towards the normal and meets the principal axis at I where the image is formed.
- Snell's law in product form for the refraction at the point N could be written as,

$$n_1 \sin i = n_2 \sin r$$

- As the angles are small, sine of the angle could be approximated to the angle itself.

$$n_1 i = n_2 r \longrightarrow (1)$$

- Let the angles,

$$\angle NOP = \alpha, \angle NCP = \beta, \angle NIP = \gamma$$

$$\tan\alpha = \frac{PN}{PO} \; ; \quad \tan\beta = \frac{PN}{PC} \; ; \; \tan\gamma = \frac{PN}{PI}$$

- As these angles are small, tan of the angle could be approximated to the angle itself.

$$\alpha = \frac{PN}{PO} \; ; \quad \beta = \frac{PN}{PC} \; ; \; \gamma = \frac{PN}{PI} - -(2)$$

- For the triangle, ΔONC,

$$i = \alpha + \beta \longrightarrow (3)$$

- For the triangle, ΔINC,

$$\beta = r + \gamma$$
$$r = \beta - \gamma \longrightarrow (4)$$

- Substituting equations (3) and (4) in (1),

$$n_1(\alpha + \beta) = n_2(\beta - \gamma)$$

- Rearranging,

$$n_1\alpha + n_2\gamma = (n_2 - n_1)\beta$$

- Substituting α, β and γ from equation(2),

$$n_1\left(\frac{PN}{PO}\right) + n_2\left(\frac{PN}{PI}\right) = (n_2 - n_1)\left(\frac{PN}{PC}\right)$$

- Further simplifying by cancelling PN,

$$\frac{n_1}{PO} + \frac{n_2}{PI} = \frac{(n_2 - n_1)}{PC} \longrightarrow (5)$$

- Following sign conventions, PO = –u, PI = +v and PC = +R in equation (5),

$$\frac{n_1}{-u} + \frac{n_2}{v} = \frac{(n_2 - n_1)}{R}$$

- After rearranging, finally we get,

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{(n_2 - n_1)}{R} \longrightarrow (6)$$

- Equation (6) gives the relation among the object distance u, image distance v, refractive indices of the two media (n_1 and n_2) and the radius of curvature R of the spherical surface. It holds for any spherical surface.

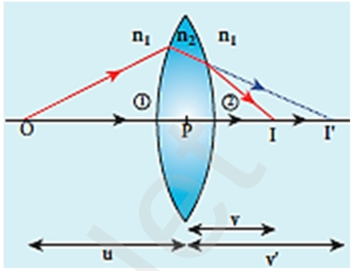
- If the first medium is air then, n_1 = 1 and the second medium is taken just as n_2 = n, then the equation is reduced to,

$$\frac{n}{v} - \frac{1}{u} = \frac{(n-1)}{R}$$

8. Obtain lens maker's formula and mention its significance.

- Let us consider a thin lens made up of a medium of refractive index n_2 is placed in a medium of refractive index n_1.

- Let R_1 and R_2 be the radii of curvature of two spherical surfaces 1 and 2 respectively and P be the pole as shown in figure.



- Consider a point object O on the principal axis. The ray which falls very close to P, after refraction at the surface 1 forms image at I'.

- Before it does so, it is again refracted by the surface 2. Therefore the final image is formed at I.

- The general equation for the refraction at a spherical surface is,

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

- For the refracting surface 1, the light goes from n_1 to n_2.

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \longrightarrow (1)$$

- For the refracting surface 2, the light goes from medium n_2 to n_1.

$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_1 - n_2}{R_2} \longrightarrow (2)$$

- Adding the above two equations (1) and (2),

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

- Further simplifying and rearranging,

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2 - n_1}{n_1}\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$
$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \longrightarrow (3)$$

- If the object is at infinity, the image is formed at the focus of the lens. Thus, for u = ∞, v = f. Then the equation becomes.

$$\frac{1}{f} - \frac{1}{\infty} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$
$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \longrightarrow (4)$$

- If the refractive index of the lens is n_2 and it is placed in air, then n_2 = n and n_1 = 1. So the equation (3) becomes,

$$\frac{1}{f} = (n-1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \longrightarrow (4)$$

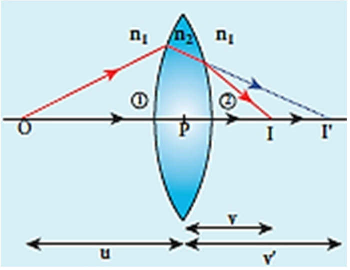
- The above equation is called the lens maker's formula.

Significance:

- This formula tells the lens manufactures what curvature is needed to make a lens of desired focal length with a material of particular refractive index.
- This formula holds good also for a concave lens.

9. Derive the equation for thin lens and obtain its magnification.

- Let us consider a thin lens made up of a medium of refractive index n_2 is placed in a medium of refractive index n_1.
- Let R_1 and R_2 be the radii of curvature of two spherical surfaces 1 and 2 respectively and P be the pole as shown in figure.



- Consider a point object O on the principal axis. The ray which falls very close to P, after refraction at the surface 1 forms image at I'.
- Before it does so, it is again refracted by the surface 2. Therefore the final image is formed at I.
- The general equation for the refraction at a spherical surface is,

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$$

- For the refracting surface 1, the light goes from n_1 to n_2.

$$\frac{n_2}{v'} - \frac{n_1}{u} = \frac{n_2 - n_1}{R_1} \longrightarrow (1)$$

- For the refracting surface 2, the light goes from medium n_2 to n_1.

$$\frac{n_1}{v} - \frac{n_2}{v'} = \frac{n_1 - n_2}{R_2} \longrightarrow (2)$$

- Adding the above two equations (1) and (2),

$$\frac{n_1}{v} - \frac{n_1}{u} = (n_2 - n_1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

- Further simplifying and rearranging,

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2 - n_1}{n_1}\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \longrightarrow (3)$$

- If the object is at infinity, the image is formed at the focus of the lens. Thus, for u = ∞, v = f. Then the equation becomes.

$$\frac{1}{f} - \frac{1}{\infty} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

$$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left[\frac{1}{R_1} - \frac{1}{R_2}\right] \longrightarrow (4)$$

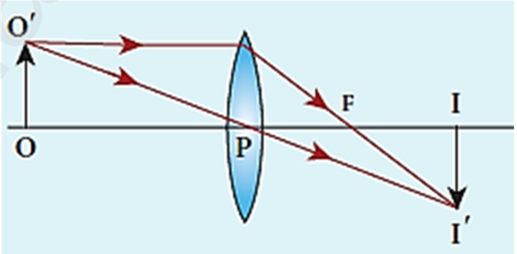
- By comparing the equations (3) and (4) we can write,

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

- This equation is known as lens equation which relates the object distance u and image distance v with the focal length f of the lens. This formula holds good for a any type of lens.

Lateral magnification in thins lens:

- Let us consider an object OO' of height h_1 placed on the principal axis with its height perpendicular to the principal axis as shown in Figure.



- The ray OP passing through the pole of the lens goes undeviated. The inverted real image II' formed has a height h_2.
- The lateral or transverse magnification m is defined as the ratio of the height of the image to that of the object.

$$m = \frac{II'}{OO'} \longrightarrow (5)$$

- From the two similar triangles Δ POO' and Δ PII', we can write,

$$\frac{II'}{OO'} = \frac{PI}{PO} \longrightarrow (6)$$

- Applying sign convention,

$$\frac{II'}{OO'} = \frac{-h_2}{h_1} = \frac{v}{-u}$$

- Substituting this in the equation (5) for magnification,

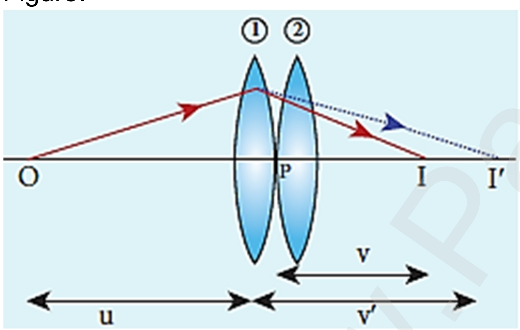
$$m = -\frac{h_2}{h_1} = -\frac{v}{u}$$

- The magnification is negative for real image and positive for virtual image.
- In the case of a concave lens, the magnification is always positive and less than one.
- We can also have the equations for magnification by combining the lens equation with the formula for magnification as,

$$m = \frac{h_2}{h_1} = \frac{f}{f+u} = \frac{f-v}{f}$$

10. Derive the equation for effective focal length for lenses in contact.

- Let us consider two lenses ① and ② of focal length f_1 and f_2 are placed coaxially in contact with each other so that they have a common principal axis.
- For an object placed at O beyond the focus of the first lens ① on the principal axis, an image is formed by it at I'.
- This image I' acts as an object for the second lens ② and the final image is formed at I as shown in Figure.



- As these two lenses are thin, the measurements are done with respect to the common optical centre P in the middle of the two lenses.
- Let, PO be object distance u and PI' be the image distance (v') for the first lens ① and object distance for the second lens ② and PI = v be the image distance for the second lens ② .
- Writing the lens equation for first lens ①,

$$\frac{1}{v'} - \frac{1}{u} = \frac{1}{f_1} \dashrightarrow (1)$$

- Writing the lens equation for second lens ② ,

$$\frac{1}{v} - \frac{1}{v'} = \frac{1}{f_2} \dashrightarrow (2)$$

- Adding equations (1) and (2),

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_1} + \frac{1}{f_2} \dashrightarrow (3)$$

- If the combination acts as a single lens, its focal length be F. For an object at the position O and its image forms at I,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{F} \dashrightarrow (4)$$

- Comparing equations (3) and (4), we get,

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

- The above equation can be extended for any number of lenses in contact as,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \frac{1}{f_4} + \cdots \dashrightarrow (5)$$

- The above equation can be written as power of the lenses as,

$$P = P_1 + P_2 + P_3 + P_4 + \cdots \dashrightarrow (6)$$

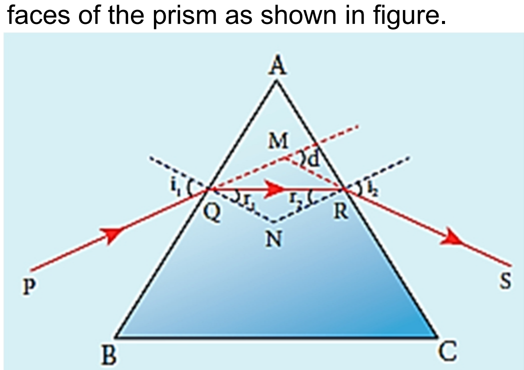
Where, P is the net power of the lens combination of lenses in contact.

- One should note that the sum in equation (6) is an algebraic sum.
- The powers of individual lenses may be positive (for convex lenses) or negative (for concave lenses).
- Combination of lenses helps to obtain diverging or converging lenses of desired magnification.
- Also, combination of lenses enhances the sharpness of the images.
- As the image formed by the first lens becomes the object for the second and so on.
- The total magnification m of the combination is a product of magnification of individual lenses. We can write,

$$m = m_1 \times m_2 \times m_3 \ldots$$

11. Derive the equation for angle of deviation produced by a prism and thus obtain the equation for refractive index of material of the prism.

- Let light ray PQ is incident on one of the refracting faces of the prism as shown in figure.



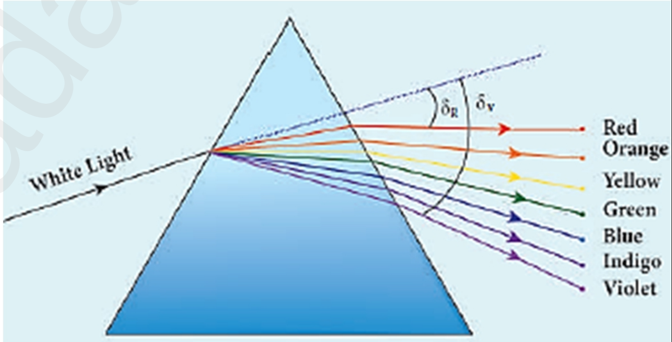
- The angles of incidence and refraction at the first face AB are i_1 and r_1.
- The path of the light inside the prism is QR. The angle of incidence and refraction at the second face AC is r_2 and i_2 respectively.
- RS is the ray emerging from the second face. Angle i_2 is also called angle of emergence.
- The angle between the direction of the incident ray PQ and the emergent ray RS is called the angle of deviation d.
- The two normals drawn at the point of incidence Q and emergence R are QN and RN.
- They meet at point N. The incident ray and the emergent ray meet at a point M.
- The deviation d_1 at the surface AB is,
$$\angle RQM = d_1 = i_1 - r_1 \dashrightarrow (1)$$
- The deviation d_2 at the surface AC is,
$$\angle QRM = d_2 = i_2 - r_2 \dashrightarrow (2)$$
- Total angle of deviation d produced is,
$$d = d_1 + d_2$$
- Substituting for d_1 and d_2,
$$d = (i_1 - r_1) + (i_2 - r_2)$$
- After rearranging,
$$d = (i_1 + i_2) - (r_1 + r_2) \dashrightarrow (3)$$
- In the quadrilateral AQNR, two of the angles (at the vertices Q and R) are right angles.
- Therefore, the sum of the other angles of the quadrilateral is 180^0.
$$\angle A + \angle QNR = 180^0 \dashrightarrow (4)$$
- From the triangle ΔQNR,
$$r_1 + r_2 + \angle QNR = 180^0 \dashrightarrow (5)$$
- Comparing these two equations (4) and (5) we get,
$$r_1 + r_2 = A \dashrightarrow (6)$$
- Substituting this in equation (3) for angle of deviation,
$$d = i_1 + i_2 - A \dashrightarrow (7)$$
- Thus, the angle of deviation depends on the angle of incidence angle of emergence and the angle for the prism.

Refractive index of material of the prism:

- At minimum deviation, d = D , $i_1 = i_2 = i$ and $r_1 = r_2 = r$. Now, the equation (7) becomes,
$$D = 2i - A$$
$$i = \frac{A + D}{2}$$
- From equation(6),
$$2r = A$$
$$r = \frac{A}{2}$$
- Substituting i and r in Snell's law,
$$n = \frac{\sin i}{\sin r}$$
$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$
- The above equation is used to find the refractive index of the material of the prism. The angles A and D can be measured experimentally.

12. Obtain the equation for dispersive power of a medium.

- Consider a beam of white light passes through a prism; it gets dispersed into its constituent colours as shown in Figure.



- Let δ_V, δ_R are the angles of deviation for violet and red light. Let n_V and n_R are the refractive indices for the violet and red light respectively.
- The refractive index of the material of a prism is given by the equation,
$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$
Here A is the angle of the prism and D is the angle of minimum deviation.
- If A be the angle of a small angle prism and δ the angle of deviation then the prism formula becomes,
$$n = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\left(\frac{A}{2}\right)} \dashrightarrow (1)$$

- If the angle of prism is small of the order of 10^0, the prism is said to be a small angle prism.
- When rays of light pass through such prisms, the angle of deviation also becomes small.
- For small angles of A and δ_m,

$$\sin\left(\frac{A+\delta}{2}\right) \approx \left(\frac{A+\delta}{2}\right) \dashrightarrow (2)$$
$$\sin\left(\frac{A}{2}\right) \approx \left(\frac{A}{2}\right) \dashrightarrow (3)$$

- Substituting equations(2) and (3) in (1),

$$n = \frac{\left(\frac{A+\delta}{2}\right)}{\left(\frac{A}{2}\right)} = \frac{A+\delta}{A} = 1 + \frac{\delta}{A}$$

- Further simplifying,

$$\frac{\delta}{A} = n - 1$$
$$\delta = (n-1)A$$

- When white light enters the prism, the deviation is different for different colours.
- Thus, the refractive index is also different for different colours.

$$For\ Violet\ light, \delta_V = (n_V - 1)A$$
$$For\ Red\ light, \delta_R = (n_R - 1)A$$

- As angle of deviation for violet colour δ_V is greater than angle of deviation for red colour δ_R, the refractive index for violet colour n_V is greater than the refractive index for red colour n_R.
- Subtracting δ_R from δ_V we get,

$$\delta_V - \delta_R = (n_V - n_R)A \dashrightarrow (4)$$

- The term (δ_V–δ_R) is the angular separation between the two extreme colours (violet and red) in the spectrum is called the angular dispersion.
- Clearly, the angular dispersion produced by a prism depends upon,
  - Angle of the prism.
  - Nature of the material of the prism.
- If we take δ is the angle of deviation for any middle ray (green or yellow) and n the corresponding refractive index. Then,

$$\delta = (n-1)A \dashrightarrow (5)$$

- Dispersive power (ω) is the ability of the material of the prism to cause dispersion. It is defined as the ratio of the angular dispersion for the extreme colours to the deviation for any mean colour.
- Dispersive power (ω),

$$\omega = \frac{angular\ dispersion}{mean\ deviation} = \frac{\delta_V - \delta_R}{\delta} \dashrightarrow (6)$$

- Substituting equations (4) and (5) in (6),

$$\omega = \frac{(n_V - n_R)}{(n-1)}$$

- Dispersive power is a dimensionless quality. It has no unit. Dispersive power is always positive.
- The dispersive power of a prism depends only on the nature of material of the prism and it is independent of the angle of the prism.

7. Wave Optics

1. What are the salient features of corpuscular theory of light?

- Light is emitted as tiny, massless (negligibly small mass) and perfectly elastic particles called corpuscles.
- As the corpuscles are very small, the source of light does not suffer appreciable loss of mass even if it emits light for a long time.
- On account of high speed, they are unaffected by the force of gravity and their path is a straight line in a medium of uniform refractive index.
- The energy of light is the kinetic energy of these corpuscles.
- When these corpuscles impinge on the retina of the eye, the vision is produced.
- The different size of the corpuscles is the reason for different colours of light.
- When the corpuscles approach a surface between two media, they are either attracted or repelled.
- The reflection of light is due to the repulsion of the corpuscles by the medium and refraction of light is due to the attraction of the corpuscles by the medium.

2. What are the demerits of corpuscular theory of light?

- This theory could not explain the reason why the speed of light is lesser in denser medium than in rarer medium.
- The phenomena like interference, diffraction and polarisation could not be explained by this theory.

3. Explain about wave theory of light.

- Wave theory explains the propagation of light through a medium.
- According to it, light is a disturbance from a source that travels as longitudinal mechanical waves through the ether medium that was presumed to pervade all space as mechanical wave requires medium for its propagation.

Demerits:

- The wave theory could successfully explain phenomena of reflection, refraction, interference and diffraction of light.
- Later, the existence of ether in all space was proved to be wrong. Hence, this theory could not explain the propagation of light through vacuum.
- The phenomenon of polarisation could not be explained by this theory as it is the property of only transverse waves.

4. Explain about electromagnetic wave theory of light.

- According to this theory, light is an electromagnetic wave, which is transverse in nature carrying electromagnetic energy.
- No medium is necessary for the propagation of electromagnetic waves. All the phenomenon of light could be successfully explained by this theory.

Demerits:

- Nevertheless, the interaction phenomenon of light with matter like photoelectric effect, Compton effect could not be explained by this theory.

5. Explain about quantum theory of light.

- Quantum theory endorsing the views of Max Plank was able to explain photoelectric effect.
- In which light interacts with matter as photons to eject the electrons.
- A photon is a discrete packet of energy. Each photon has energy,

$$E = h\nu$$

  Where, h is Plank's constant ($h = 6.625 \times 10^{-34}$ J) and ν is frequency of electromagnetic wave.
- As light has both wave as well as particle nature it is said to have dual nature. Thus, it is concluded that light propagates as a wave and interacts with matter as a particle.

6. What is a wavefront?

A wavefront is the locus of points, which are in the same state or phase of vibration.

7. What are the shapes of wavefront for (a) source at infinite, (b) point source and (c) line source?

- **source at infinite:** Plane wavefront.
- **point source:** Spherical wavefront.
- **line source:** Cylindrical wavefront.

8. State Huygen's principle.

- Each point of the wavefront is the source of secondary wavelets emanating from these points spreading out in all directions with the speed of the wave. These are called as secondary wavelets.
- The common tangent, in other words the envelope to all these wavelets gives the position and shape of the new wavefront at a later time.

9. What is interference of light?

The phenomenon of addition or superposition of two light waves which produces increase in intensity at some points and decrease in intensity at some other points is called interference of light.

10. What is constructive interference?

At points where the crest of one wave meets the crest of the other wave or the trough of one wave meets the trough of the other wave, the waves are in-phase. Hence, the displacement is maximum and these points appear bright. This type of interference is said to be constructive interference..

11. What is destructive interference?

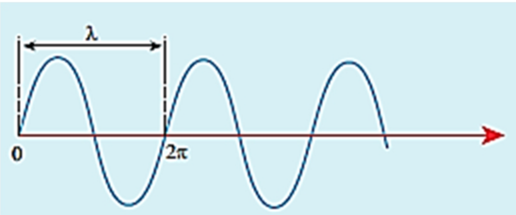
At points where the crest of one wave meets the trough of the other wave and vice versa, the waves are out-of-phase. Hence, the displacement is minimum and these points appear dark. This type of interference is said to be destructive interference.

12. What is phase of a wave?

Phase is the angular position of a vibration or wave.

13. Obtain the relation between phase difference and path difference.

- In the path of the wave, one wavelength λ corresponds to a phase of 2π as shown in Figure.



- A path difference δ corresponds to a phase difference ϕ as given by the equation,

$$\delta = \frac{\lambda}{2\pi} \times \phi$$

$$or \qquad \phi = \frac{2\pi}{\lambda} \times \delta$$

14. What are the conditions of constructive and destructive interference?

- For constructive interference, the phase difference should be, ϕ = 0, 2π, 4π . . . Hence, the path difference must be, δ = 0, λ, 2λ . . . In general, the integral multiples of λ.

$$\delta = n\lambda \quad where, n = 0, 1, 2, 3 \ldots$$

- For destructive interference, phase difference should be, ϕ = π, 3π, 5π . . . Hence, the path difference must be, $\delta = \frac{\lambda}{2}, \frac{3\lambda}{2}, ...$ In general, the half integral multiples of λ.

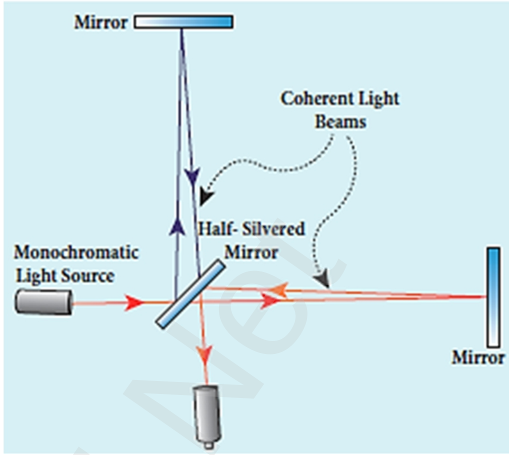
$$\delta = (2n-1)\frac{\lambda}{2} \quad where, n = 1, 2, 3 \ldots$$

15. What are coherent sources?

Two light sources are said to be coherent if they produce waves which have same phase or constant phase difference, same frequency or wavelength (monochromatic), same waveform and preferably same amplitude.

16. What is intensity or amplitude division?

- If we allow light to pass through a partially silvered mirror (beam splitter), both reflection and refraction take place simultaneously. They will be either in-phase or at constant phase difference as shown in Figure.



- As the two light beams are obtained from the same light source, the two divided light beams will be coherent beams.

- This method of producing coherent sources is called intensity or amplitude division.

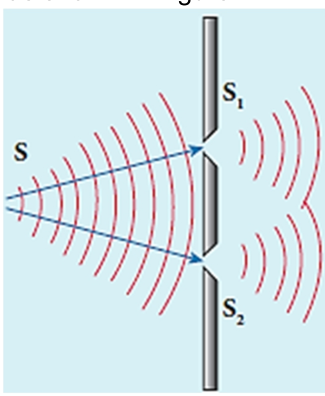
17. How does wavefront division provide coherent sources?

- This is the most commonly used method for producing two coherent sources.

- We know a point source produces spherical wavefronts.

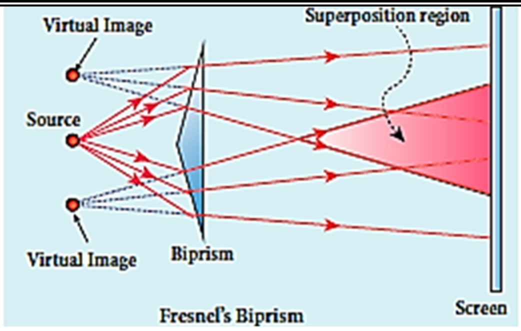
- All the points on the wavefront are at the same phase.

- If two points are chosen on the wavefront by using a double slit, the two points will act as coherent sources as shown in Figure.

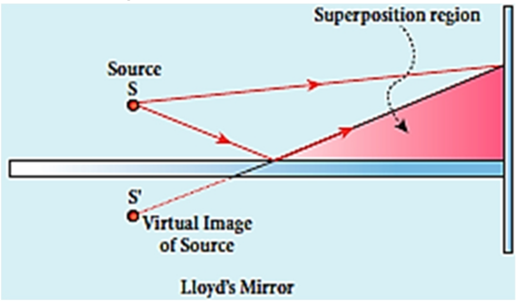


18. How do source and images behave as coherent sources?

- In this method a source and its image will act as a set of coherent source, because the source and its image will have waves in-phase or constant phase difference as shown in Figure.



- The Instrument, Fresnel's biprism uses two virtual sources as two coherent sources and the instrument, Lloyd's mirror uses a source and its virtual image as two coherent sources.



19. What is bandwidth of interference pattern?

The bandwidth (β) is defined as the distance between any two consecutive bright or dark fringes.

20. What are the c onditions for obtaining clear and broad interference bands?

- The screen should be as far away from the source as possible.
- The wavelength of light used must be larger.
- The two coherent sources (here S_1 and S_2) must be as close as possible.

21. What is diffraction?

Diffraction is bending of waves around sharp edges into the geometrically shadowed region.

22. Differentiate between Fresnel and Fraunhofer diffraction.

S.No.	Fresnel diffraction	Fraunhofer diffraction
1.	Spherical or cylindrical wavefront undergoes diffraction	Plane wavefront undergoes diffraction
2.	Light wave is from a source at finite distance	Light wave is from a source at infinity
3.	For laboratory conditions, convex lenses need not be used	In laboratory conditions, convex lenses are to be used
4.	Difficult to observe and analyse	Easy to observe and analyse

23. Discuss the special cases on first minimum in Fraunhofer diffraction.

- Let us consider the condition for first minimum with (n = 1). a sin θ = λ
- The first minimum has an angular spread of, $sin\theta = \frac{\lambda}{a}$

<u>Special cases:</u>

- When a < λ, the diffraction is not possible, because sinθ can never be greater than 1.
- When a ≥ λ, the diffraction is possible.
  - For a = λ, sinθ = 1 (*i.e,* θ = 90^0), the central maximum spreads fully in to the geometrically shadowed region leading to bending of the diffracted light to 90^0.
  - For a >> λ, sinθ << 1 *i.e,* the first minimum will fall within the width of the slit itself. The diffraction will not be noticed at all.
  - When a > λ and also comparable, say a = 2λ,
    $$sin\theta = \frac{\lambda}{a} = \frac{\lambda}{2\lambda} = \frac{1}{2}$$
    then θ = 30^0 . These are practical cases where diffraction could be observed effectively.

24. What is Fresnel's distance?

Fresnel's distance is the distance of diffracted ray upto which ray optics is obeyed and beyond which ray optics is not obeyed but, wave optics becomes significant.

25. Obtain the equation for Fresnel's distance.

- From the diffraction equation for first minimum,
$$sin\theta = \frac{\lambda}{a} \ ; \ \theta = \frac{\lambda}{a}$$
- From the definition of Fresnel's distance,
$$sin2\theta = \frac{a}{z} \ ; \ 2\theta = \frac{a}{z}$$
- Equating the above two equation gives,
$$\frac{\lambda}{a} = \frac{a}{2z}$$
- After rearranging, we get Fresnel's distance z as,
$$z = \frac{a^2}{2\lambda}$$

26. Mention the differences between interference and diffraction.

S.No.	Interference	Diffraction
1.	Superposition of two waves	Bending of waves around edges
2.	Superposition of waves from two coherent sources.	Superposition of waves emitted from various points of the same wavefront.
3.	Equally spaced fringes.	Unequally spaced fringes
4.	Intensity of all the bright fringes is almost same	Intensity falls rapidly for higher orders
5.	Large number of fringes are obtained	Less number of fringes are obtained

27. What is a diffraction grating?

Grating is a plane sheet of transparent material on which opaque rulings are made with a fine diamond pointer.

28. What is grating element?

The combined width of a ruling and a slit is called grating element (e = a + b).

29. What is corresponding points?

Points on successive slits separated by a distance equal to the grating element are called corresponding points.

30. What are resolution and resolving power?

- Resolution is the smallest seperated distance in the image of two points of the object which could be seen clearly without the blur due to diffraction.
- The inverse of resolution is called resolving power.

31. What is Rayleigh's criterion?

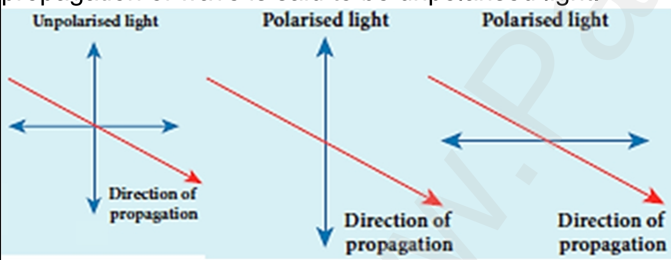
According to Rayleigh's criterion, central maximum of first image must coincide with minimum of second image and vice versa. This criterion is said to be limit of resolution.

32. What is p olarisation?

The phenomenon of restricting the vibrations of light (electric or magnetic field vector) to a particular direction perpendicular to the direction of propagation of wave is called polarization of light.

33. What is unpolarised light?

A transverse wave which has vibrations in all directions in a plane perpendicular to the direction of propagation of wave is said to be unpolarised light.

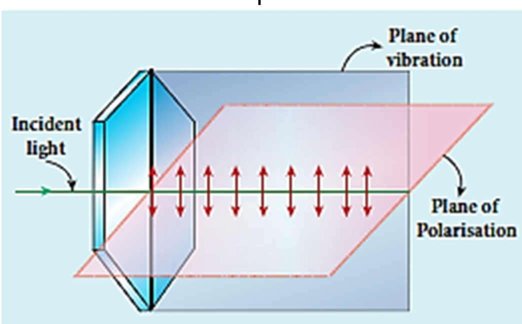


34. What is polarised or plane polarised light?

A transverse wave which has vibrations in only one direction in a plane perpendicular to the direction of propagation of wave is said to be polarised light.

35. What is plane of vibration?

The plane containing the vibrations of the electric field vector is known as the plane of vibration.



36. What is plane of polarisation?

The plane perpendicular to the plane of vibration and containing the ray of light is known as the plane of polarisation.

37. What are the four methods of polarisation?

- Polarisation by selective absorption
- Polarisation by reflection
- Polarisation by double refraction
- Polarisation by scattering.

38. Differentiate between polarised and unpolarised light

S.No.	Polarised light	Unpolarised light
1.	Consists of waves having their electric field vibrations in a single plane normal to the direction of ray.	Consists of waves having their electric field vibrations equally distributed in all directions normal to the direction of ray.
2.	Asymmetrical about the ray direction	Symmetrical about the ray direction
3.	It is obtained from unpolarised light with the help of polarisers	Produced by conventional light sources.

39. Discuss polarisation by selective absorption.

- Selective absorption is the property of a material which transmits waves whose electric fields vibrate in a plane parallel to a certain direction of orientation and absorbs all other waves.
- The polaroids or polarisers are thin commercial sheets which make use of the property of selective absorption to produce an intense beam of plane polarised light.
- Selective absorption is also called as dichroism.

40. What are polariser and analyser?

- The Polaroid, which plane polarises the unpolarisedlight passing through it is called a polariser.
- The polaroid, which is used to examine whether a beam of light is polarised or not is called an analyser.

41. What are plane polarised, unpolarised and partially polarised light?

- If the intensity of light varies from maximum to zero for every rotation of 90^0 of the analyser, the light is said to be plane polarised.
- If the intensity of light does not vary for the rotation of 90^0 of the analyser, the light is said to be unpolarised.
- If the intensity of light varies between maximum and minimum for every rotation of 90^0 of the analyser, the light is said to be partially polarised light.

42. State and obtain Malus' law.

The light transmitted of intensity I from the analyser varies directly as the square of the cosine of the angle θ between the transmission axis of polariser and analyser.

$$I = I_0 cos^2\theta$$

43. List the uses of polaroids.

- Polaroids are used in goggles and cameras to avoid glare of light.
- Polaroids are useful in three dimensional motion pictures i.e., in holography.
- Polaroids are used to improve contrast in old oil paintings.
- Polaroids are used in optical stress analysis.
- Polaroids are used as window glasses to control the intensity of incoming light.
- Polaroids are used to produce polarised laser beam acts as needle to read/write in compact discs (CDs).
- Polaroids produce polarised lights to be used in liquid crystal display (LCD).

44. State Brewster's law.

The tangent of the polarising angle for a transparent medium is equal to its refractive index.

$$i.e. \quad n = tan i_P$$

45. What is polarising or Brewster's angle?.

The angle of incidence at which a beam of unpolarised light falling on a transparent surface is reflected as a beam of plane polarised light is called polarising angle or Brewster's angle(i_P).

46. What is double refraction or birefringence?

When a ray of unpolarised light is incident on a calcite crystal, two refracted rays are produced. Hence, two images of a single object are formed. This phenomenon is called double refraction or birefringence.

47. Differentiate Ordinary and extraordinary ray.

S.No.	Ordinary ray	Extraordinary ray
1.	It obeys laws of refraction.	It does not obey laws of refraction.
2.	Inside a double refracting crystal the ordinary ray travels with same velocity in all directions.	The extra ordinary ray travels with different velocities along different directions.
3.	A point source inside a refracting crystal produces spherical wavefront for ordinary ray	A point source inside a refracting crystal produces elliptical wavefront for extraordinary ray

48. What is optic axis?

Inside the crystal, there is a particular direction in which both ordinary and extraordinary ray travel with same velocity. This direction is called optic axis.

49. Mention the types of optically active crystals with example.

- Crystals like calcite, quartz, tourmaline and ice having only one optic axis are called uniaxial crystals.
- Crystals like mica, topaz, selenite and aragonite having two optic axes are called biaxial crystals.

50. What are the us es of Nicol prism?

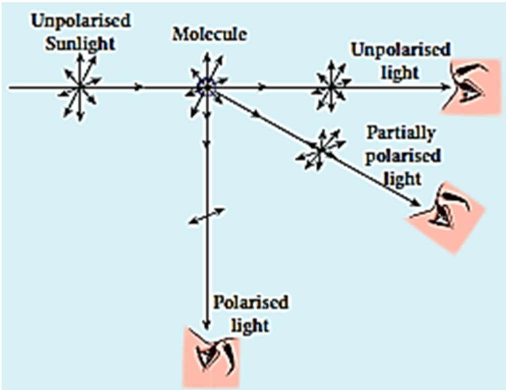
- It produces plane polarised light and functions as a polariser
- It can also be used to analyse the plane polarised light i.e used at an analyser.

51. What are the drawbacks of Nicol prism?

- Its cost is very high due to scarity of large and flawless calcite crystals.
- Due to extraordinary ray passing obliquely through it, the emergent ray is always displaced a little to one side.
- The effective field of view is quite limited.
- Light emerging out of it is not uniformly plane polarised.

52. How is polarisation of light obtained by scattering of light?

- The light from a clear blue portion of the sky shows a rise and fall of intensity when viewed through a polaroid which is rotated.
- This is because of sunlight, which has changed its direction (having been scattered) on encountering the molecules of the earth's atmosphere.
- Under the influence of electric field of the incident light, the electrons in the molecules acquire components of motion in two directions.
- We have shown an observer looking at 90^0 to the direction of the sun.



- Clearly, charges accelerating parallel do not radiate energy towards this observer since their acceleration has no transverse component.
- Hence, the radiation from perpendicularly accelerated electron reaches the observer as polarised light.

53. What are near point and normal focusing?

Near point focusing:

- The image is formed at near point, i.e. 25 cm for normal eye. This distance is also called as least distance D of distinct vision. In this position, the eye feels comfortable but there is little strain on the eye.

Normal focusing:

- The image is formed at infinity. In this position the eye is most relaxed to view the image.

54. What is simple microscope?

A simple microscope is a single magnifying (converging) lens of small focal length. It is to get an erect, magnified and virtual image of the object.

55. Why is oil immersed objective preferred in a microscope?

Oil immersed objective is preferred in a microscope to further reduce the resolving distance d_{min} and thereby increasing the magnification.

56. What is an astronomical telescope?

An astronomical telescope is used to get the magnification of distant astronomical objects like stars, planets, moon etc. The image formed here is inverted.

57. What is terrestrial telescope?

A terrestrial telescope is used to see object at long distance on the surface of earth. Hence, image should be erect.

58. What is the use of an erecting lens in a terrestrial telescope?

A terrestrial telescope has an additional erecting lens to make the final image erect.

59. What is reflecting telescope?

Telescopes with mirror objectives are called reflecting telescopes.

60. What are the advantages and disadvantages of using a reflecting telescope?

Advantages:

- Only one surface should be polished and maintained.
- Support can be given from the entire back of the mirror rather than only at the rim for lens.
- Mirrors weigh much less compared to lens.

Disadvantages:

- The objective mirror would focus the light inside the telescope tube.
- One must have an eye piece inside obstructing some light.

61. What is spectrometer? Give their basic parts.

The spectrometer is an optical instrument used to study the spectra of different sources of light and to measure the refractive indices of materials.

Basic parts:

(i) Collimator (ii) Prism table and (iii) Telescope.

62. What is the use of collimator?

The collimator is used to produce a parallel beam of light in spectrometer.

63. What are the uses of spectrometer?

- It is used to study the spectra of different sources of light.
- It is used to measure the refractive indices of materials.

64. What is myopia? W hat is its remedy?

- Myopia or nearsightedness is the defectness of the eye in which cannot see distant objects clearly.
- To overcome this problem, one should use the concave lens of calculated focal length.

65. What is hypermetr opia? What is its remedy?

- Hypermetropia or hyperopia or farsightedness is the defectness of the eye in which cannot see the objects close to the eye.
- To overcome this problem, one should use the convex lens of calculated focal length.

66. What is presbyopia?

The kind of farsightedness arising due to aging is called presbyopia.

67. What is astigmatism? What is its remedy?

- Astigmatism is the defect arising due to different curvatures along different planes in the eye lens.
- Astigmatic person cannot see all the directions equally well.
- Lenses with different curvatures in different plane are used to rectify this defect.

68. Two light sources of equal amplitudes interfere with each other. Calculate the ratio of maximum and minimum intensities.

- If $a_1 = a_2 = a$,

$$I_{max} : I_{min} = \frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{4a^2}{0} = undefined$$

Conceptual Questions:

69. Two independent monochromatic sources cannot act as coherent sources, why?

Two independent monochromatic sources can never be coherent, because they may emit waves of same frequency and same amplitude, but not with same phase.

70. Does diffraction take place at the Young's double slit?

Yes. Light waves diffracted at the slits produce interference in the screen.

71. Is there any difference between coloured light obtained from prism and colours of soap bubble?

Yes. The coloured light obtained from prism is due to refraction whereas colours of soap bubbles are due to interference.

72. A small disc is placed in the path of the light from distance source. Will the center of the shadow be bright or dark?

The center of the shadow will be bright because the light ray diffracted at the edge of the small disc interfere constructively at the center of the shadow.

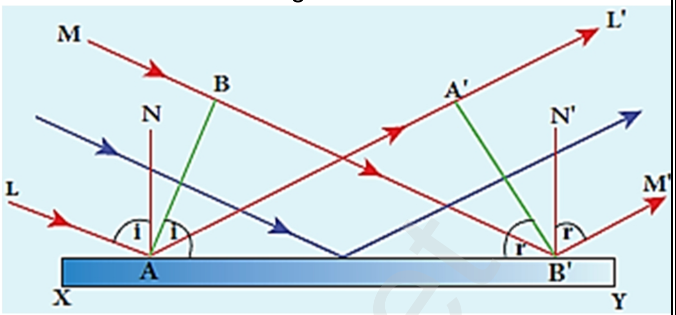
73. When a wave undergoes reflection at a denser medium, what happens to its phase?

A wave undergoes reflection at a denser medium, will get 180^0 phase difference than the incident.

5 Marks Q & A:

1. Prove laws of reflection using Huygens' principle.

- Let us consider a parallel beam of light incident on a reflecting plane surface such as a plane mirror XY as shown in Figure.



- The incident wavefront is AB and the reflected wavefront is A′B′ in the same medium.
- These wavefronts are perpendicular to the incident rays L, M and reflected rays L′ , M′ respectively.
- By the time point A of the incident wavefront touches the reflecting surface, the point B is yet to travel a distance BB′ to touch the reflecting surface at B′ .
- When the point B falls on the reflecting surface at B′ , the point A would have reached A′ .
- This is applicable to all the points on the wavefront. Thus, the reflected wavefront A′B′ emanates as a plane wavefront.
- The two normals N and N′ are considered at the points where the rays L and M fall on the reflecting surface.
- As reflection happens in the same medium, the speed of light is same before and after the reflection.
- Hence, the time taken for the ray to travel from B to B′ is the same as the time taken for the ray to travel from A to A′ .
- Thus, the distance BB′ is equal to the distance AA′; (AA′= BB′) .

Laws of reflection:

- The incident rays, the reflected rays and the normal are in the same plane.
- Angle of incidence,

$$\angle i = \angle NAL = 90^0 - \angle NAB = \angle BAB'$$

Angle of reflection,

$$\angle r = \angle N'B'M' = 90^0 - \angle N'B'A' = \angle A'B'A$$

For the two right angle triangles, Δ ABB′ and Δ B′A′A,

$$\angle B = \angle A' = 90^0 \quad ; \quad AA' = BB'$$
$$and \;\; AB' \; is \; common$$

Thus, the two triangles are congruent.

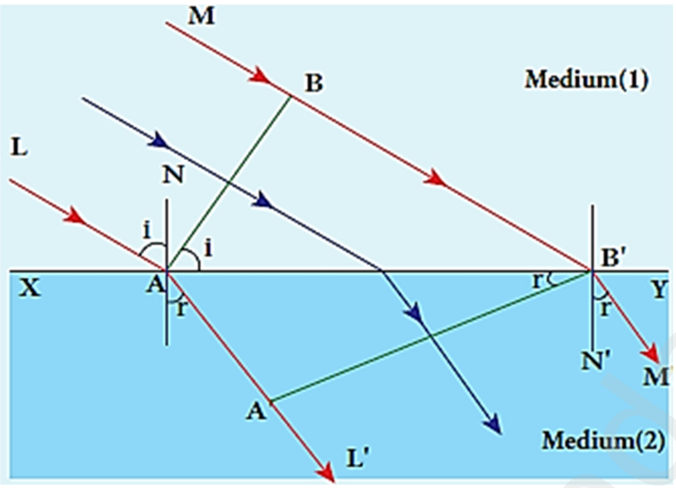
As per the property of congruency, the two angles, ∠ BAB′ and ∠ A′B′A must also be equal.

$$i = r$$

- Hence, the laws of reflection are proved.

2. Prove laws of refraction using Huygens' principle.

- Let us consider a parallel beam of light is incident on a refracting plane surface XY such as a glass surface as shown in Figure.



- The incident wavefront AB is in rarer medium (1) and the refracted wavefront A′B′ is in denser medium (2).
- These wavefronts are perpendicular to the incident rays L, M and refracted rays L′,M′ respectively.
- By the time the point A of the incident wavefront touches the refracting surface, the point B is yet to travel a distance BB′ to touch the refracting surface at B′.
- When the point B falls on the refracting surface at B′, the point A would have reached A′ in the other medium.
- This is applicable to all the points on the wavefront. Thus, the refracted wavefront A′B′ emanates as a plane wavefront.
- The two normals N and N′ are considered at the points where the rays L and M fall on the refracting surface.
- As refraction happens from rarer medium (1) to denser medium (2), the speed of light is v_1 and v_2 before and after refraction and v_1 is greater than v_2 ($v_1 > v_2$).
- But, the time taken t for the ray to travel from B to B′ is the same as the time taken for the ray to travel from A to A′ .

$$t = \frac{BB'}{v_1} = \frac{AA'}{v_2}$$

$$\frac{BB'}{AA'} = \frac{v_1}{v_2}$$

Laws of refraction:

- The incident rays, the refracted rays and the normal are in the same plane.
- Angle of incidence,

$$i = \angle NAL = 90^0 - \angle NAB = \angle BAB'$$

Angle of refraction,

$$r = \angle N'B'M' = 90^0 - \angle N'B'A' = \angle A'B'A$$

For the two right angle triangles ΔABB′ and ΔB′A′A,

$$\frac{\sin i}{\sin r} = \frac{BB'/AB'}{AA'/AB'} = \frac{BB'}{AA'} = \frac{v_1}{v_2} = \frac{c/v_2}{c/v_1}$$

Here, c is speed of light in vacuum. The ratio c/v is the constant, called refractive index of the medium.

The refractive index of medium (1) is, $c/v_1 = n_1$ and that of medium (2) is, $c/v_2 = n_2$.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

- In the product form,

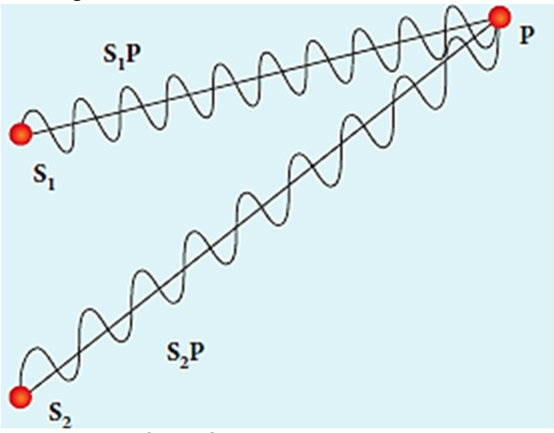
$$n_1 \sin i = n_2 \sin r$$

- Hence, the laws of refraction are proved.
- In the same way the laws of refraction can also be proved for wavefront travelling from denser to rarer medium.
- Light travels with greater speed in rarer medium and lesser speed in denser medium.
- Hence, the wavelength of the light is longer in rarer medium and shorter in denser medium.

$$\frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

3. Obtain the equation for resultant intensity due to interference of light and ratio of maximum and minimum intensities.

- Let us consider two light waves from the two sources S_1 and S_2 meeting at a point P as shown in Figure.



- The wave from S_1 at an instant t at P is,

$$y_1 = a_1 \sin \omega t$$

- The wave from S_2 at an instant t at P is,

$$y_2 = a_2 \sin(\omega t + \phi)$$

- The two waves have different amplitudes a_1 and a_2, same angular frequency ω, and a phase difference of ϕ between them.
- The resultant displacement will be given by,

$$y = y_1 + y_2 = a_1 \sin \omega t + a_2 \sin(\omega t + \phi)$$

- The simplification of the above equation by using trigonometric identities gives the equation,

$$y = A \sin(\omega t + \theta)$$

$$Where, A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2cos\phi} \longrightarrow (1)$$

$$\theta = tan^{-1}\frac{a_2 sin\phi}{a_1 + a_2 cos\phi}$$

- The resultant amplitude is maximum,

$$A_{max} = \sqrt{(a_1 + a_2)^2};\ When\ \phi = 0, \pm 2\pi, \pm 4\pi, \ldots$$

- The resultant amplitude is minimum,

$$A_{min} = \sqrt{(a_1 - a_2)^2};\ When\ \phi = \pm\pi, \pm 3\pi, \pm 5\pi, \ldots$$

- The intensity of light is proportional to square of amplitude,

$$I \propto A^2$$

- Now equation(1) becomes,

$$I \propto I_1 + I_2 + 2\sqrt{I_1 I_2}\ cos\phi \longrightarrow (2)$$

- In equation(2) if the phase difference, $\phi = 0, \pm 2\pi, \pm 4\pi, \ldots$ it corresponds to the condition for maximum intensity of light called as constructive interference.
- The resultant maximum intensity is,

$$I_{max} \propto (a_1 + a_2)^2 \propto I_1 + I_2 + 2\sqrt{I_1 I_2} \longrightarrow (3)$$

- In equation(2) if the phase difference, $\phi = \pm\pi, \pm 3\pi, \pm 5\pi, \ldots$ it corresponds to the condition for minimum intensity of light called as destructive interference.
- The resultant minimum intensity is,

$$I_{min} \propto (a_1 - a_2)^2 \propto I_1 + I_2 - 2\sqrt{I_1 I_2} \longrightarrow (4)$$

- The ratio of the maximum and minimum intensity is,

$$I_{max} : I_{min} = \frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$$

__Special case:__

- If $a_1 = a_2 = a$, then equation(1) becomes,

$$A = \sqrt{2a^2 + 2a^2 cos\phi} = \sqrt{2a^2(1 + cos\phi)}$$

$$A = \sqrt{2a^2 2\ cos^2\left(\frac{\phi}{2}\right)} = 2a\ cos\left(\frac{\phi}{2}\right)$$

$$I \propto 4a^2 cos^2\left(\frac{\phi}{2}\right) \quad [\because I \propto A^2]$$

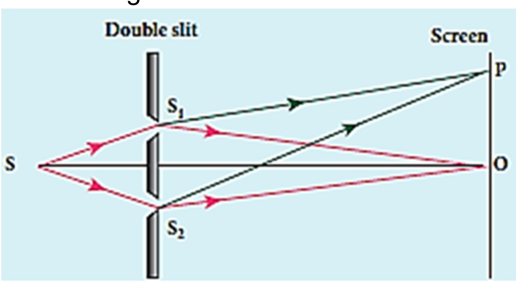
$$I = 4I_0 cos^2\left(\frac{\phi}{2}\right) \quad [\because I_0 \propto a^2]$$

$$I_{max} = 4I_0\ \ When\ \phi = 0, \pm 2\pi, \pm 4\pi, \ldots$$

$$I_{min} = 0\ \ When\ \phi = \pm\pi, \pm 3\pi, \pm 5\pi, \ldots$$

4. Explain the Young's double slit experimental setup.

- Thomas Young, a British Physicist used an opaque screen with two small openings called double slit S_1 and S_2 kept equidistance from a source S as shown in figure.



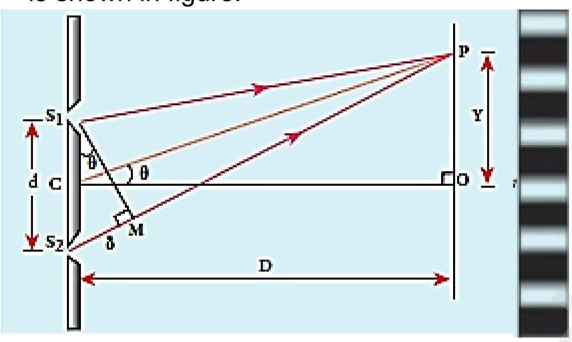
- The width of each slit is about 0.03 mm and they are separated by a distance of about 0.3 mm.
- As S_1 and S_2 are equidistant from S, the light waves from S reach S_1 and S_2 in-phase.
- So, S_1 and S_2 act as coherent sources which are the requirement of obtaining interference pattern.
- Wavefronts from S_1 and S_2 spread out and overlapping takes place to the right side of double slit.
- When a screen is placed at a distance of about 1 meter from the slits, alternate bright and dark fringes which are equally spaced appear on the screen.

- These are called interference fringes or bands. Using an eyepiece the fringes can be seen directly.
- At the center point O on the screen, waves from S_1 and S_2 travel equal distances and arrive in-phase.
- These two waves constructively interfere and bright fringe is observed at O. This is called central bright fringe.
- The fringes disappear and there is uniform illumination on the screen when one of the slits is covered.
- This shows clearly that the bands are due to interference.

5. Obtain the equation for path difference and bandwidth in Young's double slit experiment.

Equation for path difference :

- The schematic diagram of the experimental set up is shown in figure.



- Let d be the distance between the double slits S_1 and S_2 which act as coherent sources of wavelength λ.
- A screen is placed parallel to the double slit at a distance D from it.
- The mid-point of S_1 and S_2 is C and the mid-point of the screen O is equidistant from S_1 and S_2. P is any point at a distance y from O.
- The waves from S_1 and S_2 meet at P either in-phase or out-of-phase depending upon the path difference between the two waves.
- The path difference δ between the light waves from S_1 and S_2 to the point P is,

$$\delta = S_2P - S_1P$$

- A perpendicular is dropped from the point S_1 to the line S_2P at M to find the path difference more precisely.

$$\delta = S_2P - MP = S_2M$$

- The angular position of the point P from C is θ. ∠OCP = θ.
- From the geometry, the angles ∠OCP and $\angle S_2S_1M$ are equal. *i.e.* ∠OCP = ∠S2S1M = θ.
- In right angle triangle ΔS_1S_2M, the path difference, $S_2M = d \sin\theta$. So that,

$$\delta = d\,sin\theta \longrightarrow (1)$$

- From the right angle triangle ΔOCP,

$$tan\theta = \frac{y}{D} \longrightarrow (2)$$

- If the angle θ is small,

$$sin\,\theta \approx tan\,\theta \approx \theta$$

- Therefore,

$$From\ equation(1), \delta = d\,\theta \longrightarrow (3)$$

$$From\ equation(2), \theta = \frac{y}{D} \longrightarrow (4)$$

- Substituting equation(4) in (3), we get,

$$The\ path\ difference, \delta = \frac{dy}{D} \longrightarrow (5)$$

- Based on the condition on the path difference, the point P may have a bright or dark fringe.

Condition for bright fringe (or) maxima:

- The condition for the constructive interference or the point P to be have a bright fringe is,

$$Path\ difference, \delta = n\lambda\ where, n = 0, 1, 2, \ldots$$

$$\therefore \frac{dy}{D} = n\lambda$$

$$\therefore y = y_n = \frac{D}{d}n\lambda \longrightarrow (6)$$

- This is the condition for the point P to be a bright fringe. The distance is the distance of the nth bright fringe from the point O.

Condition for dark fringe (or) minima :

- The condition for the destructive interference or the point P to be have a dark fringe is,

$$Path\ difference, \delta = (2n-1)\frac{\lambda}{2}\ where, n = 0, 1, 2, \ldots$$

$$\frac{dy}{D} = (2n-1)\frac{\lambda}{2}$$

$$\therefore y = y_n = \frac{D}{d}(2n-1)\frac{\lambda}{2} \longrightarrow (7)$$

- This is the condition for the point P to be a dark fringe. The distance y_n is the distance of the nth dark fringe from the point O.

Equation for bandwidth :

- The bandwidth (β) is defined as the distance between any two consecutive bright or dark fringes.
- The distance between (n+1)th and nth consecutive bright fringes from O is given by,

$$\beta = y_{n+1} - y_n = \frac{D}{d}(n+1)\lambda - \frac{D}{d}n\lambda$$

$$\beta = \frac{\lambda D}{d} \longrightarrow (8)$$

- Similarly, the distance between (n+1)th and nth consecutive dark fringes from O is given by,

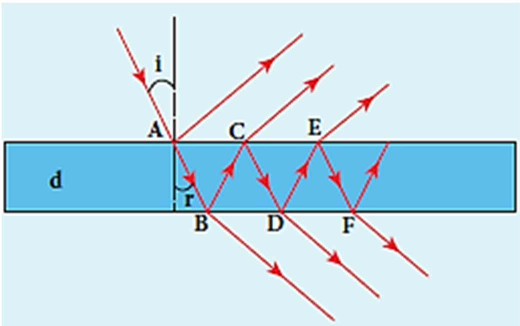
$$\beta = y_{n+1} - y_n = \frac{D}{d}[2(n+1)-1]\frac{\lambda}{2} - \frac{D}{d}(2n-1)\frac{\lambda}{2}$$

$$\beta = \frac{\lambda D}{d} \longrightarrow (9)$$

- Equations (8) and (9) show that the bright and dark fringes are of same width equally spaced on either side of central bright fringe.

6. Obtain the equations for constructive and destructive interference for transmitted and reflected waves in thin films.

- Let us consider a thin film of transparent material of refractive index μ and thickness d.
- A parallel beam of light is incident on the film at an angle *i* as shown in Figure.



- The wave is divided into two parts at the upper surface, one is reflected and the other is refracted.
- The refracted part, which enters into the film, again gets divided at the lower surface into two parts; one is transmitted out of the film and the other is reflected back in to the film.
- Reflected as well as refracted waves are sent by the film as multiple reflections take place inside the film.
- The interference is produced by both the reflected and transmitted light.

(a) For transmitted light :

- The light transmitted may interfere to produce a resultant intensity.
- Let us consider the path difference between the two light waves transmitted from B and D.
- The two waves moved together and remained in phase up to B where splitting occurred.
- The extra path travelled by the wave transmitted from D is the path inside the film, BC + CD.
- If we approximate the incidence to be nearly normal (i = 0), then the points B and D are very close to each other.
- The extra distance travelled by the wave is approximately twice thickness of the film,

$$BC + CD = 2d.$$

- As this extra path is traversed in a medium of refractive index μ, the optical path difference is,

$$\delta = 2\mu d.$$

- The condition for constructive interference in transmitted ray is,

$$2\mu d = n\lambda$$

- Similarly, the condition for destructive interference in transmitted ray is,

$$2\mu d = (2n-1)\frac{\lambda}{2}$$

(b) For reflected light :

- Let us consider the path difference between the light waves reflected by the upper surface at A and the other wave coming out at C after passing through the film.
- The additional path travelled by wave coming out from C is the path inside the film, $AB + BC$
- For nearly normal incidence this distance could be approximated as, AB + BC = 2d.
- As this extra path is travelled in the medium of refractive index μ, the optical path difference is,

$$\delta = 2\mu d$$

- The condition for constructive interference for reflected ray is,

$$2\mu d + \frac{\lambda}{2} = n\lambda$$

$$2\mu d = (2n-1)\frac{\lambda}{2}$$

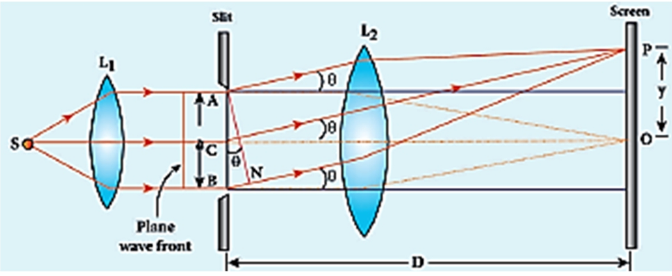
- The additional path difference λ/2 is due to the phase change of π in rarer to denser reflection taking place at A.
- The condition for destructive interference for reflected ray is,

$$2\mu d + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

$$2\mu d = n\lambda$$

7. Discuss diffraction at single slit and obtain the condition for nth minimum and maximum.

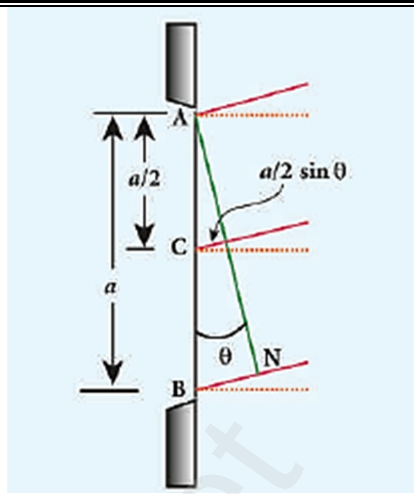
- Let a parallel beam of light fall normally on a single slit AB of width 'a' as shown in Figure.



- The diffracted beam falls on a screen kept at a distance.
- The center of the slit is C. A straight line through C perpendicular to the plane of slit meets the center of the screen at O.
- We would like to find the intensity at any point P on the screen.
- The lines joining P to the different points on the slit can be treated as parallel lines, making an angle θ with the normal CO.
- All the waves start parallel to each other from different points of the slit and interfere at point P and other points to give the resultant intensities.
- The point P is in the geometrically shadowed region, up to which the central maximum is spread due to diffraction as shown in figure above.
- We need to give the condition for the point P to be of various minima.
- The basic idea is to divide the slit into much smaller even number of parts.
- Then, add their contributions at P with the proper path difference to show that destructive interference takes place at that point to make it minimum.
- To explain maximum, the slit is divided into odd number of parts.

(a) Condition for P to be first minimum:

- Let us divide the slit AB into two half 's AC and CB.
- Now the width of AC is (a/2). We have different points on the slit which are separated by the same width (here a/2) called corresponding points as shown in Figure.



- Light waves from different corresponding points meet at point P and interfere destructively to make it first minimum.
- The path difference δ between waves from these corresponding points is,

$$\delta = \frac{a}{2}\sin\theta$$

- The condition for P to be first minimum,

$$\frac{a}{2}\sin\theta = \frac{\lambda}{2}$$
$$a\ \sin\theta = \lambda\ (first\ minimum)$$

(b) Condition for P to be second minimum:

- Let us divide the slit AB into four equal parts.
- Now, the width of each part is a/4. We have several corresponding points on the slit which are separated by the same width a/4.
- The path difference δ between waves from these corresponding points is,

$$\delta = \frac{a}{4}\sin\theta$$

- The condition for P to be second minimum,

$$\frac{a}{4}\sin\theta = \frac{\lambda}{2}$$
$$a\ \sin\theta = 2\lambda\ (second\ minimum)$$

(c) Condition for P to be third order minimum:

- The same way the slit is divided in to six equal parts to explain the condition for P to be third minimum is,

$$\frac{a}{6}\sin\theta = \frac{\lambda}{2}$$
$$a\ \sin\theta = 3\lambda\ (third\ minimum)$$

(d) Condition for P to be nth order minimum:

- Dividing the slit into 2n number of (even number of) equal parts makes the light produced by one of the corresponding points to be cancelled by its counterpart.

- Thus, the condition for n^{th} order minimum is,

$$\frac{a}{2n}\sin\theta = \frac{\lambda}{2}$$
$$a\sin\theta = n\lambda\ (n^{th}\ minimum)$$

Condition for maxima:

- For points of maxima, the slit is to be divided in to odd number of equal parts so that one part remains un-cancelled making the point P appear bright.
- The condition for first maximum is,

$$\frac{a}{3}\sin\theta = \frac{\lambda}{2}$$
$$a\sin\theta = \frac{3\lambda}{2}$$

- The condition for second maximum is,

$$\frac{a}{5}\sin\theta = \frac{\lambda}{2}$$
$$a\sin\theta = \frac{5\lambda}{2}$$

- The condition for third maximum is,

$$\frac{a}{7}\sin\theta = \frac{\lambda}{2}$$
$$a\sin\theta = \frac{7\lambda}{2}$$

- In the same way, the condition for n^{th} maximum is,

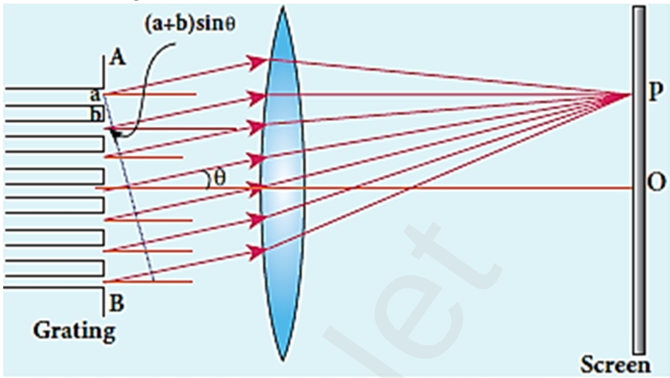
$$a\sin\theta = (2n+1)\frac{\lambda}{2}\ (n^{th}\ maximum)$$

Where, n = 0, 1, 2, 3, . . . , is the order of diffraction maximum.

- The central maximum is called 0th order maximum. The points of the maximum intensity lie nearly midway between the successive minima.

8. Discuss the diffraction at a grating and obtain the condition for the mth maximum.

- Grating has multiple slits with equal widths of size comparable to the wavelength of diffracting light.
- Grating is a plane sheet of transparent material on which opaque rulings are made with a fine diamond pointer.
- The modern commercial grating contains about 6000 lines per centimetre.
- The rulings act as obstacles having a definite width b and the transparent space between the rulings act as slit of width a.
- The combined width of a ruling and a slit is called grating element (e = a + b).
- Points on successive slits separated by a distance equal to the grating element are called corresponding points.
- A plane transmission grating is represented by AB in Figure.



- Let a plane wavefront of monochromatic light with wave length λ be incident normally on the grating.
- As the slits size is comparable to that of wavelength, the incident light diffracts at the grating.
- A diffraction pattern is obtained on the screen when the diffracted waves are focused on a screen using a convex lens.
- Let us consider a point P at an angle θ with the normal drawn from the center of the grating to the screen.
- The path difference δ between the diffracted waves from one pair of corresponding points is,

$$\delta = (a+b)\sin\theta$$

- This path difference is the same for any pair of corresponding points.
- The point P will be bright, when

$$\delta = m\lambda\ \ ;\ where\ m = 0,1,2,3,\ldots$$

- Combining the above two equations, we get,

$$(a+b)\sin\theta = m\lambda$$

Here, m is called order of diffraction.

(a) Condition for zero order maximum, m = 0 :

- For (a + b) $\sin\theta = 0$, the position, $\theta = 0$. $\sin\theta = 0$ and m = 0.
- This is called zero order diffraction or central maximum.

(b) Condition for first order maximum, m = 1 :

- If (a + b) $\sin\theta_1 = \lambda$, the diffracted light meet at an angle θ_1 to the incident direction and the first order maximum is obtained.

(c) Condition for second order maximum, m = 2 :

- Similarly, (a + b) $\sin\theta_2 = 2\lambda$ forms the second order maximum at the angular position θ_2.

(d) Condition for higher order maximum :

- On either side of central maxima different higher orders of diffraction maxima are formed at different angular positions.
- If we take,

$$N = \frac{1}{a+b}$$

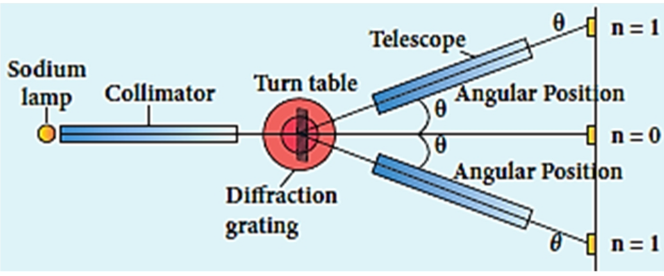
Then, N gives the number of grating elements or rulings drawn per unit width of the grating.

- Normally, this number N is specified on the grating itself. Now, the equation becomes,

$$\frac{1}{N}\sin\theta = m\lambda$$
$$\sin\theta = Nm\lambda$$

9. Discuss the experiment to determine the wavelength of monochromatic light using diffraction grating.

- The wavelength of a spectral line can be very accurately determined with the help of a diffraction grating and a spectrometer.
- Initially all the preliminary adjustments of the spectrometer are made.
- The slit of collimator is illuminated by a monochromatic light, whose wavelength is to be determined.
- The telescope is brought in line with collimator to view the image of the slit.
- The given plane transmission grating is then mounted on the prism table with its plane perpendicular to the incident beam of light coming from the collimator.
- The telescope is turned to one side until the first order diffraction image of the slit coincides with the vertical cross wire of the eye piece.
- The reading of the position of the telescope is noted.
- Similarly the first order diffraction image on the other side is made to coincide with the vertical cross wire and corresponding reading is noted.
- The difference between two positions gives 2θ. Half of its value gives θ, the diffraction angle for first order maximum as shown in Figure.



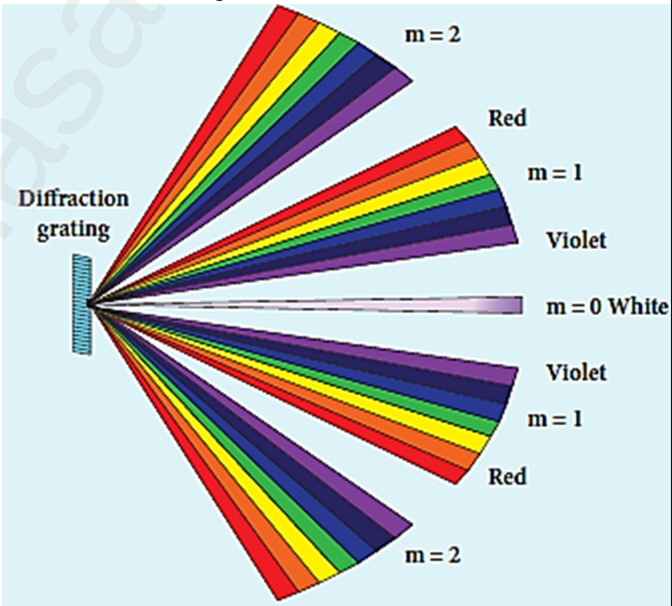
- The wavelength of light is calculated from the equation,

$$\lambda = \frac{\sin\theta}{Nm}$$

- Here, N is the number of rulings per metre in the grating and m is the order of the diffraction image.

10. Discuss the experiment to determine the wavelength of different colours using diffraction grating.

- When white light is used, the diffraction pattern consists of a white central maximum and on both sides continuous coloured diffraction patters are formed.
- The central maximum is white as all the colours meet here constructively with no path difference.
- As θ increases, the path difference, (a+b)sinθ, passes through condition for maxima of diffraction of different orders for all colours from violet to red.
- It produces a spectrum of diffraction pattern from violet to red on either side of central maximum as shown in Figure.



- By measuring the angle at which these colours appear for various orders of diffraction, the wavelength of different colours could be calculated using the formula,

$$\lambda = \frac{\sin\theta}{Nm}$$

- Here, N is the number of rulings per metre in the grating and m is the order of the diffraction image.

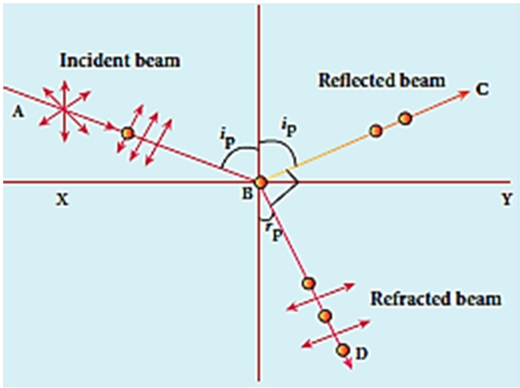
11. State and prove Brewster's law.

<u>**Brewster's law:**</u>

- The tangent of the polarising angle for a transparent medium is equal to its refractive index.

Proof:

- At the incidence of polarising angle, the reflected and transmitted rays are perpendicular to each other.



- Suppose, i_p is the polarising angle and r_p is the corresponding angle of refraction. Then from figure,

$$i_P + 90^0 + r_P = 180^0$$
$$r_P = 90^0 - i_P \longrightarrow (1)$$

- From Snell's law, the refractive index of the transparent medium is,

$$\frac{\sin i_P}{\sin r_P} = n$$

Where n is the refractive index of the medium with respect to air.

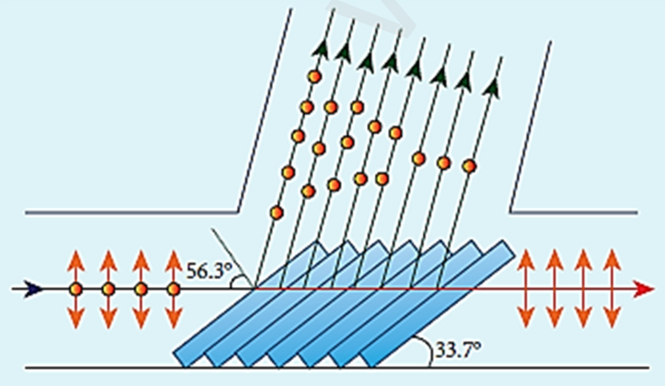
- Substituting the value of r_p from Equation(1),

$$\frac{\sin i_P}{\sin(90^0 - i_P)} = n$$
$$\frac{\sin i_P}{\cos i_P} = n$$
$$\tan i_P = n$$

- This relation is known as Brewster's law.

12) Discuss about pile of plates.

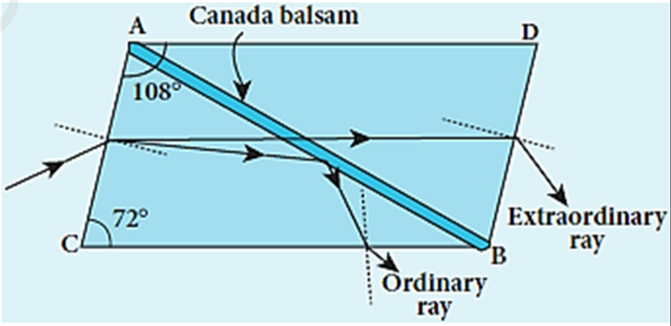
- The phenomenon of polarisation by reflection is used in the construction of pile of plates.
- It consists of a number of glass plates placed one over the other in a tube as shown in figure.



- The plates are inclined at an angle of 33.7^0 to the axis of the tube.
- A beam of unpolarised light is allowed to fall on the pile of plates along the axis of the tube.
- So, the angle of incidence of light will be at 56.3^0 which is the polarising angle for glass.
- The vibrations perpendicular to the plane of incidence are reflected at each surface and those parallel to it are transmitted.
- The larger the number of surfaces, the greater is the intensity of the reflected plane polarised light.
- The pile of plates is used as a polarizer and also as an analyser.

13) Explain about Nicol prism.

- Nicol prism is an optical device incorporated in optical instruments both for producing and analysing plane polarised light.
- The construction of a Nicol prism is based on the phenomenon of Double refraction.
- One of the most common forms of the Nicol prism is made by taking a calcite crystal which is a double refracting crystal with its length three times its breadth.
- As shown in figure below, ABCD represents the principal section of a calcite crystal.



- It is cut into two halves along the diagonal so that their face angles are 72^0 and 108^0.
- The two halves are joined together by a layer of canada balsam, a transparent cement.
- Let us consider a ray of unpolarised light from monochromatic source such as a sodium vapour lamp is incident on the face AC of the Nicol prism.
- Double refraction takes place and the ray is split into ordinary and extraordinary rays. They travel with different velocities.

- The refractive index of the crystal for the ordinary ray (monochromatic sodium light) is 1.658 and for extraordinary ray is 1.486.
- The refractive index of canada balsam is 1.523. Canada balsam does not polarise light.
- The ordinary ray is total internally reflected at the layer of canada balsam and is prevented from emerging from the other face.
- The extraordinary ray alone is transmitted through the crystal which is completely plane polarised.

14. Discuss about simple microscope and obtain the equations for magnification for near point focusing and normal focusing.

- A simple microscope is a single magnifying (converging) lens of small focal length.
- The idea is to get an erect, magnified and virtual image of the object.
- For this, the object is placed between F and P on one side of the lens and viewed from other side of the lens.
- There are two magnifications to be discussed for two kinds of focussing.

(1) Near point focusing :

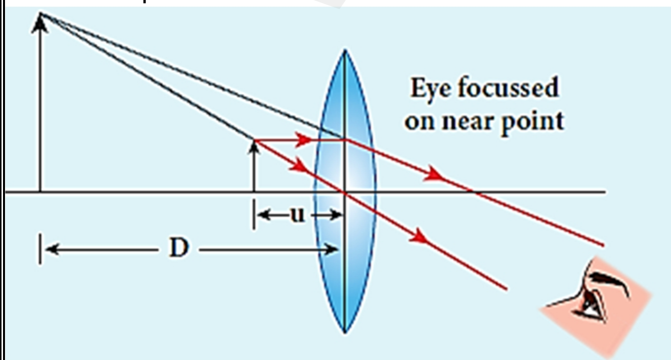
- The image is formed at near point, i.e. 25 cm for normal eye.
- This distance is also called as least distance D of distinct vision.
- In this position, the eye feels comfortable but there is little strain on the eye.

(2) Normal focusing :

- The image is formed at infinity. In this position the eye is most relaxed to view the image.

(a) Magnification in near point focusing :

- The near point focusing is shown in Figure. Object distance u is less than f. The image distance is the near point D.



- The magnification m is given by the relation,

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

- With the help of lens equation, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ the magnification can further be written as,

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

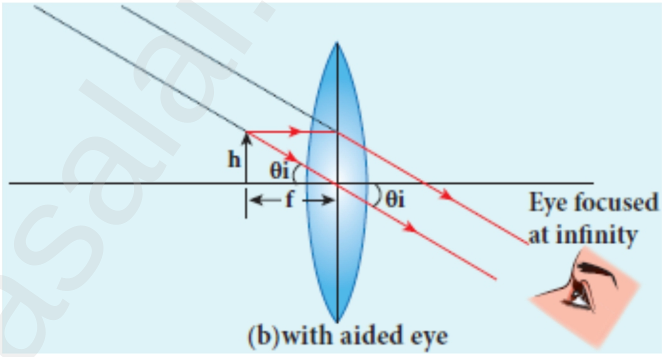
- Substituting for v with sign convention, v = –D

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

- This is the magnification for near point focusing.

(b) Magnification in normal focusing: (angular magnification)

- The normal focusing is shown in Figure(b). We will now find the magnification for the image formed at infinity.

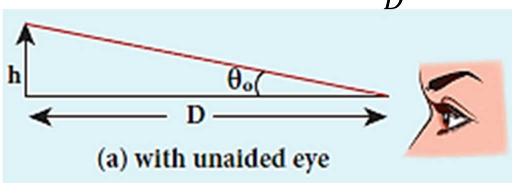


- If we take the ratio of height of image to height of object $\left(m = \frac{h'}{h}\right)$ to find the magnification, we will not get a practical relation, as the image will also be of infinite size when the image is formed at infinity.
- Hence, we can practically use the angular magnification.
- The angular magnification is defined as the ratio of angle θ_i subtended by the image with aided eye to the angle θ_0 subtended by the object with unaided eye.

$$m = \frac{\theta_i}{\theta_0}$$

- For unaided eye shown in Figure(a),

$$\tan\theta_0 \approx \theta_0 = \frac{h}{D}$$



- For aided eye shown in Figure(b),

$$\tan\theta_1 \approx \theta_1 = \frac{h}{f}$$

- The angular magnification is,

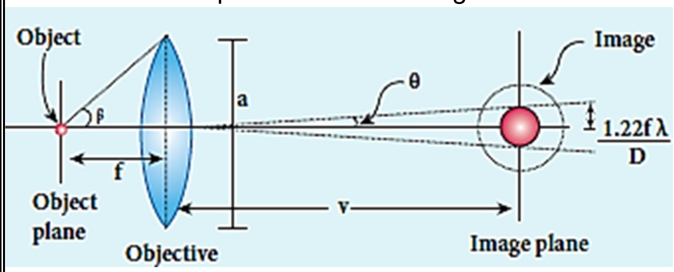
$$m = \frac{\theta_i}{\theta_0} = \frac{h/f}{h/D}$$

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

- This is the magnification for normal focusing.
- The magnification for normal focusing is one less than that for near point focusing.
- But, the viewing is more comfortable in normal focusing than near point focusing.
- For large values of D/f, the difference in magnification is usually small.

15. Obtain the equation for resolving power of microscope.

- The diagram related to the calculation of resolution of microscope is illustrated in Figure.



- A microscope is used to see the details of the object under observation.
- The ability of microscope depends not only in magnifying the object but also in resolving two points on the object separated by a small distance d_{min}.
- Smaller the value of d_{min} better will be the resolving power of the microscope.
- We know the radius of central maxima as,

$$r_0 = \frac{1.22\lambda v}{a}$$

- In the place of focal length f we have the image distance v.
- If the difference between the two points on the object to be resolved is d_{min}, then the magnification m is,

$$m = \frac{r_0}{d_{min}}$$

$$d_{min} = \frac{r_0}{m} = \frac{1.22\lambda v}{a\,m} = \frac{1.22\lambda v}{a\,(v/u)} = \frac{1.22\lambda u}{a} \quad \left[\because m = \frac{v}{u}\right]$$

$$d_{min} = \frac{1.22\lambda f}{a} \quad [\because u \approx f]$$

- On the object side,

$$2\,tan\beta \approx 2sin\beta = \frac{a}{f} \quad [\because a = f\ 2\sin\beta]$$

$$d_{min} = \frac{1.22\lambda}{2\sin\beta}$$

- To further reduce the value of d_{min} the optical path of the light is increased by immersing the objective of the microscope in to a bath containing oil of refractive index n.

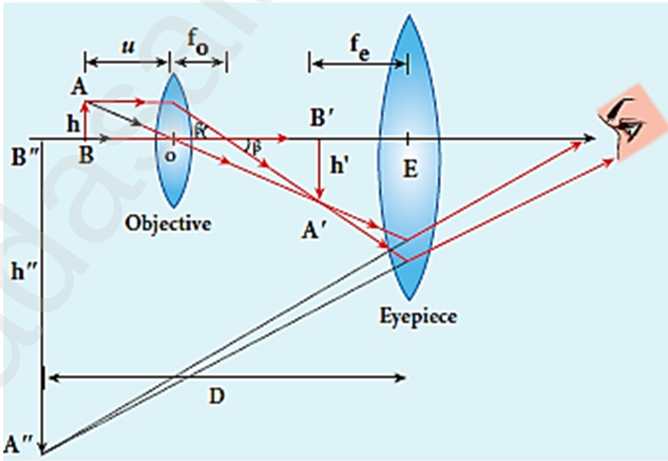
$$d_{min} = \frac{1.22\lambda}{2\,\mathrm{n}\sin\beta}$$

- Such an objective is called oil immersed objective. The term n sin β is called numerical aperture NA.

$$d_{min} = \frac{1.22\lambda}{2\,(NA)}$$

16. Explain about compound microscope and obtain the equation for magnification.

- The diagram of a compound microscope is shown in Figure.



- The lens near the object, called the objective, forms a real, inverted, magnified image of the object.
- This serves as the object for the second lens which is the eyepiece.
- Eyepiece serves as a simple microscope that produces finally an enlarged and virtual image.
- The first inverted image formed by the objective is to be adjusted close to, but within the focal plane of the eyepiece so that the final image is formed nearly at infinity or at the near point.
- The final image is inverted with respect to the original object.
- We can obtain the magnification for a compound microscope.

Magnification of compound microscope:

- From the ray diagram, the linear magnification due to the objective is,

$$m_0 = \frac{h'}{h}$$

- From the Figure, $\tan\beta = \frac{h}{f_0} = \frac{h'}{L}$ then,

$$\frac{h}{h'} = \frac{L}{f_0}$$

$$m_0 = \frac{L}{f_0}$$

- Here, the distance L is between the first focal point of the eyepiece to the second focal point of the objective.
- This is called the tube length L of the microscope as f_o and f_e are comparatively smaller than L.
- If the final image is formed at P (near point focussing), the magnification m_e of the eyepiece is,

$$m_e = 1 + \frac{D}{f_e}$$

- The total magnification m in near point focusing is,

$$m = m_o m_e = \frac{L}{f_0}\left(1 + \frac{D}{f_e}\right)$$

- If the final image is formed at infinity (normal focusing), the magnification m_e of the eyepiece is,

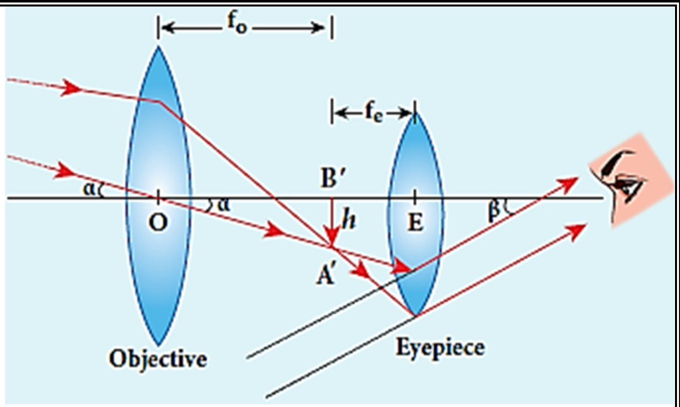
$$m_e = \frac{D}{f_e}$$

- The total magnification m in normal focusing is,

$$m = m_o m_e = \left(\frac{L}{f_0}\right)\left(\frac{D}{f_e}\right)$$

17. Discuss about astronomical telescope and obtain the equation for magnification.

- An astronomical telescope is used to get the magnification of distant astronomical objects like stars, planets, moon etc.
- The image formed by astronomical telescope will be inverted.
- It has an objective of long focal length and a much larger aperture than the eyepiece as shown in Figure.



- Light from a distant object enters the objective and a real image is formed in the tube at its second focal point.
- The eyepiece magnifies this image producing a final inverted image.

Magnification of astronomical telescope :

- The magnification m is the ratio of the angle β subtended at the eye by the final image to the angle α which the object subtends at the lens or the eye.

$$m = \frac{\beta}{\alpha}$$

- From the diagram,

$$m = \frac{h/f_e}{h/f_o}$$

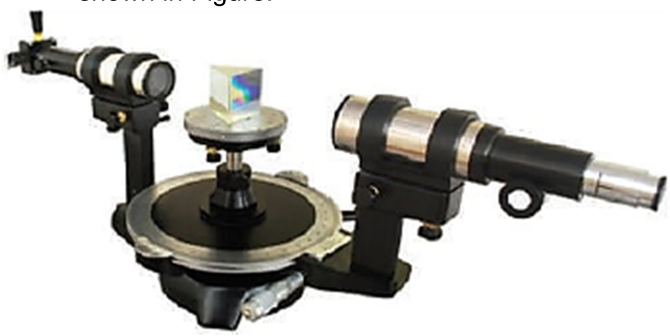
$$m = \frac{f_o}{f_e}$$

- The length of the telescope is approximately,

$$L = f_o + f_e$$

18. Mention different parts of spectrometer and explain the preliminary adjustments.

- The spectrometer is an optical instrument used to study the spectra of different sources of light and to measure the refractive indices of materials. It is shown in Figure.



- It consists of basically three parts. They are,
  - Collimator
  - Prism table
  - Telescope.

(i) Collimator:

- The collimator is an arrangement to produce a parallel beam of light.
- It consists of a long cylindrical tube with a convex lens at the inner end and a vertical slit at the outer end of the tube.
- The distance between the slit and the lens can be adjusted such that the slit is at the focus of the lens.
- The slit is kept facing the source of light. The width of the slit can be adjusted.
- The collimator is rigidly fixed to the base of the instrument.

(ii) Prism table:

- The prism table is used for mounting the prism, grating etc.
- It consists of two circular metal discs provided with three levelling screws.
- It can be rotated about a vertical axis passing through its centre and its position can be read with verniers V_1 and V_2 .
- The prism table can be raised or lowered and can be fixed at any desired height.

(iii) Telescope :

- The telescope is an astronomical type. It consists of an eyepiece provided with cross wires at one end and an objective lens at its other end.
- The distance between the objective lens and the eyepiece can be adjusted so that the telescope forms a clear image at the cross wires, when a parallel beam from the collimator is incident on it.
- The telescope is attached to an arm which is capable of rotation about the same vertical axis as the prism table.
- A circular scale graduated in half degree is attached to it.
- Both the telescope and prism table are provided with radial screws for fixing them in a desired position and tangential screws for fine adjustments.

Adjustments of the spectrometer :

- The following adjustments must be made before doing the experiment using spectrometer.

(a) Adjustment of the eyepiece:

- The telescope is turned towards an illuminated surface and the eyepiece is moved to and fro until the cross wires are clearly seen.

(b) Adjustment of the telescope:

- The telescope is adjusted to receive parallel rays by turning it towards a distant object and adjusting the distance between the objective lens and the eyepiece to get a clear image on the cross wire.

(c) Adjustment of the collimator :

- The telescope is brought along the axial line with the collimator.
- The slit of the collimator is illuminated by a source of light.
- The distance between the slit and the lens of the collimator is adjusted until a clear image of the slit is seen at the cross wire of the telescope.
- Since the telescope is already adjusted for parallel rays, a well-defined image of the slit can be formed, only when the light rays emerging from the collimator are parallel.

(d) Levelling the prism table :

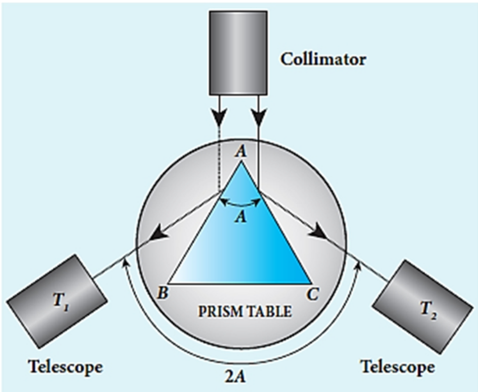
- The prism table is adjusted or levelled to be in horizontal position by means of levelling screws and a spirit level.

10. Explain the experimental determination of refractive index of the material of the prism using spectrometer.

- The preliminary adjustments of the telescope, collimator and the prism table of the spectrometer are made.
- The refractive index of the prism can be determined by knowing the angle of the prism and the angle of minimum deviation.

(a) Angle of the prism (A):

- The prism is placed on the prism table with its refracting edge facing the collimator as shown in Figure.

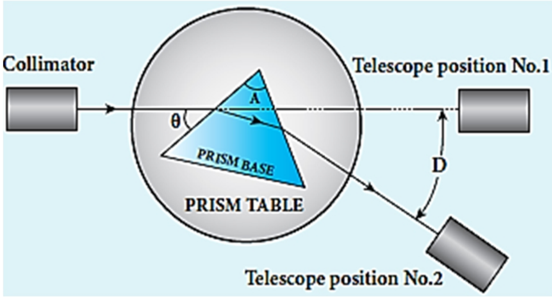


- The slit is illuminated by a sodium light (monochromotic light).
- The parallel rays coming from the collimator fall on the two faces AB and AC.
- The telescope is rotated to the position T_1 until the image of the slit formed by the reflection at the face AB is made to coincide with the vertical cross wire of the telescope. The readings of the verniers are noted.

- The telescope is then rotated to the position T_2 where the image of the slit formed by the reflection at the face AC coincides withthe vertical cross wire. The readings are again noted.
- The difference between these two readings gives the angle rotated by the telescope, which is twice the angle of the prism.
- Half of this value gives the angle of the prism A.

(b) Angle of minimum deviation (D):

- The prism is placed on the prism table so that the light from the collimator falls on a refracting face, and the refracted image is observed through the telescope as shown in Figure.



- The prism table is now rotated so that the angle of deviation decreases.
- A stage comes when the image stops for a moment and if we rotate the prism table further in the same direction, the image is seen to recede and the angle of deviation increases.
- The vertical cross wire of the telescope is made to coincide with the image of the slit where it turns back.
- This gives the minimum deviation position. The readings of the verniers are noted.
- Now, the prism is removed and the telescope is turned to receive the direct ray and the vertical cross wire is made to coincide with the image. The readings of the verniers are noted.
- The difference between the two readings gives the angle of minimum deviation D.
- The refractive index of the material of the prism n is calculated using the formula,

$$n = \frac{\sin\left[\frac{A+D}{2}\right]}{\sin\left[\frac{A}{2}\right]}$$

- The refractive index of a liquid may be determined in the same way using a hollow glass prism filled with the given liquid.

8. Dual nature of radiation and matter

1. What is a particle and a wave?

- Particle is a material object which is considered as a tiny concentration of matter.
- Wave is a broad distribution of energy.

2. What is surface barrier?

The potential barrier which prevents free electrons from leaving the metallic surface is called surface barrier.

3. Why do metals have a large number of free electrons?

In metals, the electrons in the outer most shells are loosely bound to the nucleus. So even at room temperature, there are a large number of free electrons moving randomly inside the metal.

4. What is electron emission?

The liberation of electrons from any surface of a substance is called electron emission.

5. What is work function?Give its unit.

The minimum energy needed for an electron to escape from the metal surface is called work function(ϕ_0) of that metal. Its unit is electron volt(eV).

$$[1\ eV = 1.602 \times 10^{-19} J]$$

6. What are the types of electron emission?

- Thermionic emission.
- Field emission.
- Photo electric emission.
- Secondary emission.

7. What is thermionic emission?Give examples.

- When a metal is heated to a high temperature, the free electrons on the surface of the metal are emitted due to thermal energy. This type of emission is known as thermionic emission.
- Ex: Cathode ray tubes, electron microscopes, X-ray tubes, etc.,

8. What is field emission?Give examples.

- When strong electric field is applied across the metal, electron emission takesplace. This is called field emission.
- Ex: Field emission scanning electron microscopes, Field-emission display etc.

9. What is photoelctric emission?Give examples.

- When an electromagnetic radiation of suitable frequency is incident on the surface of the metal, electron emission takesplace. This is called photo electric emission.
- Ex: Photo diodes, photo electric cells etc.

10. What is secondary emission?Give examples.

- When a beam of fast moving electrons strikes the surface of the metal, the free electrons on the metal surface gain kinetic energy and come out from the surface. This is called secondary emission.
- Ex: Image intensifiers, photo multiplier tubes etc.

11. What is photoelectric effect?

The ejection of electrons from a metal plate when illuminated by light or any other electromagnetic radiation of suitable wavelength (or frequency) is called photoelectric effect.

12. What are photosensitive materials?

The materials which eject photoelectrons upon irradiation of electromagnetic wave of suitable wavelength are called photosensitive materials.

13. What are the factors affecting photoelectric current?

- Intensity of incident light.
- The potential difference between the electrodes.
- The nature of the material.
- Frequency of incident light.

14. How does photocurrent vary with the intensity of the incident light?

Photocurrent is directly proportional to the intensity of the incident light.

15. Give the definition of intensity of light and its unit.

Intensity(brightness) of light is defined as the rate at which light energy is delivered to a unit of surface. Its unit is candela(Cd).

16. What is stopping or cut-off potential?

The negative potential of the collecting electrode at which photocurrent gets zero is called stopping or cut-off potential(V_0) .

17. What is threshold frequency?

The minimum frequency above which the emission of photoelectrons takes place for given surface is called the threshold frequency.

18. State laws of photoelectric effect.

- For a given frequency of incident light, the number of photoelectrons emitted is directly proportional to the intensity of the incident light. The saturation current is also directly proportional to the intensity of incident light.
- Maximum kinetic energy of the photo electrons is independent of intensity of the incident light.
- Maximum kinetic energy of the photo electrons from a given metal is directly proportional to the frequency of incident light.
- For a given surface, the emission of photoelectrons takes place only if the frequency of incident light is greater than a certain minimum frequency called the threshold frequency.
- There is no time lag between incidence of light and ejection of photoelectrons.

19. What is photoelectric cell or photocell? Write its principle.

- Photo electric cell or photo cell is a device which converts light energy into electrical energy.
- Principle: Photoelectric effect.

20. Mention the types of photoelectric cells.

- Photo emissive cell.
- Photo voltaic cell.
- Photo conductive cell.

21. What is photo emissive cell?

The photocell, which generates electrical energy by electron emission due to irradiation of light or other radiations is called photo emissive cell.

22. What is photo voltaic cell?

The photocell, which generates electrical energy when the intensity of light or other radiations incident on the sensitive element made of semiconductor.

23. What is photo conductive cell?

The photocell, which generates electrical energy when the resistance of the semiconductor changes in accordance with the radiant energy incident on it.

24. State de Broglie hypothesis or What is de Broglie or matter waves?

According to de Broglie hypothesis, all matter particles like electrons, protons, neutrons in motion are associated with waves. These waves are called de Broglie waves or matter waves.

25. What is de Broglie wavelength?

This wavelength of the matter waves is known as de Broglie wavelength. $i.e.\quad \lambda = \frac{h}{mv} = \frac{h}{p}$

26. Why we do not see the wave properties of a baseball?

de Broglie wavelength is inversely proportional to the mass of the object for a given velocity. So, the bigger objects like base ball do not show wave properties considerably.

27. Write the expression for the de Broglie wavelength associated with a charged particle of charge q and mass m, when it is accelerated through a potential V.

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2qmV}}$$

28. A proton and an electron have same kinetic energy. Which one has greater de Broglie wavelength? Justify.

de Broglie wavelength is inversely proportional to the mass of the object for a given kinetic energy. Since the mass of the electron is very less compared to mass of the proton, de Broglie wavelength of electron is greater than proton.

29. Write the relationship of de Broglie wavelength λ associated with a particle of mass m in terms of its kinetic energy K.

$$de\ Broglie\ wavelength\quad \lambda = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2mK}}$$

Where, h –Planck's constant

30. An electron and an alpha particle have same kinetic energy. How are the de Broglie wavelengths associated with them related?

de Broglie wavelength is inversely proportional to the mass of the object for a given kinetic energy. Since the mass of the electron is very less compared to mass of the alpha particle, de Broglie wavelength of electron is greater than alpha particle.

31. Why electron is preferred over X-ray microscope?

- X-rays cannot be converged or diverged through any optical or magnetic lenses.
- Object which is to be observed in microscope will be ionised by X-rays.
- Due to these reasons, electron is preferred over X-ray microscope

32. What are X-rays?

X-rays are electromagnetic waves of short wavelength ranging from 0.1 to 100Å.

33. What are the properties of X-rays?

- X-rays travel along straight lines with the velocity of light.
- X-rays are not affected by electric and magnetic fields.
- X-ray photons are highly energetic because of its high frequency or short wavelength. Therefore, they can pass through materials which are opaque to visible light.

34. Mention the two features of x-ray spectra, not explained by classical electromagnetic theory.

- For a given accelerating voltage, the lower limit for the wavelength of continuous x-ray spectra is same for all targets. This minimum wavelength is called cut-off wavelength.
- The intensity of x-rays is significantly increased at certain well-defined wavelengths as in the case of characteristic x-ray spectra for molybdenum.

35. What is Bremsstralung or braking radiation?

The radiation produced from decelerating electron is called Bremsstrahlung or braking radiation.

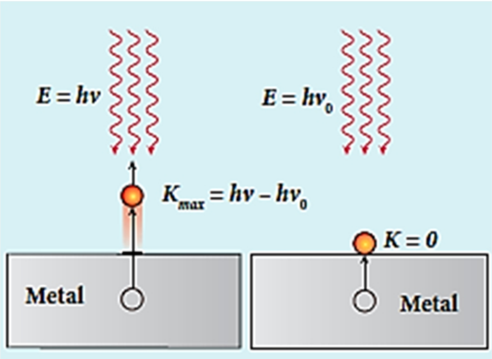
5 Marks Q & A:

1. Obtain Einstein's photoelectric equation with necessary explanation.

- When a photon of energy hν is incident on a metal surface, it is completely absorbed by a single electron and the electron is ejected.
- In this process, a part of the photon energy is used for the ejection of the electrons from the metal surface (photoelectric work function ϕ_0) and the remaining energy as the kinetic energy of the ejected electron.
- From the law of conservation of energy,

$$h\nu = \phi_0 + \frac{1}{2}mv^2 \longrightarrow (1)$$

Where m is the mass of the electron and υ its velocity.



- If we reduce the frequency of the incident light, the speed or kinetic energy of photo electrons is also reduced.
- At some frequency ν_0 of incident radiation, the photo electrons are ejected with almost zero kinetic energy (Figure above).
- Then the equation (1) becomes,

$$h\nu_0 = \phi_0$$

where ν_0 is the threshold frequency.

- By rewriting the equation (1), we get,

$$h\nu = h\nu_0 + \frac{1}{2}mv^2 \longrightarrow (2)$$

- The equation(2) is known as Einstein's photoelectric equation.
- If the electron does not lose energy by internal collisions, then it is emitted with maximum kinetic energy K_{max}. Then,

$$K_{max} = \frac{1}{2}mv_{max}^2$$

Where υ_{max} is the maximum velocity of the electron ejected.

- The equation (1) is rearranged as follows:

$$K_{max} = h\nu - \phi_0 \longrightarrow (3)$$

2. Explain experimentally observed facts of photoelectric effect with the help of Einstein's explanation.

- As each incident photon liberates one electron, then the increase of intensity of the light increases the number of electrons emitted thereby increasing the photocurrent. The same has been experimentally observed.
- From $K_{max} = h\nu - \phi_0$, it is evident that K_{max} is proportional to the frequency of the light and is independent of intensity of the light.
- As given in equation (2), there must be minimum energy (equal to the work function of the metal) for incident photons to liberate electrons from the metal surface. Below which, emission of electrons is not possible. Correspondingly, there exists minimum frequency called threshold frequency below which there is no photoelectric emission.
- According to quantum concept, the transfer of photon energy to the electrons is instantaneous so that there is no time lag between incidence of photons and ejection of electrons.

36. What are the characteristics of photons?

- The photons of light of frequency ν and wavelength λ will have energy, given by,

$$E = h\nu = \frac{hc}{\lambda}$$

- The energy of a photon is determined by the frequency of the radiation and not by its intensity and the intensity has no relation with the energy of the individual photons in the beam.
- The photons travel with the velocity of light and its momentum is given by,

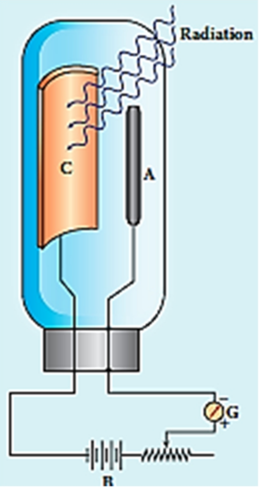
$$p = \frac{h}{\lambda} = \frac{h\nu}{c}$$

- Since photons are electrically neutral, they are unaffected by electric and magnetic fields.
- When a photon interacts with matter (photon-electron collision), the total energy, total linear momentum and angular momentum are conserved. Since photon may be absorbed or a new photon may be produced in such interactions, the number of photons may not be conserved.

3. Give the construction and worki ng of photo emissive cell.

Construction:

- It consists of an evacuated glass or quartz bulb in which two metallic electrodes – that is, a cathode and an anode are fixed as shown in figure.



- The cathode C is semi-cylindrical in shape and is coated with a photo sensitive material.
- The anode A is a thin rod or wire kept along the axis of the semi-cylindrical cathode.
- A potential difference is applied between the anode and the cathode through a galvanometer G.

Working:

- When cathode is illuminated, electrons are emitted from it.
- These electrons are attracted by anode and hence a current is produced which is measured by the galvanometer.
- For a given cathode, the magnitude of the current depends on,
  - The intensity to incident radiation.
  - The potential difference between anode and cathode.

4. What are the applications of photo cells?

- It is used in switches and sensors.
- It is used to automatic on or off the street lights during night and day respectively.
- It is used for reproduction of sound in motion pictures.
- It is used as timers to measure the speeds of athletes during a race.
- It is used in exposure meters to measure the intensity of the given light and to calculate the exact time of exposure of light in photography.

5. Derive an expression for de Broglie wavelength.

- The momentum of photon of frequency ν is given by,

$$p = \frac{h\nu}{c} = \frac{h}{\lambda} \quad [\because\ c = \nu\,\lambda]$$

- The wavelength of a photon in terms of its momentum is,

$$\lambda = \frac{h}{p} - - (1)$$

- According to de Broglie, the above equation is completely a general one and this is applicable to material particles as well.
- Therefore, for a particle of mass m travelling with speed υ , the wavelength is given by,

$$\lambda = \frac{h}{mv} = \frac{h}{p} \dashrightarrow (2)$$

- This wavelength of the matter waves is known as de Broglie wavelength.
- This equation relates the wave character (the wave length λ) and the particle character (the momentum p) through Planck's constant.

6. Derive an expression for de Broglie wavelength of electrons.

- An electron of mass m is accelerated through a potential difference of V volt. The kinetic energy acquired by the electron is given by,

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

- Therefore, the speed υ of the electron is,

$$v = \sqrt{\frac{2eV}{m}} \dashrightarrow (1)$$

- The de Broglie wavelength of the electron is,

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2emV}}$$

- Substituting the known values in the above equation, we get,

$$\lambda = \frac{6.626 \times 10^{-34}}{\sqrt{2V \times 1.6 \times 10^{-19} \times 9.11 \times 10^{-31}}}$$

$$\lambda = \frac{12.27 \times 10^{-10}}{\sqrt{V}} m$$

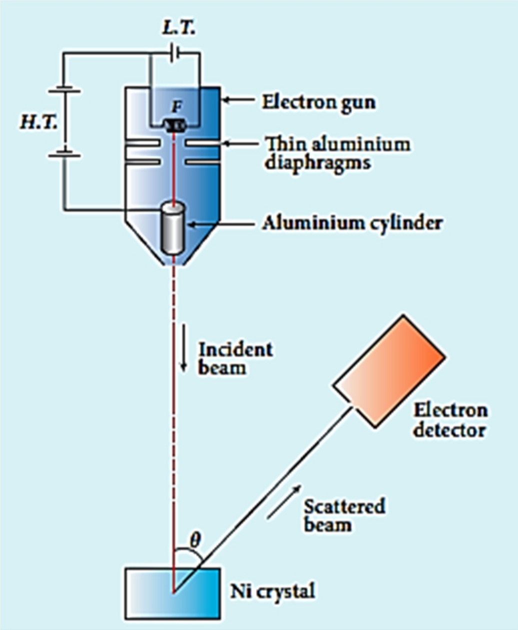
$$or \quad \lambda = \frac{12.27}{\sqrt{V}} \text{Å}$$

- Since the kinetic energy of the electron, K = eV, then the de Broglie wavelength associated with electron can be also written as,

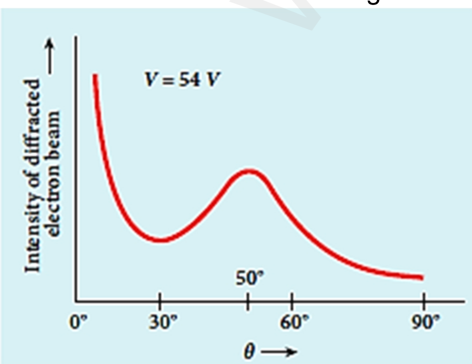
$$\lambda = \frac{h}{\sqrt{2mK}}$$

7. Describe briefly Davisson – Germer experiment which demonstrated the wave nature of electrons.

- Figure below shows a schematic representation of the apparatus for the experiment.



- The filament F is heated by a low tension (L.T.) battery. Electrons are emitted from the hot filament by thermionic emission.
- They are then accelerated due to the potential difference between the filament and the anode aluminium cylinder by a high tension (H.T.) battery.
- Electron beam is collimated by using two thin aluminium diaphragms and is allowed to strike a single crystal of Nickel.
- The electrons scattered by Ni atoms in different directions are received by the electron detector which measures the intensity of scattered electron beam.
- The detector is rotatable in the plane of the paper so that the angle θ between the incident beam and the scattered beam can be changed at our will.
- The intensity of the scattered electron beam is measured as a function of the angle θ.



- Above figure shows the variation of intensity of the scattered electrons with the angle θ for the accelerating voltage of 54V.
- For a given accelerating voltage V, the scattered wave shows a peak or maximum at an angle of 50^0 to the incident electron beam.
- This peak in intensity is attributed to the constructive interference of electrons diffracted from various atomic layers of the target material.
- From the known value of interplanar spacing of Nickel, the wavelength of the electron wave has been experimentally calculated as 1.65 Å.
- The wavelength can also be calculated from de Broglie relation for V = 54 V as,

$$\lambda = \frac{12.27}{\sqrt{V}} \text{Å} = \frac{12.27}{\sqrt{54}} = 1.67\text{Å}$$

- This value agrees well with the experimentally observed wavelength of 1.65 Å.
- Thus, this experiment directly verifies de Broglie's hypothesis of the wave nature of moving particles.

8. Briefly explain the principle and working of electron microscope.

Principle:

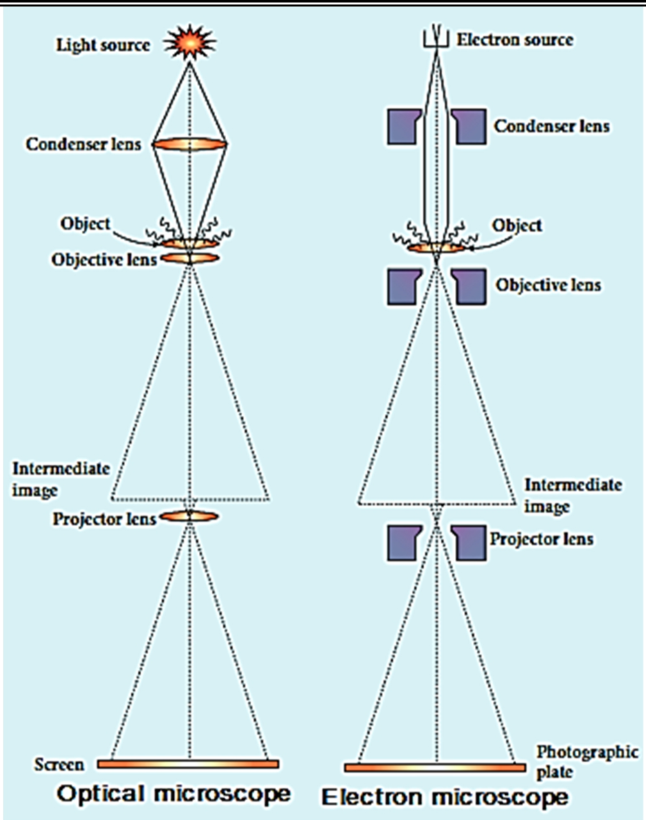
- Wave nature of an electron.

Description:

- The resolving power of a microscope is inversely proportional to the wavelength of the radiation used for illuminating the object under study.
- Higher magnification as well as higher resolving power can be obtained by employing the waves of shorter wavelengths.
- De Broglie wavelength of electron is very much less than (a few thousands less) that of the visible light being used in optical microscopes.
- As a result, the microscopes employing de Broglie waves of electrons have very much higher resolving power than optical microscope.
- Electron microscopes giving magnification more than 2,00,000 times are common in research laboratories.

Working:

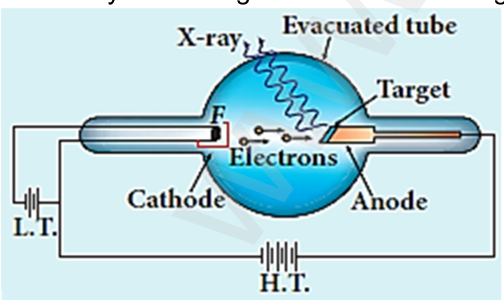
- The construction and working of an electron microscope is similar to that of an optical microscope except that in electron microscope focussing of electron beam is done by the electrostatic or magnetic lenses.
- The electron beam passing across a suitably arranged either electric or magnetic fields undergoes divergence or convergence thereby focussing of the beam is done (Figure).



- The electrons emitted from the source are accelerated by high potentials.
- The beam is made parallel by magnetic condenser lens.
- When the beam passes through the sample whose magnified image is needed, the beam carries the image of the sample.
- With the help of magnetic objective lens and magnetic projector lens system, the magnified image is obtained on the screen.

9. Explain the production of X-rays using discharge tube.

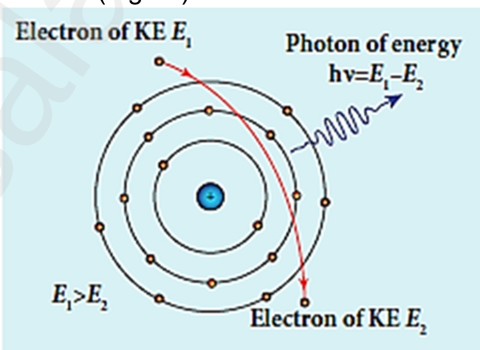
- X-rays are produced in x-ray tube which is essentially a discharge tube as shown in figure.



- A tungsten filament F is heated to incandescence by a battery. As a result, electrons are emitted from it by thermionic emission.
- The electrons are accelerated to high speeds by the voltage applied between the filament F and the anode.
- The target materials like tungsten, molybdenum are embedded in the face of the solid copper anode.
- The face of the target is inclined at an angle with respect to the electron beam so that x-rays can leave the tube through its side.
- When high-speed electrons strike the target, they are decelerated suddenly and lose their kinetic energy. As a result, x-ray photons are produced.
- Since most of the kinetic energy of the bombarding electrons gets converted into heat, targets made of high-melting-point metals and a cooling system are usually employed.

10. Explain about continuous X-ray spectra.

- When a fast moving electron penetrates and approaches a target nucleus, the interaction between the electron and the nucleus either accelerates or decelerates it which results in a change of path of the electron.
- The radiation produced from such decelerating electron is called Bremsstrahlung or braking radiation (Figure).



- The energy of the photon emitted is equal to the loss of kinetic energy of the electron.
- Since an electron may lose part or all of its energy to the photon, the photons are emitted with all possible energies (or frequencies).
- The continuous x-ray spectrum is due to such radiations.
- When an electron gives up all its energy, then the photon is emitted with highest frequency ν_0 (or lowest wavelength λ_0).
- The initial kinetic energy of an electron is given by eV where V is the accelerating voltage. Therefore, we have,

$$h\nu_0 = eV$$

$$\frac{hc}{\lambda_0} = eV$$

$$\lambda_0 = \frac{hc}{eV}$$

Where λ_0 is the cut-off wavelength.

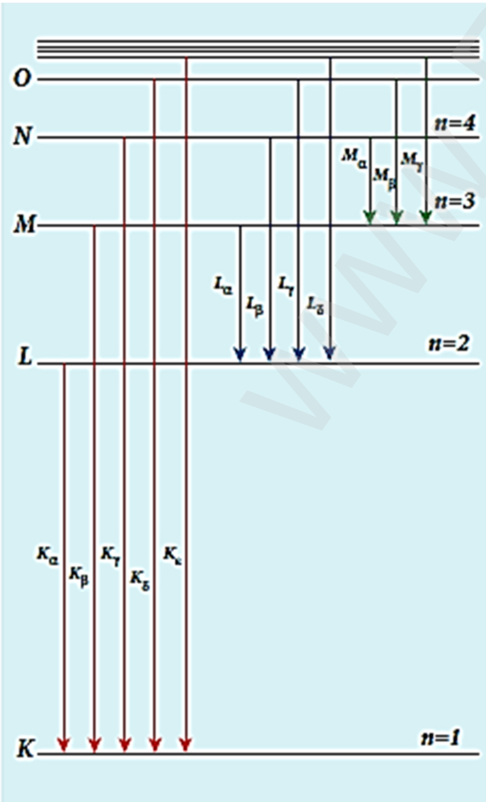
- Substituting the known values in the above equation, we get,

$$\lambda_0 = \frac{12400}{V} Å$$

- The above equation is known as the Duane – Hunt formula.

11) Explain about characteristic X-ray spectra.

- X – ray spectra show some narrow peaks at some well – defined wavelengths when the target is hit by fast electrons.
- The line spectrum showing these peaks is called characteristic x – ray spectrum.
- This x – ray spectrum is due to the electronic transitions within the atoms.
- When an energetic electron penetrates into the target atom and removes some of the K-shell electrons.
- Then the electrons from outer orbits jump to fill up the vacancy so created in the K-shell.
- During the downward transition, the energy difference between the levels is given out in the form of x– ray photon of definite wavelength.
- Such wavelengths, characteristic of the target, constitute the line spectrum.
- From the figure, it is evident that K-series of lines in the x-ray spectrum of an element arises due to the electronic transitions from L, M, N, . . levels to the K-level.



- Similarly, the longer wavelength L-series originates when an L-electron is knocked out of the atom and the corresponding vacancy is filled by the electronic transitions from M, N, O,... and so on.

12) What are the applications of X-rays?

Medical diagnosis:

- X-rays can pass through flesh more easily than through bones. Thus an X-ray radiograph containing a deep shadow of the bones and a light shadow of the flesh may be obtained.
- X-ray radiographs are used to detect fractures, foreign bodies, diseased organs etc.

Medical therapy:

- Since X-rays can kill diseased tissues, they are employed to cure skin diseases, malignant tumours etc.

Industry:

- X-rays are used to check for flaws in welded joints, motor tyres, tennis balls and wood. At the custom post, they are used for detection of contraband goods.

Scientific research:

X-ray diffraction is important tool to study the structure of the crystalline materials – that is, the arrangement of atoms and molecules in crystals.

9. Atomic and Nuclear Physics

1. What is discharge tube?

A device used to study the conduction of electricity through gases is known as gas discharge tube.

2. What are events happend in electric discharge through a gas at various mercury pressures?

- ❖ Upto 110 mm of Hg – No discharge takesplace.
- ❖ At 100 mm of Hg - Irregular streaks and crackling sound.
- ❖ At 10 mm of Hg - Luminous positive column.
- ❖ At 0.01 mm of Hg - Positive column disappears, Crooke's dark space formed, tube walls appear green colour.

3. What are cathode rays?

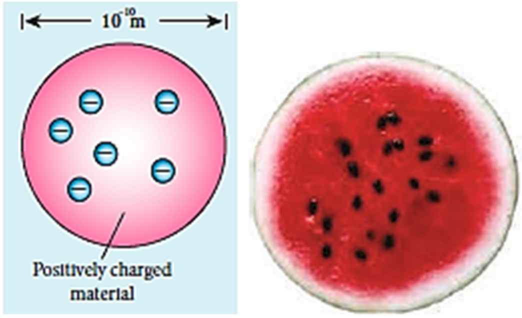
At 0.01 mm of Hg in discharge tube, some invisible rays emanate from cathode, which is called cathode rays.

4. Write the properties of cathode rays.

- ❖ Cathode rays possess energy and momentum.
- ❖ It travels in a straight line with high speed of the order of $10^7 m\ s^{-1}$.
- ❖ It can be deflected by application of electric and magnetic fields.
- ❖ The direction of deflection indicates that they are negatively charged particles.
- ❖ When the cathode rays are allowed to fall on matter, they produce heat.
- ❖ They affect the photographic plates.
- ❖ It produces fluorescence when they fall on certain crystals and minerals.
- ❖ When the cathode rays fall on a material of high atomic weight, X-rays are produced.
- ❖ Cathode rays ionize the gas through which they pass.
- ❖ The speed of cathode rays is up to $\left(\frac{1}{10}\right)$th of the speed of light.

5. Write the concepts of J.J. Thomson's atom model (Water melon model).

- ❖ The atoms are visualized as homogeneous spheres which contain uniform distribution of positively charged particles.
- ❖ The negatively charged particles known as electrons are embedded in it like seeds in water melon as shown in Figure.



- ❖ The atoms are electrically neutral, this implies that the total positive charge in an atom is equal to the total negative charge.

6. Write the drawbacks of J.J. Thomson's atom model.

- ❖ According to this model, all the charges are assumed to be at rest.
- ❖ But from classical electrodynamics, no stable equilibrium points exist in electrostatic configuration (this is known as Earnshaw's theorem) and hence such an atom cannot be stable.
- ❖ Further, it fails to explain the origin of spectral lines observed in the spectrum of hydrogen atom and other atoms.

7. Give the results of Rutherford alpha scattering experiment.

- ❖ Most of the alpha particles are undeflected through the gold foil and went straight.
- ❖ Some of the alpha particles are deflected through a small angle.
- ❖ A few alpha particles (one in thousand) are deflected through the angle more than 90^0.
- ❖ Very few alpha particles returned back (back scattered) –that is, deflected back by 180^0.

8. Write the concepts of Rutherford atom model.

- ❖ An atom has a lot of empty space and contains a tiny matter known as nucleus whose size is of the order of 10^{-14}m.
- ❖ The nucleus is positively charged and most of the mass of the atom is concentrated in nucleus.
- ❖ The nucleus is surrounded by negatively charged electrons.
- ❖ Since static charge distribution cannot be in a stable equilibrium, he suggested that the electrons are not at rest and they revolve around the nucleus in circular orbits like planets revolving around the sun.

9. Define distance of closest approach.

The minimum distance between the centre of the nucleus and the alpha particle just before it gets reflected back through 180^0 is defined as the distance of closest approach or contact distance(r_0).

10. Define impact parameter.

The impact parameter(**b**) is defined as the perpendicular distance between the centre of the gold nucleus and the direction of velocity vector of alpha particle when it is at a large distance.

11. Write the drawbacks of Rutherford atom model.

- This model fails to explain the distribution of electrons around the nucleus and also the stability of the atom.
- According to this model, emission of radiation must give continuous emission spectrum but experimentally we observe only line emission spectrum for atoms.

12. Write down the postulates of Bohr atom model.

- The electron in an atom moves around nucleus in circular orbits under the influence of Coulomb electrostatic force of attraction.
- Electrons in an atom revolve around the nucleus only in certain discrete orbits called stationary orbits where it does not radiate electromagnetic energy.
- The angular momentum of the electron in these stationary orbits are quantized.

$$i.e. \quad l = \frac{nh}{2\pi} = n\hbar \quad where\ \hbar = \frac{h}{2\pi}$$

Here,

l – angular momentum.
h – Planck's constant.
n – Principal quantum number of the orbit.
$\hbar$ - Reduced Planck's constant.

This condition is known as angular momentum quantization condition.

- Energy of orbits are not continuous but discrete. This is called the quantization of energy. An electron can jump from one orbit to another orbit by absorbing or emitting a photon whose energy is equal to the difference in energy (ΔE) between the two orbital levels.

$$\triangle E = E_f - E_i = h\nu = \frac{hc}{\lambda}$$

13. What is meant by excitation energy?

The energy required to excite an electron from lower energy state to any higher energy state is known as excitation energy.

14. Define excitation potential.

Excitation potential is defined as excitation energy per unit charge.

15. What is ionization energy?

The minimum energy required to remove an electron from an atom in the ground state is known as binding energy or ionization energy.

16. What is first ionization energy?

The amount of energy spent to remove an electron from the ground state of an atom is known as first ionization energy. Its value is13.6 eV.

17. Define ionization potential.

Ionization potential is defined as ionization energy per unit charge.

18. What is wave number?

Inverse of wavelength is known as wave number.

$$i.e. \ \bar{\nu} = \frac{1}{\lambda}$$

19. What are the limitations of Bohr atom model?

- Bohr atom model is valid only for hydrogen atom or hydrogen like-atoms but not for complex atoms.
- When the spectral lines are closely examined, individual lines of hydrogen spectrum is accompanied by a number of faint lines. These are often called fine structure. This is not explained by Bohr atom model.
- Bohr atom model fails to explain the intensity variations in the spectral lines.
- The distribution of electrons in atoms is not completely explained by Bohr atom model.

20. What is atomic number?

The number of protons in the nucleus is called the atomic number(Z).

21. What is mass number?

The total number of neutrons and protons in the nucleus is called the mass number. i.e. A = Z+N.

22. Write a general notation of nucleus of element X. What each term denotes?

The general notation of any element is,

$${}^{A}_{Z}X$$

Where,

X – the chemical symbol of the element.
A – the mass number.
Z – the atomic number.

23. What are isotopes? Give an example.

Isotopes are atoms of the same element having same atomic number Z, but different mass number A.

Ex: ${}^{11}_{6}C, {}^{12}_{6}C, {}^{13}_{6}C\ and\ {}^{14}_{6}C$

24. What are isobars? Give an example.

Isobars are the atoms of different elements having the same mass number A, but different atomic number Z.

Ex: ${}^{40}_{16}S, {}^{40}_{17}Cl, {}^{40}_{18}Ar, {}^{40}_{19}K \text{ and } {}^{40}_{20}Ca$

25. What are isotones? Give an example.

Isotones are the atoms of different elements having same number of neutrons.

Ex: ${}^{12}_{5}B \text{ and } {}^{13}_{6}C$

26. Define atomic mass unit u.

One atomic mass unit (u) is defined as the 1/12th of the mass of the isotope of carbon ${}^{12}_{6}C$.

$$1\,u = 1.66 \times 10^{-27} kg$$

27. Show that nuclear density is almost constant for nuclei with Z > 10.

- The radius of the nuclei for Z > 10 is,

$$R = R_0 A^{\frac{1}{3}}$$

- The volume of the nucleus,

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$$

- The total mass of the nucleus,

$$M = Am$$

where m – mass of the proton or neutron.

- Therefore, nuclear density,

$$\rho = \frac{mass\ of\ the\ nuclei}{Volume\ of\ the\ nuclei}$$

$$\rho = \frac{A.m}{\frac{4}{3}\pi R_0^3 A} = \frac{m}{\frac{4}{3}\pi R_0^3}$$

- It show that nuclear density is almost constant for nuclei with Z > 10.

28. What is mass defect?

The experimental mass of any nucleus is less than the total mass of its individual constituents. This difference in mass is called mass defect(Δm).

$$\triangle m = (Zm_p + Nm_n) - M$$

29. What is binding energy of a nucleus? Give its expression.

The energy corresponds to the mass defect of the nucleus is called binding energy(BE).

$$BE = (\triangle m)c^2$$

30. Give the physical meaning of binding energy per nucleon.

The average binding energy per nucleon is the energy required to separate single nucleon from the particular nucleus.

$$\overline{BE} = \frac{BE}{A} = \frac{(\triangle m)c^2}{A}$$

31. Calculate the energy equivalent of 1 atomic mass unit.

- 1 atomic mass unit(1 u) = 1.66×10^{-27} kg.
- The speed of light in vacuum, c= 3×10^8 ms^{-1}.
- Using Eintein's mass-energy equivalence,

$$E = mc^2$$

$$E = 1.66 \times 10^{-27} \times (3 \times 10^8)^2$$

$$E = 14.94 \times 10^{-11} J$$

$$or \quad E = \frac{14.94 \times 10^{-11}}{1.6 \times 10^{-19}} = 931 \times 10^6 eV = 931\ MeV$$

32. What is strong nuclear force?

The attractive force, which holds the nucleus together is called strong nuclear force.

33. What are the properties of strong nuclear force?

- The strong nuclear force is of very short range, acting only up to a distance of a few Fermi.
- Nuclear force is stronger than gravitational and Coulomb forces. Hence, it is the strongest force in nature.
- The strong nuclear force is attractive and acts with an equal strength between proton-proton, proton-neutron, and neutron – neutron.
- Strong nuclear force does not act on the electrons. So, it does not alter the chemical properties of the atom.

34. What is meant by radioactivity?

The phenomenon of spontaneous emission of highly penetrating radiations such as α, β and γ rays by an element with Z>82 is called radioactivity.

35. Give the symbolic representation of alpha decay, beta decay and gamma decay.

- <u>α - decay:</u>

$${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

Here,

X - Parent nucleus.
Y – Daughter nucleus.
A – Mass number.
Z – Atomic number.
${}^{4}_{2}He$ - α - particle.

- <u>β - decay:</u>

1. <u>β^- decay:</u>

$${}^{A}_{Z}X \rightarrow {}_{Z+1}{}^{A}Y + e^- + \bar{\nu}$$

Here,

X - Parent nucleus.
Y – Daughter nucleus.
A – Mass number.
Z – Atomic number.
e^- - Electron.
$\bar{\nu}$ – Antineutrino.

2. β^+ decay:

$$^{A}_{Z}X \rightarrow {}_{Z-1}^{A}Y + e^{+} + \nu$$

Here,

X - Parent nucleus.
Y – Daughter nucleus.
A – Mass number.
Z – Atomic number.
e^+ - Positron.
ν – Neutrino.

- γ - decay:

$$^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + \gamma - rays$$

Here,

X - Parent nucleus.
Z – Atomic number.

36. What is meant α-decay? Give an example.

When unstable nuclei decay by emitting an α-particle, its atomic number decreases by 2, the mass number decreases by 4. It is called α- decay.

Ex:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

37. In alpha decay, why does the unstable nucleus emit $^{4}_{2}He$ nucleus? Why it does not emit four separate nucleons?

- $^{4}_{2}He$ consists of four nucleons viz. two protons and two neutrons.
- Suppose $^{238}_{92}U$ nucleus decays into $^{234}_{90}Th$ by emitting 4 separate nucleons (2 protons and 2 neutrons) instead of $^{4}_{2}He$, then the disintegration energy Q for this process turns out to be negative.
- It implies that the total mass of products is greater than that of parent($^{238}_{92}U$) nucleus.
- This kind of process cannot occur in nature because it would violate conservation of energy.
- In any decay process, the conservation of energy, linear momentum and angular momentum must be obeyed.

38. What is meant β^- decay? Give an example.

When unstable nuclei decay by emitting an β^- particle(i.e. electron), its atomic number increases by 1, the mass number remains the same. It is called β^- decay.

Ex:

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + e^{-} + \bar{\nu}$$

39. What is meant β^+ decay? Give an example.

When unstable nuclei decay by emitting an β^+ particle(i.e. positron), its atomic number decreases by 1, the mass number remains the same. It is called β^+ decay.

Ex:

$$^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + e^{+} + \nu$$

40. What are the properties of neutrino?

- It has zero charge .
- It has an antiparticle called anti-neutrino.
- Recent experiments showed that the neutrino has very tiny mass.
- It interacts very weakly with the matter.

41. What is meant γ -decay? Give an example.

In gamma decay, there is no change in the mass number or atomic number of the nucleus. Only energy changes.

Ex:

$$^{12}_{6}C^{*} \rightarrow {}^{12}_{6}C + \gamma - rays$$

42. Define activity(R). Give its unit.

Activity or decay rate is defined as the number of nuclei decayed per second. Its unit is Bequerel(Bq). The another unit is Curie(Ci).

43. Define 1 Bequerel.

One Bequerel is defined as one decay per second.

44. Define 1 Curie.

One Curie is defined as 3.7 X 10^{10} decays per second. It is equal to activity of 1g of radium.

45. State law of radioactive decay.

At any instant t, the number of decays per unit time(or rate of decay (dN/dt)) is proportional to the number of nuclei (N) at the same instant.

46. Define half-life. Give the expression.

Half-life($T_{1/2}$) if defined as the time required for the number of atoms initially present to reduce to one half of the initial amount.

$$T_{1/2} = \frac{0.6931}{\lambda}$$

47. Define Mean life. Give the expression.

The mean life time(τ) of the nucleus is the ratio of sum or integration of life times of all nuclei to the total number nuclei present initially.

$$\tau = \frac{1}{\lambda} = \frac{T_{1/2}}{0.6931}$$

48. What is Carbon dating?

The method of finding the age of the ancient object or non-living organism is called Carbon dating.

49. What are the properties of neutron?

- Neutrons are chargeless. So they are not affected by electric and magnetic fields.
- It has slighly higher mass than the proton.
- It has high penetrating power and it can easily penetrate the thick layer of lead.
- It is stable inside the nucleus. But outside the necleus, it decays into proton, electron and antineutrino.

- Neutrons are classified into two according to their kinetic energies as,

  (i) Slow neutrons (0 eV to 1000 eV)

  (ii) Fast neutrons (0.5 MeV to 10 MeV)

- The neutrons with average energy of about 0.025 eV in thermal equilibrium are called thermal neutron.

50. What is nuclear fission?

The process of breaking up of the nucleus of a heavier atom into two smaller nuclei with the release of a large amount of energy is called nuclear fission.

51. What is chain reaction?Write their types.

When one $^{235}_{92}U$ nucleus undergoes fission, the energy released might be small. But from each fission reaction, three neutrons are released. These three neutrons cause further fission in another three $^{235}_{92}U$ nuclei which in turn produce nine neutrons. These nine neutrons initiate fission in another $^{235}_{92}U$ nuclei and so on. This is called a chain reaction.

<u>Types:</u>

(i) Uncontrolled chain reaction.
(ii) Controlled chain reaction.

52. What is a nuclear reactor?

Nuclear reactor is a system in which the nuclear fission takes place in a self-sustained controlled manner.

53. What is a nuclear fusion?

When two or more light nuclei (A<20) combine to form a heavier nucleus, then it is called nuclear fusion.

54. Write the proton-proton cycle happend in Sun.

$$^1_1H + ^1_1H \rightarrow ^2_1H + e^+ + \nu$$
$$^1_1H + ^2_1H \rightarrow ^3_1He + \gamma\ (27\ MeV)$$
$$^3_1He + ^3_1He \rightarrow ^4_1He + ^1_1H + ^1_1H$$

55. What are quarks? Give their types.

Quarks are elementary particles and have fractional charges.

<u>Types:</u> Up, down,charm,strange, top and bottom.

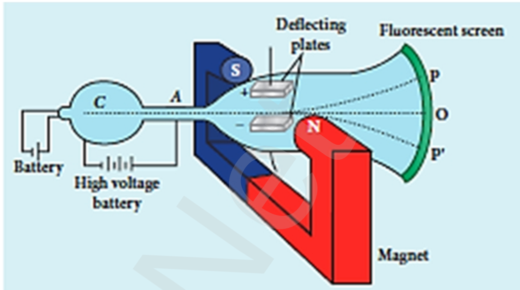
56. What are the constituent particles of neutron and proton?

- Charge of top quark = $+\frac{2}{3}e$
- Charge of down quark = $-\frac{1}{3}e$
- Proton is made up of two up quarks and one down quark. (1 p = uud)
- Neutron is made up of one up quark and two down quarks. (1 n = udd)

<u>5 Marks Q & A:</u>

1. Explain the J.J. Thomson experiment to determine the specific charge of electron. Explain the J.J. Thomson experiment to determine the specific charge of electron.

- The charge per unit mass(e/m) is called mass normalized charge or specific charge.
- The arrangement of J. J. Thomson's experiment is shown in Figure.



- A highly evacuated discharge tube is used and cathode rays (electron beam) produced at cathode are attracted towards anode disc A.
- Anode disc is made with pin hole in order to allow only a narrow beam of cathode rays.
- These cathode rays are now allowed to pass through the parallel metal plates, maintained at high voltage.
- Further, this gas discharge tube is kept in between pole pieces of magnet such that both electric and magnetic fields are perpendicular to each other.
- When the cathode rays strike the screen, they produce scintillation and hence bright spot is observed. This is achieved by coating the screen with zinc sulphide.

(i) Determination of velocity of cathode rays:

- For a fixed electric field between the plates, the magnetic field is adjusted such that the cathode rays strike at the original position O.
- This means that the magnitude of electric force is balanced by the magnitude of force due to magnetic field. Let e be the charge of the cathode rays, then

$$eE = eBv$$
$$v = \frac{E}{B} \longrightarrow (1)$$

(ii) Determination of specific charge:

- Since the cathode rays are accelerated from cathode to anode, the potential energy of the electron beam at the cathode is converted into kinetic energy of the electron beam at the anode.
- Let V be the potential difference between anode and cathode, then the potential energy is eV. Then from law of conservation of energy,

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

$$\frac{e}{m} = \frac{v^2}{2V}$$

- ❖ Substituting the value of velocity from equation (1), we get,

$$\frac{e}{m} = \frac{1}{2V}\frac{E^2}{B^2} \longrightarrow (2)$$

- ❖ Substituting the values of E, B and V, the specific charge can be determined as,

$$\frac{e}{m} = 1.7 \times 10^{11} C\ kg^{-1}$$

(iii)Deflection of charge only due to uniform electric field

- ❖ When the magnetic field is turned off, the deflection is only due to electric field.

- ❖ The deflection in vertical direction is due to the electric force.

$$F_e = eE \longrightarrow (3)$$

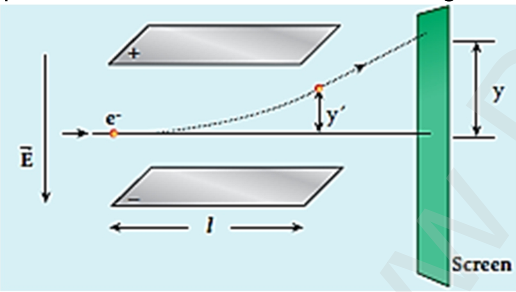
- ❖ Let m be the mass of the electron and by applying Newton's second law of motion, acceleration of the electron is,

$$a_e = \frac{F_e}{m} \longrightarrow (4)$$

- ❖ Substituting equation (3) in equation (4),

$$a_e = \frac{eE}{m} \longrightarrow (4)$$

- ❖ Let y be the deviation produced from original position on the screen as shown in Figure.



- ❖ Let the initial upward velocity of cathode ray be u = 0 before entering the parallel electric plates.

- ❖ Let t be the time taken by the cathode rays to travel in electric field. Let l be the length of one of the plates, then the time taken is,

$$t = \frac{l}{v} \longrightarrow (5)$$

- ❖ Hence, the deflection y′ of cathode rays is,

$$y' = ut + \frac{1}{2}a_e t^2$$

- ❖ Substituting u = 0 , a_e from equation(4) and t from equation(5), we get,

$$y' = \frac{1}{2}\left(\frac{eE}{m}\right)\left(\frac{l}{v}\right)^2$$

$$y' = \frac{1}{2}\left(\frac{e}{m}\right)\frac{l^2B^2}{E} \longrightarrow (6) \qquad \left[\because\ v = \frac{E}{B}\right]$$

- ❖ Therefore, the deflection y on the screen is,

$$y \propto y'$$
$$y = Cy'$$

Where C is proportionality constant which depends on the geometry of the discharge tube.

- ❖ Substituting y′ value from equation(6), we get

$$y = C\frac{1}{2}\left(\frac{e}{m}\right)\frac{l^2B^2}{E}$$

- ❖ Rearranging the above equation as,

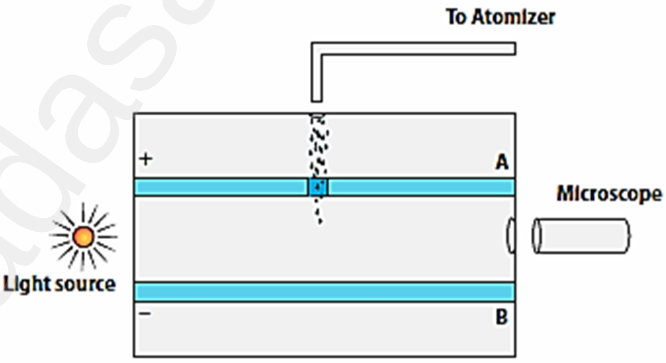
$$\frac{e}{m} = \frac{2yE}{Cl^2B^2}$$

- ❖ Substituting the values on RHS, the value of specific charge is calculated as,

$$\frac{e}{m} = 1.7 \times 10^{11} C\ kg^{-1}$$

2. Discuss the Millikan's oil drop experiment to determine the charge of an electron.

- ❖ The experimental arrangement is shown in Figure.



- ❖ The apparatus consists of two horizontal circular metal plates A and B each with diameter around 20 cm and are separated by a small distance 1.5 cm.

- ❖ These two parallel plates are enclosed in a chamber with glass walls.

- ❖ Further, plates A and B are given a high potential difference around 10 kV such that electric field acts vertically downward.

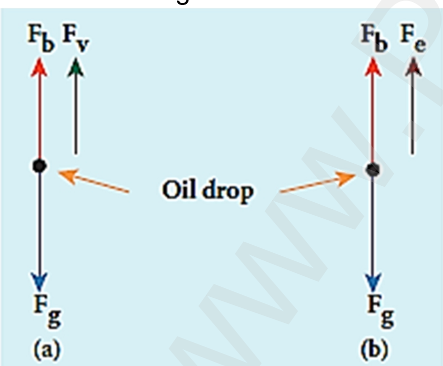
- ❖ A small hole is made at the centre of the upper plate A and atomizer is kept exactly above the hole to spray the liquid.

- ❖ When a fine droplet of highly viscous liquid (like glycerine) is sprayed using atomizer, it falls freely downward through the hole of the top plate only under the influence of gravity.

- Few oil drops in the chamber can acquire electric charge (negative charge) because of friction with air or passage of x-rays in between the parallel plates.
- Further the chamber is illuminated by light which is passed horizontally and oil drops can be seen clearly using microscope placed perpendicular to the light beam.
- These drops can move either upwards or downward. Let m be the mass of the oil drop and q be its charge.
- Then the forces acting on the droplet are
  (a) gravitational force F_g = mg
  (b) electric force F_e = qE
  (c) buoyant force F_b
  (d) viscous force F_v

(a) Determination of radius of the droplet:

- When the electric field is switched off, the oil drop accelerates downwards.
- Due to the presence of air drag forces, the oil drops easily attain its terminal velocity and moves with constant velocity.
- This velocity can be carefully measured by noting down the time taken by the oil drop to fall through a predetermined distance.
- The free body diagram of the oil drop is shown in Figure(a), we note that viscous force and buoyant force balance the gravitational force.



- Let the gravitational force acting on the oil drop (downward) be F_g = mg.
- Let us assume that oil drop to be spherical in shape.
- Let ρ be the density of the oil drop, and r be the radius of the oil drop, then the mass of the oil drop can be expressed in terms of its density as,

$$\rho = \frac{m}{V}$$

$$m = \rho V = \rho\left(\frac{4}{3}\pi r^3\right) \quad \left[\because V = \frac{4}{3}\pi r^3\right]$$

- The gravitational force can be written in terms of density as,

$$F_g = mg = \rho\left(\frac{4}{3}\pi r^3\right)g$$

- Let σ be the density of the air, the upthrust force experienced by the oil drop due to displaced air is,

$$F_b = \sigma\left(\frac{4}{3}\pi r^3\right)g$$

- Once the oil drop attains a terminal velocity υ, the net downward force acting on the oil drop is equal to the viscous force acting opposite to the direction of motion of the oil drop.
- From Stokes law, the viscous force on the oil drop is,

$$F_v = 6\pi r v\eta$$

- From the free body diagram as shown in Figure(a), the force balancing equation is,

$$F_g = F_b + F_v$$

$$\rho\left(\frac{4}{3}\pi r^3\right)g = \sigma\left(\frac{4}{3}\pi r^3\right)g + 6\pi r v\eta$$

$$\frac{4}{3}\pi r^3(\rho - \sigma)g = 6\pi r v\eta$$

$$\frac{2}{3}\pi r^3(\rho - \sigma)g = 3\pi r v\eta$$

$$r = \left[\frac{9\eta v}{2(\rho - \sigma)g}\right]^{\frac{1}{2}} \longrightarrow (1)$$

- Thus, equation (1) gives the radius of the oil drop.

(b) Determination of electric charge:

- When the electric field is switched on, charged oil drops experience an upward electric force (qE).
- Among many drops, one particular drop can be chosen in the field of view of microscope and strength of the electric field is adjusted to make that particular drop to be stationary.
- Under these circumstances, there will be no viscous force acting on the oil drop.
- Then, from the free body diagram shown Figure(b), the net force acting on the oil droplet is,

$$F_e + F_b = F_g$$

$$qE + \sigma\left(\frac{4}{3}\pi r^3\right)g = \rho\left(\frac{4}{3}\pi r^3\right)g$$

$$qE = \frac{4}{3}\pi r^3(\rho - \sigma)g$$

$$q = \frac{4}{3E}\pi r^3(\rho - \sigma)g \longrightarrow (2)$$

- Substituting equation (1) in equation (2), we get,

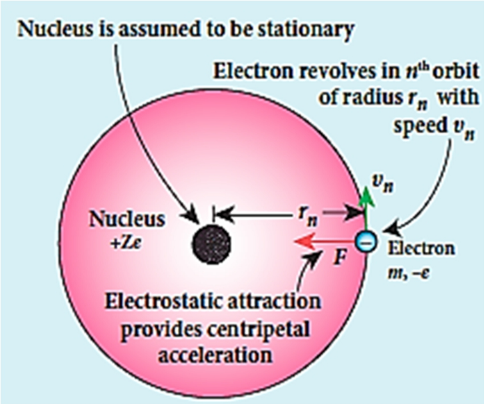
$$q = \frac{18\pi}{E}\left[\frac{\eta^3 v^3}{2(\rho-\sigma)g}\right]^{\frac{1}{2}}$$

- Millikan repeated this experiment several times and computed the charges on oil drops.
- He found that the charge of any oil drop can be written as integral multiple of a basic value, -1.6×10^{-19}C, which is nothing but the charge of an electron.

3. Derive the expression for radius of the orbit and velocity of an electron of hydrogen atom using Bohr atom model.

(a) Radius of the orbit:

- Consider an atom which contains the nucleus at rest and an electron revolving around the nucleus in a circular orbit of radius r_n as shown in Figure.



- Nucleus is made up of protons and neutrons. Since proton is positively charged and neutron is electrically neutral, the charge of a nucleus is purely the total charge of protons.
- Let Z be the atomic number of the atom, then +Ze is the charge of the nucleus. Let –e be the charge of the electron.
- From Coulomb's law, the force of attraction between the nucleus and the electron is,

$$\vec{F}_{Coloumb} = \frac{1}{4\pi\varepsilon_0}\frac{(+Ze)(-e)}{r_n^2}\hat{r}$$

$$\vec{F}_{Coloumb} = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2}\hat{r}$$

- This force provides necessary centripetal force,

$$\vec{F}_{Centripetal} = \frac{mv_n^2}{r_n}\hat{r}$$

Where m be the mass of the electron that moves with a velocity υ_n in a circular orbit.

- Therefore,

$$\left|\vec{F}_{Coloumb}\right| = \left|\vec{F}_{Centripetal}\right|$$

$$\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2} = \frac{mv_n^2}{r_n}$$

$$r_n = \frac{4\pi\varepsilon_0(mv_nr_n)^2}{Zme^2}$$

- From Bohr's assumption, the angular momentum quantization condition,

$$mv_nr_n = l_n = n\hbar$$

$$r_n = \frac{4\pi\varepsilon_0(n\hbar)^2}{Zme^2} = \frac{4\pi\varepsilon_0 n^2\hbar^2}{Zme^2}$$

$$r_n = \left(\frac{\varepsilon_0 h^2}{\pi me^2}\right)\frac{n^2}{Z} \qquad \left[\because \hbar = \frac{h}{2\pi}\right]$$

- Since, ε_0, h, e and π are constants. Therefore, the radius of the orbit becomes,

$$r_n = a_0\frac{n^2}{Z} \longrightarrow (1)$$

Where $a_0 = \frac{\varepsilon_0 h^2}{\pi me^2}$, is known as Bohr radius, which is the smallest radius of the orbit in an atom.

- Bohr radius is also used as unit of length called Bohr. 1 Bohr = a_0 = 0.53 Å.
- For hydrogen atom (Z = 1), the radius of nth orbit is,

$$r_n = a_0 n^2$$

  - For n=1, $r_1 = a_0$ = 0.53Å
  - For n=2, $r_1 = 4a_0$ = 2.116Å
  - For n=3, $r_1 = 9a_0$ = 4.761Å

and so on.

- Thus, $r_n \propto n^2$

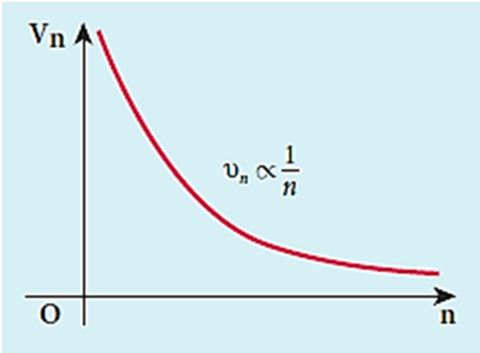
(b) Velocity of the orbit:

- Bohr's angular momentum quantization condition is,

$$mv_nr_n = mv_na_0n^2 = n\frac{h}{2\pi}$$

$$v_n = \frac{h}{2\pi ma_0}\frac{Z}{n}$$

- Thus, $v_n \propto \frac{1}{n}$
- Note that the velocity of electron decreases as the principal quantum number increases as shown in Figure.



- This curve is the rectangular hyperbola. This implies that the velocity of electron in ground state is maximum when compared to excited states.

4. Derive the energy expression for hydrogen atom using Bohr atom model.

- Since the electrostatic force is a conservative force, the potential energy for the nth orbit is,

$$U_n = \frac{1}{4\pi\varepsilon_0}\frac{(+Ze)(-e)}{r_n} = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n}$$

$$U_n = -\frac{1}{4\varepsilon_0^2}\frac{Z^2me^4}{h^2n^2} \quad \left[\because r_n = \left(\frac{\varepsilon_0 h^2}{\pi m e^2}\right)\frac{n^2}{Z}\right]$$

- The kinetic energy for the nth orbit is,

$$KE_n = \frac{1}{2}mv_n^2 = \frac{me^4}{8\varepsilon_0^2h^2}\frac{Z^2}{n^2}$$

Since,

$$|\vec{F}_{Coloumb}| = |\vec{F}_{Centripetal}|$$

$$\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n^2} = \frac{mv_n^2}{r_n}$$

$$mv_n^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n} = \frac{me^4}{4\varepsilon_0^2h^2}\frac{Z^2}{n^2}$$

$$\left[\because r_n = \left(\frac{\varepsilon_0 h^2}{\pi m e^2}\right)\frac{n^2}{Z}\right]$$

- This implies that $U_n = -2\,KE_n$. Total energy in the nth orbit is,

$$E_n = KE_n + U_n = KE_n - 2KE_n = -KE_n$$

$$E_n = -\frac{me^4}{8\varepsilon_0^2h^2}\frac{Z^2}{n^2}$$

- For hydrogen atom (Z = 1),

$$E_n = -\frac{me^4}{8\varepsilon_0^2h^2}\frac{1}{n^2} = -13.6\frac{1}{n^2}\ eV$$

  - For n=1, E_1 = -13.6 eV
  - For n=2, E_2 = -3.4 eV
  - For n=3, E_3 = -1.51 eV

  and so on.

- The ground state energy of hydrogen (–13.6 eV) is used as a unit of energy called Rydberg.

$$\left(1\ Rydberg = \frac{me^4}{8\varepsilon_0^2h^2} - 13.6\ eV\right)$$

5. Discuss the spectral series of hydrogen atom.

- The wavelengths of spectral lines of hydrogen atom perfectly agree with the equation derived from Bohr atom model.

$$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{n^2} - \frac{1}{m^2}\right) \longrightarrow (1)$$

Where,

ν - wave number(inverse of wavelength)
R - Rydberg constant(1.09737 X 10^7 m^{-1}).
m,n - positive integers such that m > n.

- The various spectral series are discussed below:

(a) Lyman series:

- Put n = 1 and m = 2,3,4....... in equation (1). The wave number or wavelength of spectral lines of Lyman series which lies in ultra-violet region is,

$$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{m^2}\right)$$

(b) Balmer series:

- Put n = 2 and m = 3,4,5....... in equation (1). The wave number or wavelength of spectral lines of Balmer series which lies in visible region is,

$$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{m^2}\right)$$

(c) Paschen series :

- Put n = 3 and m = 4,5,6....... in equation (1). The wave number or wavelength of spectral lines of Paschen series which lies in infra-red region (near IR) is,

$$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{m^2}\right)$$

(d) Brackett series :

- Put n = 4 and m = 5,6,7........ in equation (1). The wave number or wavelength of spectral lines of Brackett series which lies in infra-red region (middle IR) is,

$$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{m^2}\right)$$

(e) Pfund series :

- Put n = 5 and m = 6,7,8........ in equation (1). The wave number or wavelength of spectral lines of Pfund series which lies in infra-red region (far IR) is,

$$\bar{\nu} = \frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{m^2}\right)$$

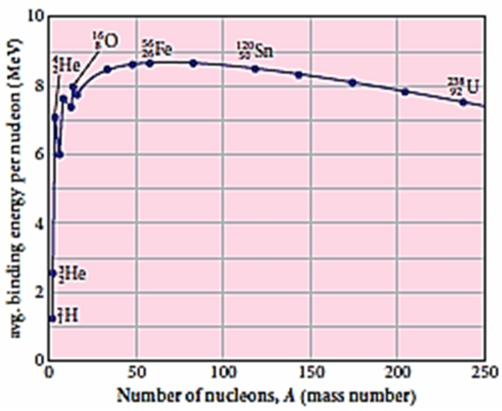
6. Explain the variation of average binding energy with the mass number by graph and discuss its features.

- The average value of BE/A rises as the mass number increases until it reaches a maximum value of 8.8 MeV for A = 56 (iron) and then it slowly decreases.

- The average binding energy per nucleon is about 8.5 MeV for nuclei having mass number between A= 40 and 120. These elements are comparatively more stable and not radioactive.

- For higher mass numbers, the curve reduces slowly and BE for uranium is about 7.6 MeV. They are unstable and radioactive.

- From Figure, if two light nuclei with A<28 combine with a nucleus with A<56, the binding energy per nucleon is more for final nucleus than initial nuclei. Thus, if the lighter elements combine to produce a nucleus of medium value A, a large amount of energy will be released. This is the basis of nuclear fusion.



- If a nucleus of heavy element is split (fission) into two or more nuclei of medium value A, the energy released would again be large.

7. Obtain the law of radioactivity.

- At any instant t, the number of decays per unit time, called rate of decay $\left(\frac{dN}{dt}\right)$ is proportional to the number of nuclei (N) at the same instant.

$$\frac{dN}{dt} \propto N$$

- By introducing a proportionality constant, the relation can be written as,

$$\frac{dN}{dt} = -\lambda N \longrightarrow (1)$$

Here, λ is called decay constant which is different for different radioactive sample and the negative sign idicates that the N is decreasing with time.

- By rewriting the equation (1), we get,

$$\frac{dN}{N} = -\lambda dt \longrightarrow (2)$$

Here dN represents the number of nuclei decaying in the time interval dt.

- Let
  N_0 - the number of nuclei present in the radioactive sample at time t = 0s,
  N - the number of nuclei present in the radioactive sample at any time t.

- Integrating the equation (2), we get,

$$\int_{N_0}^{N} \frac{dN}{N} = -\int_0^t \lambda dt$$

$$[\ln N]_{N_0}^{N} = -\lambda dt$$

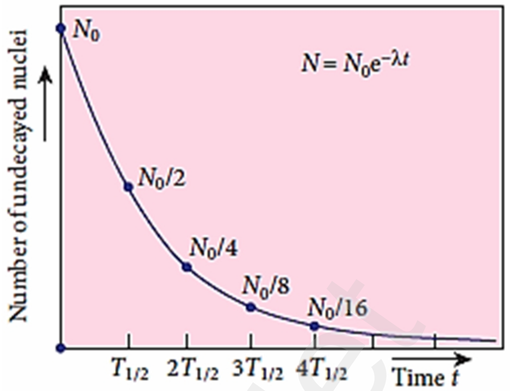
$$\ln N - \ln N_0 = -\lambda dt$$

$$\ln\left[\frac{N}{N_0}\right] = -\lambda dt$$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$N = N_0 e^{-\lambda t}$$

- Note that the number of atoms is decreasing exponentially over the time. This implies that the time taken for all the radioactive nuclei to decay will be infinite.



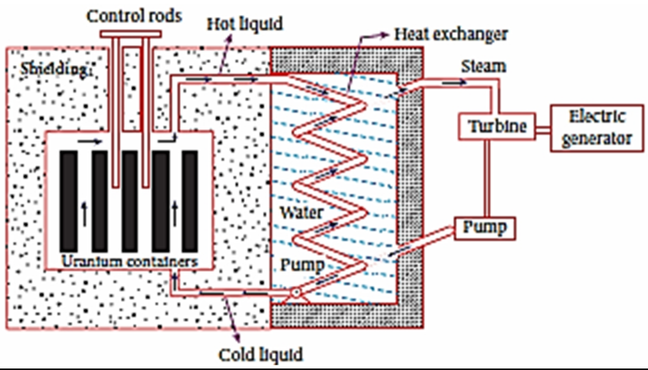
8. Describe the working of nuclear reactor with a block diagram.

Nuclear reactor:

- Nuclear reactor is a system in which the nuclear fission takes place in a self-sustained controlled manner and the energy produced is used either for research purpose or for power generation.

(a) Fuel:

- The fuel is fissionable material, usually uranium or plutonium.
- Naturally occurring uranium contains only 0.7% of $^{235}_{92}U$ and 99.3% are only $^{238}_{92}U$.
- So the $^{238}_{92}U$ must be enriched such that it contains at least 2 to 4% of $^{235}_{92}U$.
- In addition to this, a neutron source is required to initiate the chain reaction for the first time.
- A mixture of beryllium with plutonium or polonium is used as the neutron source.
- During fission of $^{235}_{92}U$, only fast neutrons are emitted but the probability of initiating fission by it in another nucleus is very low.
- Therefore, slow neutrons are preferred for sustained nuclear reactions.



(b) Moderators:

- The moderator is a material used to convert fast neutrons into slow neutrons.
- Usually the moderators are chosen in such a way that it must be very light nucleus having mass comparable to that of neutrons.
- Hence, these light nuclei undergo collision with fast neutrons and the speed of the neutron is reduced.
- Most of the reactors use water, heavy water (D_2O) and graphite as moderators.
- The blocks of uranium stacked together with blocks of graphite (the moderator) to form a large pile is shown in the Figure.

(c) Control rods:

- The control rods are used to adjust the reaction rate.
- During each fission, on an average 2.5 neutrons are emitted and in order to have the controlled chain reactions, only one neutron is allowed to cause another fission and the remaining neutrons are absorbed by the control rods.
- Usually cadmium or boron acts as control rod material and these rods are inserted into the uranium blocks.

(d) Shielding:

- For a protection against harmful radiations, the nuclear reactor is surrounded by a concrete wall of thickness of about 2 to 2.5 m.

(e) Cooling system:

- The cooling system removes the heat generated in the reactor core.
- Ordinary water, heavy water and liquid sodium are used as coolant since they have very high specific heat capacity and have large boiling point under high pressure.
- This coolant passes through the fuel block and carries away the heat to the steam generator through heat exchanger.
- The steam runs the turbines which produces electricity in power reactors.

10. Electronics And Communication

1. What is energy band?

The band of very large number of closely spaced energy levels in a very small energy range is known as energy band.

2. What is valence band?

The energy band formed due to the valence orbitals is called valence band.

3. What is conduction band?

The energy band formed due to the unoccupied orbitals to which electron can jump when energised is called conduction band.

4. What is forbidden energy gap?

The energy gap between the valence band and the conduction band is called forbidden energy gap.

5. Give the forbidden energy gap and resistivity values of insulator, conductor and semiconductor.

S.No.	Materials	Forbidden energy gap	Resistivity (Ωm)
1.	Insulators	6eV	$10^{11} - 10^{19}$
2.	Conductors	0eV	$10^{-2} - 10^{-8}$
3.	Semiconductor	<3eV	$10^{-5} - 10^{6}$
	(a) Silicon(Si)	1.1 eV	
	(b) Germanium(Ge)	0.7 eV	

6. Why is temperature co-efficient of resistance negative for semiconductor?

When the temperature of the semiconductor is increased, more number of electrons are promoted to conduction band. It increases the conduction and decreases resistance. Hence, semiconductors are said to have negative temperature coefficient of resistance.

7. What is intrinsic semiconductor?Give examples.

A semiconductor in its pure form without impurity is called an intrinsic semiconductor.

<u>Ex:</u> Pure Si and Ge.

8. What is doping and dopants?

- The process of adding impurities to the intrinsic semiconductor is called doping. (Normal doping Value is approximately 100ppm(parts per million)).
- The impurity atoms are called dopants.

9. What is extrinsic semiconductor?Give their types.

A semiconductor with impurity added is called an extrinsic semiconductor.

<u>Types:</u> (a) n-type semiconductor.
(b) p-type semiconductor.

10. What is n-type semiconductor?

A semiconductor, which is obtained by doping a pure Germanium (or Silicon) crystal with a dopant from group V pentavalent elements like Phosphorus, Arsenic, and Antimony is called n-type semiconductor.

11. What is p-type semiconductor?

A semiconductor, which is obtained by doping a pure Germanium (or Silicon) crystal with a dopant from group III trivalent elements like Boron, Aluminium, Gallium and Indium is called p-type semiconductor.

12. What are donor impurities?

The group V pentavalent impurity atoms donate electrons to the conduction band and are called donor impurities.

13. What are acceptor impurities?

The group III trivalent impurity atoms accept electrons from neighbouring atoms and are called acceptor impurities.

14. Distinguish between intrinsic and extrinsic semiconductors.

S.No.	Intrinsic Semiconductor	Extrinsic Semiconductor
1.	It is pure and not doped with any dopants.	It is doped with 3 valance or 5 valance dopants.
2.	Its conductivity is low.	Its conductivity is high.
3.	Here, Number of free electrons are equal to number of holes.	Here, Number of free electrons are not equal to holes.

15. How p-n junction is formed?

A p-n junction is formed by joining n-type and p-type semiconductor materials.

16. What is depletion region?

The region at either side of p-n junction junction consists of immovable ions is called depleted region.

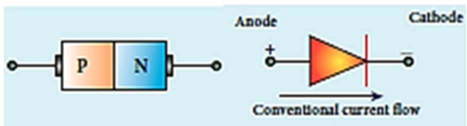
17. What is barrier potential?

The difference in potential across the depletion layer is called the barrier potential.

[For Si ->0.7 V and for Ge -> 0.3V]

18. What is p-n junction diode?Give its symbol.

A device with single p-n junction is called p-n junction diode.



19. What is biasing? Give their types.

Biasing means providing external energy to charge carriers to overcome the barrier potential and make them move in a particular direction.

<u>Types:</u> (a) Forward bias.
(b) Reverse bias.

20. What is bias voltage?

The external voltage applied to the p-n junction is called bias voltage.

21. What is forward bias?

If the positive terminal of the external voltage source is connected to the p-side and the negative terminal to the n-side, it is called forward bias.

22. What is reverse bias?

If the positive terminal of the external voltage source is connected to the n-side and the negative terminal to the p-side, it is called reverse bias.

23. A diode is called as a unidirectional device. Explain.

A diode is called as a unidirectional device because it conducts more electricity in forward bias than in reverse bias.

24. What is forward V-I characteristics of p-n junction diode?

A graph is plotted by taking the forward bias voltage (V) along the x-axis and the current (I) through the diode along the y-axis. This graph is called the forward V-I characteristics of the p-n junction diode

25. What is threshold or cut-in or knee voltage?

The potential difference of forward biased p-n junction diode, beyond which the forward current increases significantly is called threshold or cut-in or knee voltage.

26. What do you mean by leakage current in a diode?

When diode is given reverse bias, a very small current in μA, flows across the junction. This is due to the flow of the minority charge carriers called the leakage current or reverse saturation current.

27. What is rectification?

The process of converting alternating current into direct current is called rectification.

28. What is rectifier? Name their types.

A device, which is doing rectification is called rectifier.

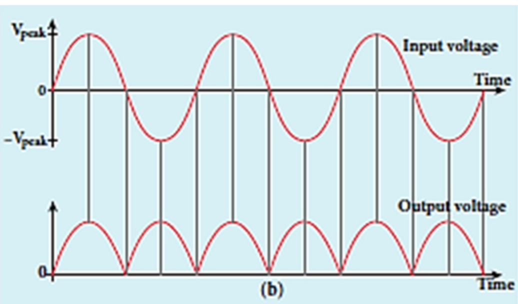
Types: Half wave rectifier, Full wave rectifier.

29. Define efficiency of a rectifier.

Efficiency(η) of a rectifier is defined as the ratio of the output dc power to the ac input power supplied to the circuit.

- For half wave rectifier, η = 40.6 %
- For full wave rectifier, η = 80.2 %

30. Draw the input and output waveform of a full wave rectifier.



31. What is breakdown voltage?

The reverse voltage at which the p-n junction breaks down and the reverse current rises sharply is called break down voltage.

32. What is Zener breakdown?

When a reverse voltage across the heavily doped p-n junction which has narrow depletion layer ($<10^{-6}$ m) is increased to the breakdown limit, a very strong electric field(3×10^{7} Vm^{-1}) is set up across the narrow layer. This strong electric field breaks the covalent bonds in the lattice and thereby generating electron-hole pairs. This effect is called Zener effect or zener breakdown.

33. What is avalanche breakdown?

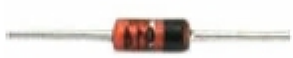
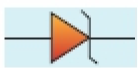
When a reverse voltage across the lighly doped p-n junction which has wide depletion layer is increased to the breakdown limit, a weak electric field is set up across the wide layer. This weak electric field accelerate minority charge carriers, which collide with atoms in covalent bonds in the lattice and breaks it. Thereby generating electron-hole pairs. This effect is called avalanche breakdown.

34. Distinguish between avalanche and zener breakdown.

S.No.	Avalanche breakdown	Zener breakdown
1.	It occurs in lightly doped diode.	It occurs in heavily doped diode.
2.	In this process, depletion layer is narrowed.	In this process, depletion layer is widen.
3.	Weak electric field is developed across depletion layer.	Strong electric field is developed across depletion layer.
4.	Here covalent bonds are broken due to collision of of accelerated minority charge carriers with atoms.	Here covalent bonds are broken due to Strong electric field.

35. What is Zener diode?Give its symbol.

Zener diode is a heavily doped silicon diode used in reverse biased condition and is specially designed to be operated in the breakdown region.

36. What is Zener breakdown voltage?

The reverse voltage of Zener diode at which the reverse current increases rapidly is called Zener breakdown voltage(V_Z).

37. What are the applications of Zener diode?

- Voltage regulators.
- Calibrating voltages.
- Provide fixed reference voltage in a network for biasing.
- Protection of any gadget against damage from accidental application of excessive voltage.

38. What is Optoelectronics?

Optoelectronics deals with devices which convert electrical energy into light and light into electrical energy through semiconductors.

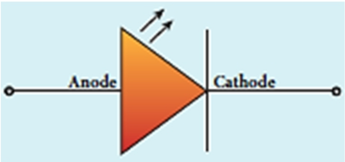
39. What is Optoelectronic devices? Give examples.

Optoelectronic device is an electronic device which utilizes light for useful applications.

Ex: Light emitting diodes(LED), photo diodes and solar cells.

40. What is light emitting diode(LED)?Give its symbol.

LED is a p-n junction diode which emits visible or invisible light when it is forward biased.



41. What is electroluminescence?

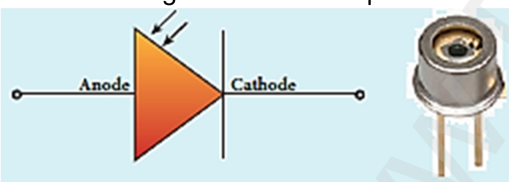
The process of converting electrical energy in to light energy is called electroluminenscence.

42. What are the applications of light emitting diode?

- Indicator lamps on the front panel of the scientific and laboratory equipments.
- Seven-segment displays.
- Traffic signals, emergency vehicle lighting etc.
- Remote control of television, airconditioner etc.

43. What is photodiode?Give its symbol.

A p-n junction diode which converts an optical signal into electric signal is known as photodiode.



44. What is dark current in photodiode? How it is generated?

The reverse current produced in the photodiode, in the absence of incident light is called dark current. It is due to the thermally generated minority carriers.

45. What are the applications of photodiode?

- Alarm system.
- Count items on a conveyer belt.
- Photoconductors.
- Compact disc players, smoke detectors.
- Medical applications such as detectors for computed tomography etc.

46. What is solar cell?Give its types.

A solar cell isalso known as photovoltaic cell which converts light energy directly into electricity or electric potential difference by photovoltaic effect.

Types: (a) n - type solar cell.
(b) p – type solar cell.

47. Give the principle of solar cells.

Solar cells are working under the principle of photovoltaic effect in which emf is generated when solar radiation falls on it.

48. What are the applications of solar cell?

- Solar cells are widely used in calculators, watches, toys, portable power supplies, etc.
- Solar cells are used in satellites and space applications.
- Solar panels are used to generate electricity.

49. What is transistor?Give its types.

Transistor is a semiconductor device which has two p-n junctions and consists of three ohmic contacts in three regions namely emiiter, base and collector.

Types: (a) NPN transistors.
(b) PNP transistors.

50. Why can't we interchange the emitter and collector even though they are made up of the same type of semiconductor material?

Because of the differing size and the amount of doping, the emitter and collector cannot be interchanged even though they are made up of the same type of semiconductor material.

51. What is transistor biasing?

The application of suitable dc voltages across the transistor terminals is called transistor biasing.

52. Discuss the biasing polarities(modes of transistor biasing) in an NPN and PNP transistors.

(a) Forward Active:

- Emitter-base junction is forward biased.
- Collector-base junction is reverse biased.
- The transistor is in the active mode of operation.
- In this mode, the transistor functions as an amplifier.

(b) Saturation:

- Here, the emitter-base junction and collector-base junction are forward biased.
- The transistor has a very large flow of currents across the junctions.
- In this mode, transistor is used as a closed switch.

(c) Cut-off:

- In this bias, the emitter-base junction and collector-base junction are reverse biased.
- Transistor in this mode is an open switch.

53. Explain the current flow in a NPN transistor.

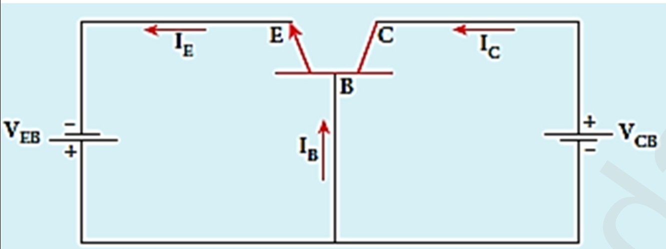
- When transistor is biased, the majority charge carriers in emitter region flow through forward biased emitter-base junction constitutes the emitter current I_E.
- At base, some of the majority charge carriers recombine with their opposite pair forms small base current I_B in μA.
- Then most of the majority charge carriers reach collector, which constitue collector current I_C.
- Therefore,

$$I_E = I_B + I_C$$

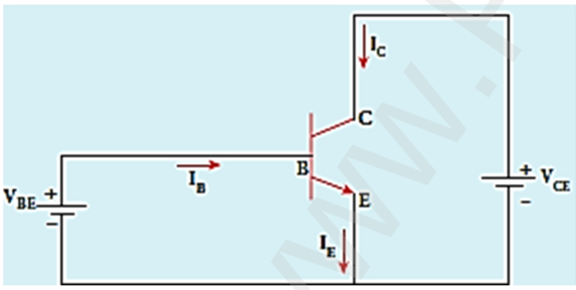
54. What are the types of circuit connections in transistors?

- Common-Base(CB) configuartion.
- Common-Emitter(CE) configuartion.
- Common-Collector(CC) configuartion.

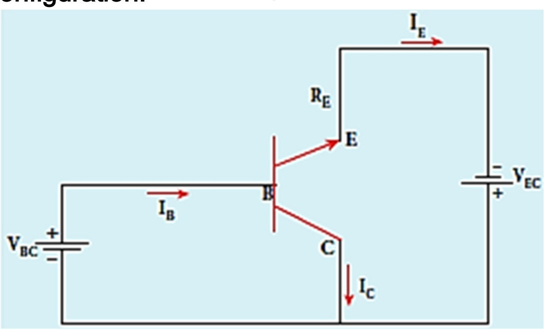
55. Draw the schematic circiut diagram of CB configuration.



56. Draw the schematic circiut diagram of CE configuration.



57. Draw the schematic circiut diagram of CC configuration.



58. What are the three static characteristics of the Bipolar Junction Transistor(BJT)?

- Input characteristics.
- Output characteristics.
- Transfer characteristics.

59. What is input impedance?

The ratio of the change in base-emitter voltage to the change in base current at a constant collector-emitter voltage is called the input impedance.

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

60. What is output impedance?

The ratio of the change in collector-emitter voltage to the change in collector current at a constant base current is called the output impedance.

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

61. What is forward current gain?

The ratio of the change in collector current to the change in base current at a constant collector-emitter voltage is called the output impedance.

$$\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

62. Write the relation between α and β?

$$\alpha = \frac{\beta}{1+\beta} \quad or \quad \beta = \frac{\alpha}{1-\alpha}$$

Where,

α - Current gain in CB configuration.
β - Current gain in CE configuartion.

63. What is Operating point?

The operating point is a point where the transistor can be operated efficiently.

64. What is dc load line?

A line that is drawn with the values V_{CC} (when I_C = 0) and I_C (when V_{CE} = 0) is called the dc load line.

65. What is amplification?

Amplification is the process of increasing the signal strength (increase in the amplitude).

66. What is the phase relationship between the AC input and output voltages in a common emitter amplifier? What is the reason for the phase reversal?

- The phase relationship between the AC input and output voltages in a CE amplifier is 180^0.
- When base current increase, it will increase collector current and hence the voltage drop across collector resistor. Therefore, the output voltage decreases. This makes phase reversal.

67. What is an electronic oscillator?Give their types.

An electronic oscillator basically converts dc energy into ac energy of high frequency ranging from a few Hz to several MHz.

Types: (a) Sinusoidal oscillators.
(b) non-sinusoidal oscillators.

68. Write the Barkhausen conditions for sustained oscillations.

- The loop phase shift must be 0^0 or integral multiples of 2π.
- The loop gain must be unity. $A\beta = 1$.

Here, A→Voltage gain of the amplifier.
b →feedback ratio.

69. Explain the need for a feedback circuit in a transistor oscillator.

- If feedback circuit is not used in transistor oscillator, damped oscillations are produced.
- Therefore, for undamped sustained oscillations, feedback circuit is necessary in a transistor oscillator.

70. What are the applications of oscillators?

- to generate a periodic sinusoidal or non sinusoidal wave forms.
- to generate RF carriers.
- to generate audio tones.
- to generate clock signal in digital circuits.
- as sweep circuits in TV sets and CRO.

71. What is digital electronics?

Digital Electronics is the sub-branch of electronics which deals with digital signals.

72. What is an analog signal?

An analog signal is a continuously varying voltage or current with respect to time.

73. What is digital signals?

Digital signals are signals which contain only discrete values of voltages. Digital signals need two states: switch ON and OFF.

74. What are logic gates?Name their types.

Logic gates are electronic circuits, they function based on digital signals.

Types:

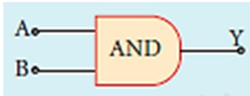
Basic logic gates	Other logic gates
AND gate	NAND gate
OR gate	NOR gate
NOT gate	Ex-OR gate

75. Why are NOR and NAND gates called universal gates?

The basic logic gates like OR, AND and NOT can be formed by using NOR and NAND gates.So NOR and NAND gates are called universal gates.

76. Write the circuit symbol, truth table and Boolean equation for AND gate.

Circuit Symbol:



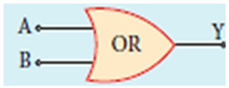
Truth table:

Inputs		Output
A	B	$Y = A + B$
0	0	0
0	1	0
1	0	0
1	1	1

Boolean equation: $Y = A.B$

77. Write the circuit symbol, truth table and Boolean equation for OR gate.

Circuit Symbol:



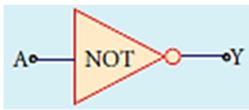
Truth table:

Inputs		Output
A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

Boolean equation: $Y = A + B$

78. Write the circuit symbol, truth table and Boolean equation for NOT gate.

Circuit Symbol:



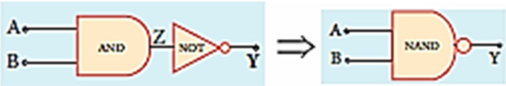
Truth table:

Inputs	Output
A	$Y = \bar{A}$
0	1
1	0

Boolean equation: $Y = \bar{A}$

79. Write the circuit symbol, truth table and Boolean equation for NAND gate.

Circuit Symbol:



Truth table:

Input		Output (AND)	Output (NAND)
A	B	Z= A.B	$Y=\overline{A.B}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

Boolean equation: $Y=\overline{A.B}$

80. Write the circuit symbol, truth table and Boolean equation for NOR gate.

Circuit Symbol:

Truth table:

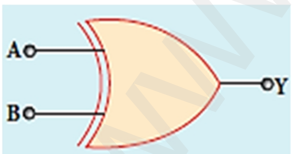
Inputs		Output (OR)	Output (NOR)
A	B	Z=A+B	$Y=\overline{A+B}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

Boolean equation:

$$Y=\overline{A+B}$$

81. Write the circuit symbol, truth table and Boolean equation for Ex-OR gate.

Circuit Symbol:



Truth table:

Inputs		Output (Ex-OR)
A	B	$Y=A\oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

Boolean equation:

$$Y=A\cdot\bar{B}+\bar{A}\cdot B=A\oplus B$$

82. Write the laws of Boolean operations.

(a) Commutative laws:

$$A+B=B+A$$
$$A\cdot B=B\cdot A$$

(b) Associative laws:

$$A+(B+C)=(A+B)+C$$
$$A\cdot(B\cdot C)=(A\cdot B)\cdot C$$

(c) Distributive laws:

$$A(B+C)=AB+AC$$
$$A+BC=(A+B)+(A+C)$$

83. What is Integrated Circuits(IC) or Chip or microchip?write their types.

IC is a device, which consists of thousands to millions of transistors, resistors, capacitors, etc. integrated on a small flat piece of semiconductor material that is normally Silicon.

Types: (a) Linear IC or Analog IC.
(b) Digital IC.

84. What are advantages of IC?

- Low cost.
- High performance.
- Miniature size.
- High speed.
- High capacity.

85. What are difference between linear and digital ICs?

S.No.	Linear IC	Digital IC
1.	It process analog signals	It process digital signals
2.	It works with continuous values.	It works with two discret values namely 0 and 1.
3.	It is used in audio and radio frequency amplification.	It is used in computers, networking equipment and most consumer electronics.

86. What is meant by modulation? Give its types.

The process of superposition of low frequency baseband signal onto a high frequency radio signal(carrier wave) is called modulation.

Types:

- Amplitude modulation(AM).
- Frequency modulation(FM).
- Phase modulation(PM).

87. What is amplitude modulation(A M)?

If the amplitude of the carrier signal is modified in proportion to the instantaneous amplitude of the baseband , then it is called amplitude modulation.

88. What are the advantages of amplitude modulation?

- Easy transmission and reception.
- Lesser bandwidth requirements.
- Low cost.

89. What are the limitations of amplitude modulation?
- Noise level is high.
- Low transmission efficiency.
- Small operating range.

90. What is frequency modulation(FM)?

If the frequency of the carrier signal is modified in proportion to the instantaneous amplitude of the baseband , then it is called amplitude modulation.

91. What is centre or resting frequency?

The frequency of the carrier wave for zero baseband signal voltage, is called centre frequency or resting frequency.

92. What are the advantages of frequency modulation?
- Noise level is low.
- High operating range.
- High transmission efficiency.
- Better quality than AM.

93. What are the limitations of frequency modulation?
- Requires wider bandwidth.
- FM transmitters and receivers are more complex and costly.
- In FM reception, less area is covered compared to AM.

94. What is phase modulation(PM)?

If the phase of the carrier signal is modified in proportion to the instantaneous amplitude of the baseband , then it is called phase modulation.

95. What are the advantages of phase modulation?
- FM signal produced from PM signal is very stable.
- The centre frequency called resting frequency is extremely stable.

96. What is meant by range in communication system?

The maximum distance between the source and the destination up to which the signal is received with sufficient strength is called range.

97. What is meant by noise in communication system? Give examples.
- The undesirable electrical signal that interferes with the transmitted signal is called noise.
- <u>Examples:</u>
  - **Man-made noises:** Automobiles, Welding machines, Electric motors etc.
  - **Natural noises:** Lightning, Environmental effects, Radiation from sun and stars.

98. What is meant by Attenuation in communication system?

The loss of strength of a signal while propagating through a medium is known as attenuation.

99. What is bandwidth of baseband signal?

The frequency range over which the baseband signals or the information signals such as voice, music, picture etc is transmitted is known as bandwidth.

100. What is bandwidth of transmission system?

The range of frequencies required to transmit a piece of specified information in a particular channel is called channel bandwidth or the bandwidth of the transmission system.

101. What are modes of propagation of electromagnetic waves?
- Ground wave propagation (or) surface wave propagation. **(2 kHz to 2 MHz)**
- Sky wave propagation (or) ionospheric propagation. **(3 MHz to 30 MHz)**
- Space wave propagation. **(30 MHz to 400 GHz)**

102. What is ground wave propagation?

If the electromagnetic waves transmitted by the transmitter glide over the surface of the earth to reach the receiver, then the propagation is called ground wave propagation.

103. What is sky wave propagation?

The mode of propagation in which the electromagnetic waves radiated from an antenna, directed upwards at large angles, gets reflected by the ionosphere back to earth is called sky wave propagation or ionospheric propagation.

104. What is skip distance?

The shortest distance between the transmitter and the point of reception of the sky wave along the surface is called as the skip distance.

105. Wha t is skip zone or skip area?

A zone at which no reception of electromagnetic waves neither ground nor sky is called skip zone or skip area.

106. What is space wave propagation?

The process of sending and receiving information signal through space is called space wave propagation.

107. What is satellite communication?

The satellite communication is a mode of communication of signal between transmitter and receiver via satellite.

108. What are the applications of satellite communication?

- **Weather satellites:** predict rain and dangerous storms like hurricanes, cyclones etc.
- **Communication satellites:** used to transmit television, radio, internet signals etc.
- **Navigation satellites:** to determine the geographic location of ships, aircrafts or any other object.

109. What is fibre optic communication?Write its principle.

- The method of transmitting information from one place to another in terms of light pulses through an optical fiber is called fiber optic communication.
- It works under the principle of total internal reflection.

110. What are the applications of fibre optic communication?

- International communication.
- Inter-city communication.
- Data links.
- Plant and traffic control.
- Defense applications.

111. What are the merits of fibre optic communication?

- Fiber cables are very thin and weigh lesser than copper cables.
- This system has much larger band width. This means that its information carrying capacity is larger.
- Fiber optic system is immune to electrical interferences.
- Fiber optic cables are cheaper than copper cables.

112. What are the demerits of fibre optic communication?

- Fiber optic cables are more fragile when compared to copper wires.
- It is an expensive technology.

113. What does Radar stands for? What does it use?

- Radar basically stands for RAdio Detection and Ranging System.
- It is used to sense, detect, and locate distant objects like aircraft, ships, spacecraft, etc.

114. What are the applications of Radar?

- In military, it is used for locating and detecting the targets.
- It is used in navigation systems such as ship borne surface search, air search and missile guidance systems.
- Measuring precipitation rate and wind speed in meteorological observations.
- Locate and rescue people in emergency situations.

115. What is mobile communication?

Mobile communication is used to communicate with others in different locations without the use of any physical connection like wires or cables.

116. What are the applications of mobile communication?

- It is used for personal communication and cellular phones offer voice and data connectivity with high speed.
- Transmission of news across the globe is done within a few seconds.
- Using Internet of Things (**IoT**), it is made possible to control various devices from a single device.

  <u>Example:</u> home automation using a mobile phone.
- It enables smart classrooms, online availability of notes, monitoring student activities etc. in the field of education.

117. What do you mean by Internet of Things?

The Internet of Things(IoT) is a network method, in which physical objects are connected through internet with unique IP address and the communication can be done through these objects.

118. What is Internet?

Internet is the largest computer network recognized globally that connects millions of people through computers.

119. What are the applications of Internet?

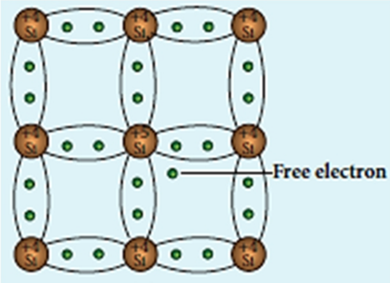
- **Search engine :** Search information on world wide web.
- **Communication:** Connects people through social networking like emails,instant messaging services and social networking tools.
- **E-Commerce:** Buying and selling of goods and services, transfer of funds.

5 Marks Q & A:

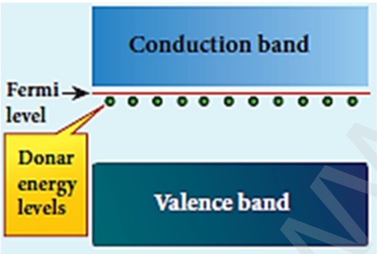
✓ **Elucidate the formation of a n-type and p-type semiconductors.**

(a) Formation of n-type semiconductor:

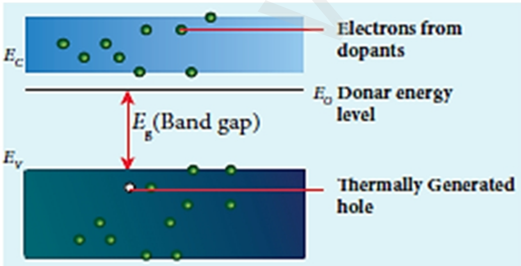
- A n-type semiconductor is obtained by doping a pure Germanium (or Silicon) crystal with a dopant from group V pentavalent elements like Phosphorus, Arsenic, and Antimony as shown in Figure.



- The dopant has five valence electrons while the Germanium atom has four valence electrons.
- During the process of doping, a few of the Germanium atoms are replaced by the group V dopants.
- Four of the five valence electrons of the impurity atom are bound with the 4 valence electrons of the neighbouring replaced Germanium atom.
- The fifth valence electron of the impurity atom will be loosely attached with the nucleus as it has not formed the covalent bond.
- The energy level of the loosely attached fifth electron from the dopant is found just below the conduction band edge and is called the donor energy level as shown in Figure.



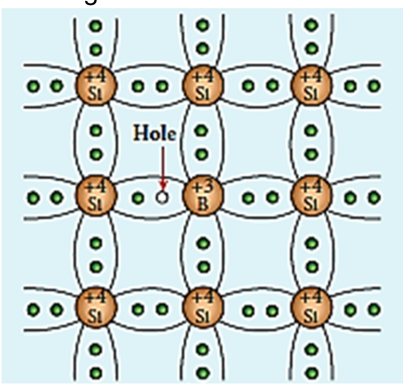
- At room temperature, these electrons can easily move to the conduction band with the absorption of thermal energy. It is shown in the Figure below.



- Besides, an external electric field also can set free the loosely bound electrons and lead to conduction.
- It is important to note that the energy required for an electron to jump from the valence band to the conduction band (E_g) in an intrinsic semiconductor is 0.7 eV for Ge and 1.1 eV for Si, while the energy required to set free a donor electron is only 0.01 eV for Ge and 0.05 eV for Si.
- The group V pentavalent impurity atoms donate electrons to the conduction band and are called donor impurities.
- Therefore, each impurity atom provides one extra electron to the conduction band in addition to the thermally generated electrons.
- These thermally generated electrons leave holes in valence band.
- Hence, the majority carriers of current in an n-type semiconductor are electrons and the minority carriers are holes.
- Such a semiconductor doped with a pentavalent impurity is called an n-type semiconductor.

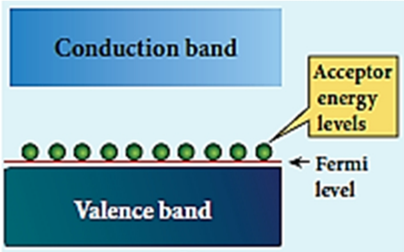
(b) Formation of p-type semiconductor:

- Here, a trivalent atom from group III elements such as Boron, Aluminium, Gallium and Indium is added to the Germanium or Silicon substrate.
- The dopant with three valence electrons are bound with the neighbouring Germanium atom as shown in Figure.

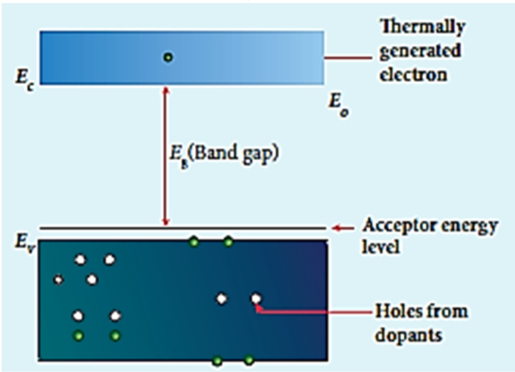


- As Germanium atom has four valence electrons, one electron position of the dopant in the Germanium crystal lattice will remain vacant.
- The missing electron position in the covalent bond is denoted as a hole.
- To make complete covalent bonding with all four neighbouring atoms, the dopant is in need of one more electron.
- These dopants can accept electrons from the neighbouring atoms.
- Therefore, this impurity is called an acceptor impurity.

- The energy level of the hole created by each impurity atom is just above the valence band and is called the acceptor energy level, as shown in Figure.



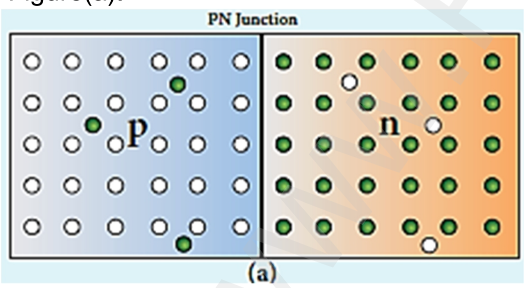
- For each acceptor atom, there will be a hole in the valence band in addition to the thermally generated holes.
- In such an extrinsic semiconductor, holes are the majority carriers and thermally generated electrons are minority carriers as shown in Figure.



- The semiconductor thus formed is called a p-type semiconductor.

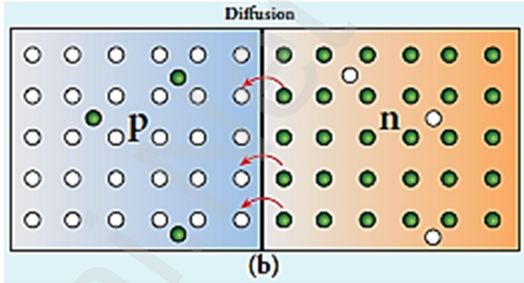
2. Explain the formation of PN junction diode. Discuss its V–I characteristics.

- A p-n junction is formed by joining n-type and p-type semiconductor materials as shown in Figure(a).



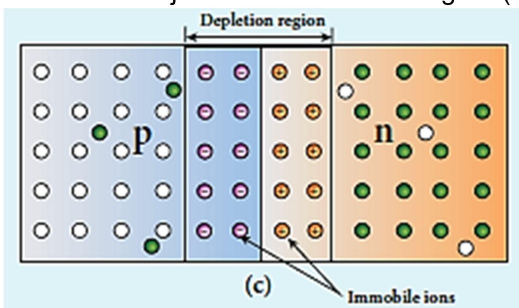
(a)

- Since the n-region has a high electron concentration and the p-region a high hole concentration, electrons diffuse from the n-side to the p-side.
- This causes diffusion current which exists due to the concentration difference of electrons.
- The electrons diffusing into the p-region may occupy holes in that region and make it negative.
- The holes left behind by these electrons in the n-side are equivalent to the diffusion of holes from the p-side to the n-side.
- If the electrons and holes were not charged, this diffusion process would continue until the concentration of electrons and holes on the two sides were the same.
- But, in a p-n junction, when the electrons and holes move to the other side of the junction, they leave behind exposed charges on dopant atom sites, which are fixed in the crystal lattice and are unable to move.
- On the n-side, positive ion cores are exposed and on the p- side, negative ion cores are exposed as shown in Figure (b).



(b)

- An electric field E forms between the positive ion cores in the n-type material and negative ion cores in the p-type material.
- The electric field sweeps free carriers out of this region and hence it is called depletion region as it is depleted of free carriers.
- A barrier potential V_b due to the electric field E is formed at the junction as shown in Figure (c).



(c)

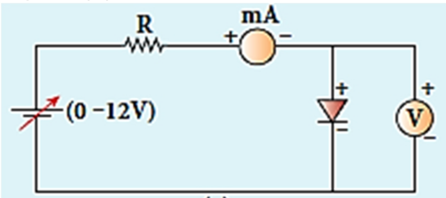
- As this diffusion of charge carriers from both sides continues, the negative ions form a layer of negative space charge region along the p-side.
- Similarly, a positive space charge region is formed by positive ions on the n-side.
- The positive space charge region attracts electrons from p-side to n-side and the negative space charge region attracts holes from n-side to p-side.
- This movement of carriers happen in this region due to the formed electric field and it constitutes a current called drift current.
- The diffusion current and drift current flow in the opposite direction and at one instant they both become equal. Thus, a p-n junction is formed.

V-I characteristics:

- A graph plotted by taking the voltage (V) along the x-axis and the current (I) through the diode along the y-axis is called the V-I characteristics of the p-n junction diode.
- There are two types V-I characteristics namely forward and reverse.

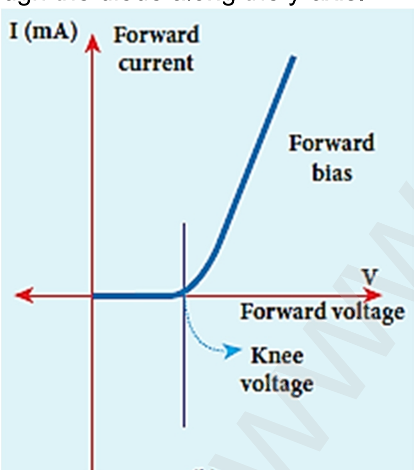
(a) Forward V-I characteristics:

- It is the study of the variation in current through the diode with respect to the applied voltage across the diode when it is forward biased.
- The p-n junction diode is forward biased as shown in Figure (a).



(a)

- An external resistance (R) is used to limit the flow of current through the diode.
- The voltage across the diode is varied by varying the biasing voltage across the dc power supply.
- The forward bias voltage and the corresponding forward bias current are noted.
- A graph is plotted by taking the forward bias voltage (V) along the x-axis and the current (I) through the diode along the y-axis.



(b)

- Three inferences can be brought out from the graph:

(i) At room temperature, a potential difference equal to the barrier potential is required before a reasonable forward current starts flowing across the diode.

This voltage is known as threshold voltage or cut-in voltage or knee voltage (V_{th}).

It is approximately 0.3 V for Germanium and 0.7V for Silicon.

The current flow is negligible when the applied voltage is less than the threshold voltage.

Beyond the threshold voltage, increase in current is significant even for a small increase in voltage.

(ii) The graph clearly infers that the current flow is not linear and is exponential. Hence it does not obey Ohm's law.

(iii) The forward resistance (r_f) of the diode is the ratio of the small change in voltage (ΔV)to the small change in current(ΔI),

$$r_f = \frac{\Delta V}{\Delta I}$$

(iv) Thus the diode behaves as a conductor when it is forward biased.

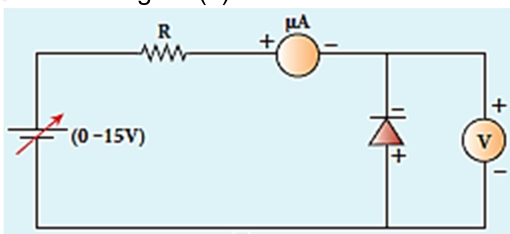
However, if the applied voltage is increased beyond a rated value, it will produce an extremely large current which may destroy the junction due to overheating. This is called as the breakdown of the diode.

The voltage at which the diode breaks down is called the breakdown voltage.

Thus, it is safe to operate a diode well within the threshold voltage and the breakdown voltage.

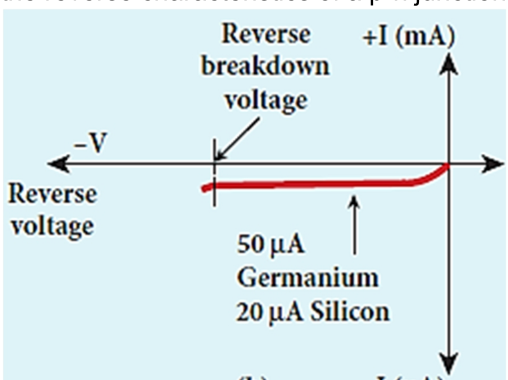
(b) Reverse V-I characteristics:

- The circuit to study the reverse characteristics is shown in Figure (a).



(a)

- In the reverse bias, the p-region of the diode is connected to the negative terminal and n-region to the positive terminal of the dc power supply.
- A graph is drawn between the reverse bias voltage and the current across the junction, which is called the reverse characteristics of a p-n junction diode.

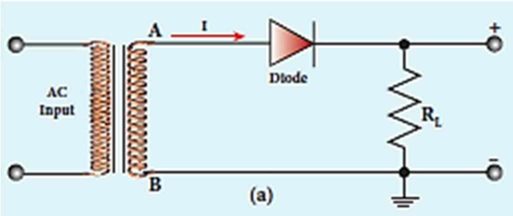


(b)

- Under this bias, a very small current in μA, flows across the junction.
- This is due to the flow of the minority charge carriers called the leakage current or reverse saturation current.
- Besides, the current is almost independent of the voltage.
- The reverse bias voltage can be increased only up to the rated value otherwise the diode will enter into the breakdown region.

3. Draw the circuit diagram of a half wave rectifier and explain its working.

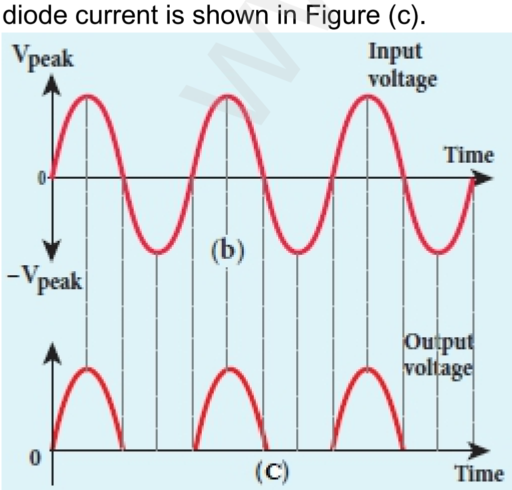
- The half wave rectifier circuit is shown in Figure(a).



- The circuit consists of a transformer, a p-n junction diode and a resistor.
- In a half wave rectifier circuit, either a positive half or the negative half of the AC input is passed through while the other half is blocked.
- Only one half of the input wave reaches the output. Therefore, it is called half wave rectifier.
- Here, a p-n junction diode acts as a rectifier diode.

(a) During the positive half cycle:

- When the positive half cycle of the ac input signal passes through the circuit, terminal A becomes positive with respect to terminal B.
- The diode is forward biased and hence it conducts.
- The current flows through the load resistor R_L and the AC voltage developed across R_L constitutes the output voltage V_0 and the waveform of the diode current is shown in Figure (c).

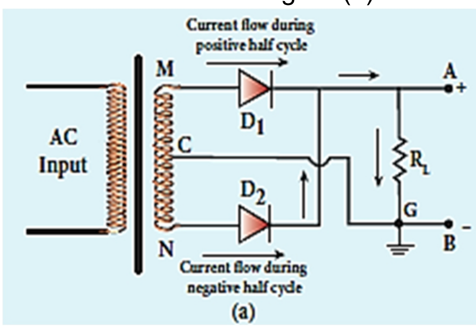


(b) During the negative half cycle:

- When the negative half cycle of the ac input signal passes through the circuit, terminal A is negative with respect to terminal B.
- Now the diode is reverse biased and does not conduct and hence no current passes through R_L.
- The reverse saturation current in a diode is negligible.
- Since there is no voltage drop across R_L, the negative half cycle of ac supply is suppressed at the output.
- The output waveform is shown in Figure (c).
- The output of the half wave rectifier is not a steady dc voltage but a pulsating wave.
- This pulsating voltage can not be used for electronic equipments.
- A constant or a steady voltage is required which can be obtained with the help of filter circuits and voltage regulator circuits.
- Efficiency (η) is the ratio of the output dc power to the ac input power supplied to the circuit.
- Its value for half wave rectifier is 40.6 %

4. Explain the construction and working of a full wave rectifier.

- The positive and negative half cycles of the AC input signal pass through the full wave rectifier circuit and hence it is called the full wave rectifier.
- The circuit is shown in Figure (a).



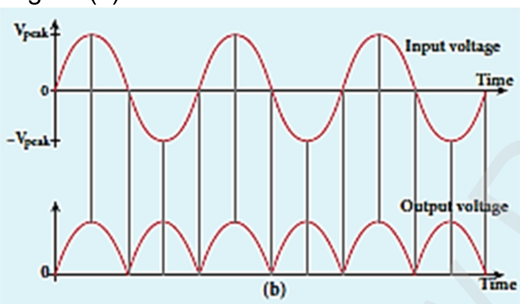
- It consists of two p-n junction diodes, a center tapped transformer, and a load resistor (R_L).
- The centre is usually taken as the ground or zero voltage reference point.
- Due to the centre tap transformer, the output voltage rectified by each diode is only one half of the total secondary voltage.

(a) During positive half cycle:

- When the positive half cycle of the ac input signal passes through the circuit, terminal M is positive, G is at zero potential and N is at negative potential.
- This forward biases diode D_1 and reverse biases diode D_2.
- Hence, being forward biased, diode D_1 conducts and current flows along the path MD_1AGC.
- As a result, positive half cycle of the voltage appears across R_L in the direction G to C.

(b) During negative half cycle :

- When the negative half cycle of the ac input signal passes through the circuit, terminal N is positive, G is at zero potential and M is at negative potential.
- This forward biases diode D_2 and reverse biases diode D_1.
- Hence, being forward biased, diode D_2 conducts and current flows along the path ND_2BGC.
- As a result, -ve half cycle of the voltage appears across R_L in the same direction from G to C.
- Hence in a full wave rectifier both postive and negative half cycles of the input signal pass through the load in the same direction as shown in Figure (b).

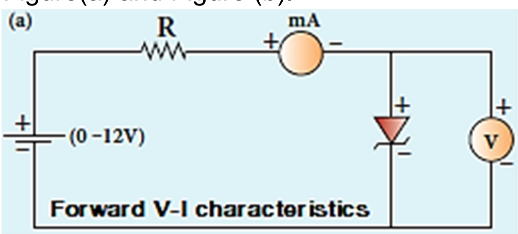


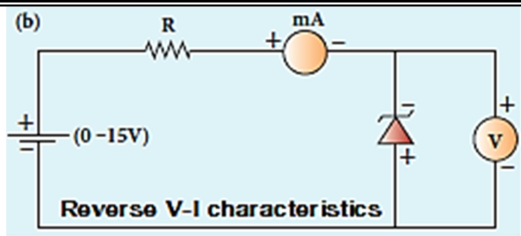
(b)

- Though both positive and negative half cycles of ac input are rectified, the output is still pulsating in nature.
- The efficiency (η) of full wave rectifier is twice that of a half wave rectifier and is found to be 81.2 %.
- It is because both the positive and negative half cycles of the ac input source are rectified.

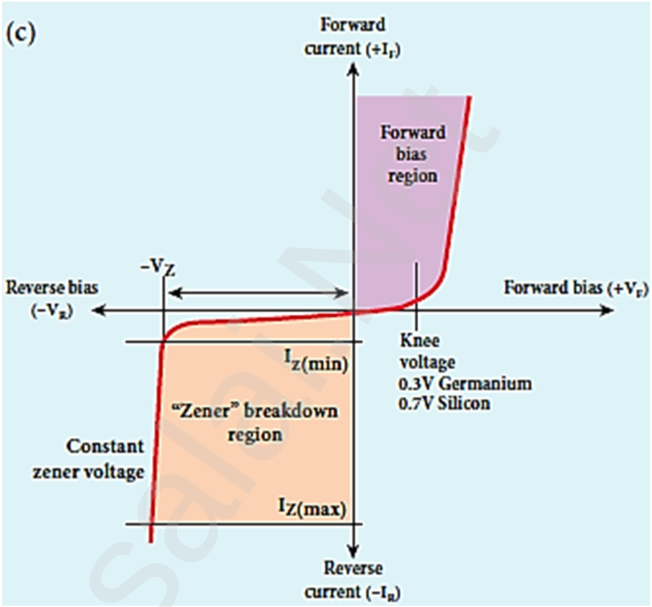
5. Discuss the V–I characteristics of Zener diode.

- The circuit to study the forward and reverse characteristics of a Zener diode is shown in Figure(a) and Figure (b).





- The V-I characteristics of a Zener diode is shown in Figure (c).

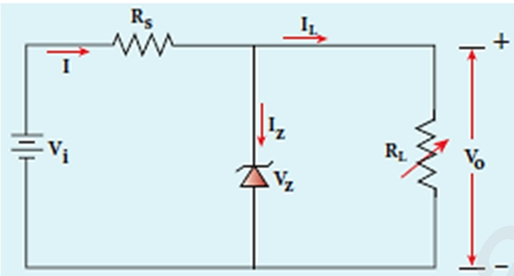


- The forward characteristics of a Zener diode is similar to that of an ordinary p-n junction diode. It starts conducting approximately around 0.7 V.
- However, the reverse characteristics is highly significant in Zener diode.
- The increase in reverse voltage normally generates very small reverse current.
- While in Zener diode, when the reverse voltage is increased to the breakdown voltage (V_Z), the increase in current is very sharp.
- The voltage remains almost constant throughout the breakdown region.
- In Figure (c), $I_{Z(max)}$ represents the maximum reverse current.
- If the reverse current is increased further, the diode will be damaged.
- The important parameters on the reverse characteristics are
  - V_Z→Zener breakdown voltage
  - $I_{Z(min)}$→minimum current to sustain breakdown
  - $I_{Z(max)}$→maximum current limited by maximum power dissipation.

- The Zener diode is operated in the reverse bias having the voltage greater than V_Z and current less than $I_{Z(max)}$.
- The reverse characteristics is not exactly vertical which means that the diode possesses some small resistance called Zener dynamic impedance.
- Zener resistance is the inverse of the slope in the breakdown region.
- It means an increase in the Zener current produces only a very small increase in the reverse voltage. However this can be neglected.
- The voltage of an ideal Zener diode does not change once it goes into breakdown.
- It means that V_Z remains almost constant even when I_Z increases considerably.

6. Zener diode acts as a voltage regulator. Explain.

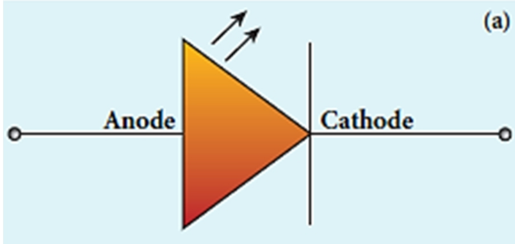
- A Zener diode working in the breakdown region can serve as a voltage regulator.
- It maintains a constant output voltage even when input voltage V_i or load current I_L varies.
- The circuit used for the same is shown in Figure.



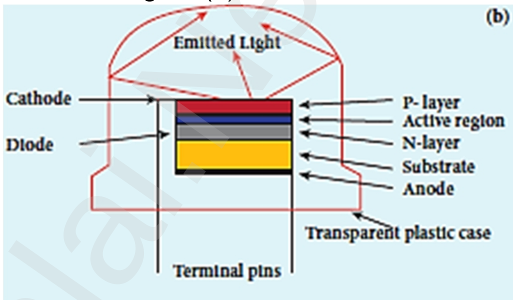
- Here in this circuit, the input voltage V_i is regulated at a constant voltage, V_z (Zener voltage) at the output represented as V_0 using a Zener diode.
- The output voltage is maintained constant as long as the input voltage does not fall below V_z .
- When the potential developed across the diode is greater than V_Z , the diode moves into the Zener breakdown region.
- It conducts and draws relatively large current through the series resistance R_s.
- The total current I passing through R_s equals the sum of diode current I_Z and load current I_L ($I = I_Z + I_L$).
- It is to be noted that the total current is always less than the maximum Zener diode current.
- Under all conditions $V_o = V_Z$. Thus, output voltage is regulated.

7. What is LED? Give the principle of operation with a diagram.

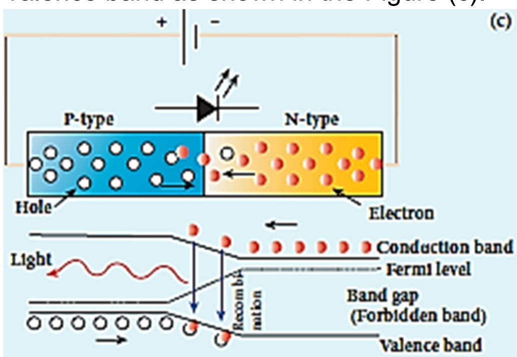
- LED is a p-n junction diode which emits visible or invisible light when it is forward biased.
- Since, electrical energy is converted into light energy, this process is also called electroluminescence.
- The circuit symbol of LED is shown in Figure (a).



- The cross-sectional view of a commercial LED is shown in Figure (b).



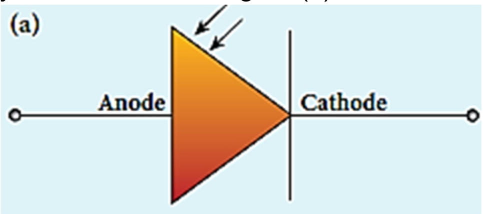
- It consists of a p-layer, n-layer and a substrate. A transparent window is used to allow light to travel in the desired direction.
- An external resistance in series with the biasing source is required to limit the forward current through the LED.
- In addition, it has two leads; anode and cathode.
- When the p-n junction is forward biased, the conduction band electrons on n-side and valence band holes on p-side diffuse across the junction.
- When they cross the junction, they become excess minority carriers (electrons in p-side and holes in n-side).
- These excess minority carriers recombine with oppositely charged majority carriers in the respective regions, i.e. the electrons in the conduction band recombine with holes in the valence band as shown in the Figure (c).



- During recombination process, energy is released in the form of light (radiative) or heat (non-radiative).
- For radiative recombination, a photon of energy hν is emitted.
- For non-radiative recombination, energy is liberated in the form of heat.
- The colour of the light is determined by the energy band gap of the material.
- Therefore, LEDs are available in a wide range of colours such as blue (SiC), green (AlGaP) and red (GaAsP).
- Now a days, LED which emits white light (GaInN) is also available.

8. Write notes on Photodiode.

- A p-n junction diode which converts an optical signal into electric signal is known as photodiode.
- Thus, the operation of photodiode is exactly inverse to that of an LED.
- Photo diode works in reverse bias. Its circuit symbol is shown in Figure (a).

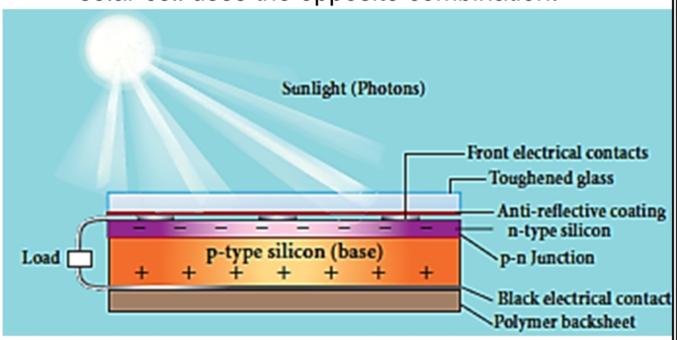


- The direction of arrows indicates that the light is incident on the photo diode.
- The device consists of a p-n junction semiconductor made of photosensitive material kept safely inside a plastic case as shown in Figure (b).

- It has a small transparent window that allows light to be incident on the p-n junction.
- Photodiodes can generate current when the p-n junction is exposed to light and hence are called as light sensors.
- When a photon of sufficient energy (hν) strikes the depletion region of the diode, some of the valence band electrons are elevated into conduction band, in turn holes are developed in the valence band. This creates electron-hole pairs.
- The amount of electronhole pairs generated depends on the intensity of light incident on the p-n junction.
- These electrons and holes are swept across the p-n junction by the electric field created by reverse voltage before recombination takes place.
- Thus, holes move towards the n-side and electrons towards the p-side.
- When the external circuit is made, the electrons flow through the external circuit and constitute the photocurrent.
- When the incident light is zero, there exists a reverse current which is negligible.
- This reverse current in the absence of any incident light is called dark current and is due to the thermally generated minority carriers.

9. Explain the working principle of a solar cell.

- A solar cell, also known as photovoltaic cell, converts light energy directly into electricity or electric potential difference by photovoltaic effect.
- It is basically a p-n junction which generates emf when solar radiation falls on the p-n junction.
- A solar cell is of two types: p-type and n-type. Both types use a combination of p-type and n-type silicon which together forms the p-n junction of the solar cell.
- The difference is that p-type solar cells use p-type Silicon as the base with an ultra-thin layer of n-type Silicon as shown in Figure, while n-type solar cell uses the opposite combination.

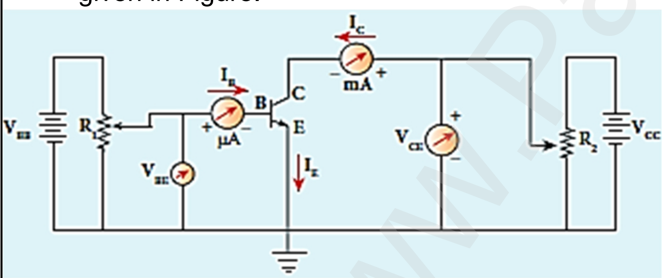


- The other side of the p-Silicon is coated with metal which forms the back electrical contact.
- On top of the n-type Silicon, metal grid is deposited which acts as the front electrical contact.
- The top of the solar cell is coated with anti-reflection coating and toughened glass.

- In a solar cell, electron–hole pairs are generated due to the absorption of light near the junction.
- Then the charge carriers are separated due to the electric field of the depletion region.
- Electrons move towards n–type Silicon and holes move towards p-type Silicon layer.
- The electrons reaching the n-side are collected by the front contact and holes reaching p-side are collected by the back electrical contact.
- Thus a potential difference is developed across solar cell.
- When an external load is connected to the solar cell, photocurrent flows through the load.
- Many solar cells are connected together either in series or in parallel combination to form solar panel or module.
- Many solar panels are connected with each other to form solar arrays.
- For high power applications, solar panels and solar arrays are used.

10. Sketch the static characteristics of a common emitter transistor and bring out the essence of input, output and current transfer characteristics.

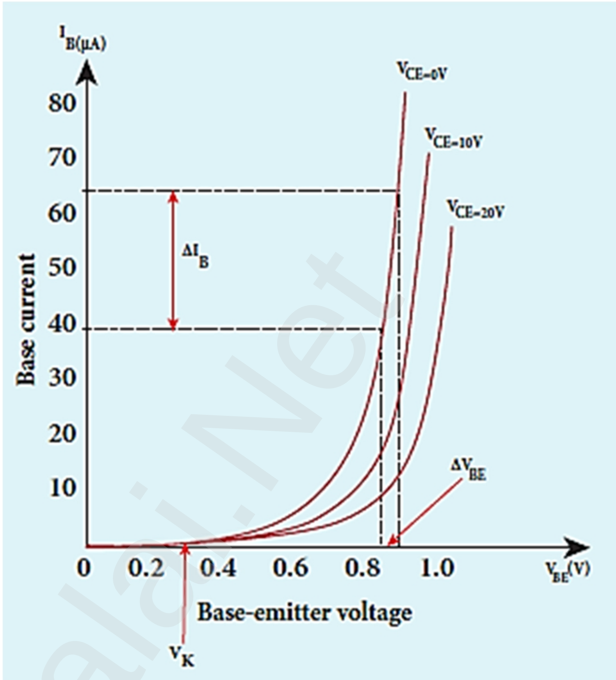
- The circuit to study the static characteristics of an NPN transistor in the common emitter mode is given in Figure.



- The bias supply voltages V_{BB} and V_{CC} bias the base-emitter junction and collectoremitter junction respectively.
- The junction potential at the base-emitter is represented as V_{BE} and the collector-emitter as V_{CE}.
- The rheostats $R_1$and R_2 are used to vary the base and collector currents respectively.
- The static characteristics of the BJT are
  1. Input characteristics
  2. Output characteristics
  3. Transfer characteristics

(a) Input Characteristics:

- Input Characteristics curves give the relationship between the base current (I_B) and base to emitter voltage (V_{BE}) at constant collector to emitter voltage (V_{CE}) and are shown in Figure.



- Initially, the collector to emitter voltage (V_{CE}) is set to a particular voltage (above 0.7 V to reverse bias the junction).
- Then the base-emitter voltage (V_{BE}) is increased in suitable steps and the corresponding base-current (I_B) is recorded.
- A graph is plotted with V_{BE} along the x-axis and I_B along the y-axis.
- The procedure is repeated for different values of V_{CE}.
- The following observations are made from the graph.
  - The curve looks like the forward characteristics of an ordinary p-n junction diode.
  - There exists a threshold voltage or knee voltage (V_k) below which the base current is very small. The value is 0.7 V for Silicon and 0.3 V for Germanium transistors. Beyond the knee voltage, the base current increases with the increase in base-emitter voltage.
  - It is also noted that the increase in the collector-emitter voltage decreases the base current. This shifts the curve outward. This is because the increase in collector-emitter voltage increases the width of the depletion region in turn, reduces the effective base width and thereby the base current.

Input impedance:

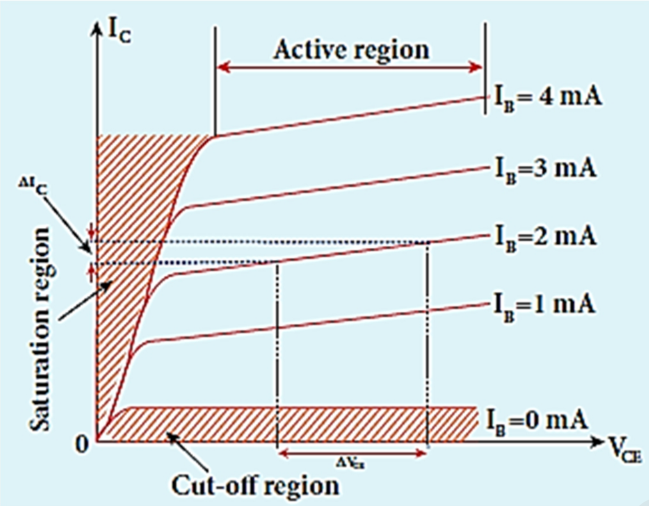
- The ratio of the change in base-emitter voltage (ΔV_{BE}) to the change in base current (ΔI_B) at a constant collector-emitter voltage (V_{CE}) is called the input impedance (r_i).
- The input impedance is not linear in the lower region of the curve.

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

- The input impedance is high for a transistor in common emitter configuration.

(b) Output Characteristics:

- The output characteristics give the relationship between collector current (I_C) with respect to the collector-emitter voltage (V_{CE}) at constant input current (I_B) as shown in Figure.



- Initially, the base current (I_B) is set to a particular value.
- Then collector-emitter voltage (V_{CE}) is increased in suitable steps and the corresponding collector current (I_C) is recorded.
- A graph is plotted with the V_{CE} along the x-axis and I_C along the y-axis.This procedure is repeated for different values of I_B.
- The four important regions in the output characteristics are:

(i) Saturation region: When V_{CE} is increased above 0 V, the I_C increases rapidly to a saturation value almost independent of I_B (Ohmic region, OA) called knee voltage. Transistors are always operated above this knee voltage.

(ii) Cut-off region: A small collector current (I_C) exists even after the base current (I_B) is reduced to zero. This current is due to the presence of minority carriers across the collector-base junction and is called surface leakage current (I_{CEO}). This region is called as the cut-off region, because the main collector current is cut-off.

(iii) Active region: In this region, the emitter-base junction is forward biased and the collector-base junction is reverse biased. The transistor in this region can be used for voltage, current and power amplification.

(iv) Breakdown region: If the collector-emitter voltage (V_{CE}) is increased beyond the rated value given by the manufacturer,the collector current (I_C) increases enormously leading to the junction breakdown of the transistor. This avalanche breakdown can damage the transistor.

Output impedance:

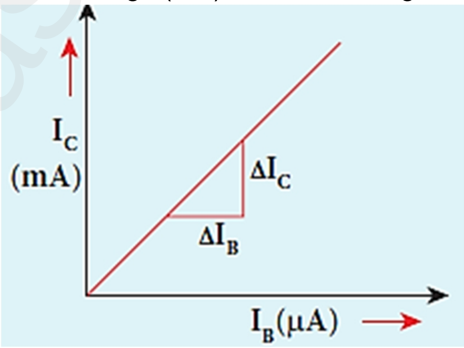
- The ratio of the change in the collector-emitter voltage (ΔV_{CE}) to the corresponding change in the collector current (ΔI_C) at constant base current (I_B) is called output impedance (r_O).

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

- The output impedance for transistor in common emitter configuration is very low.

(C) Current transfer characteristics:

- This gives the variation of collector current (I_C) with changes in base current (I_B) at constant collector-emitter voltage (V_{CE}) as shown in Figure.



- It is seen that a small I_C flows even when I_B is zero. This current is called the common emitter leakage current (I_{CEO}), which is due to the flow of minority charge carriers.

Forward current gain :

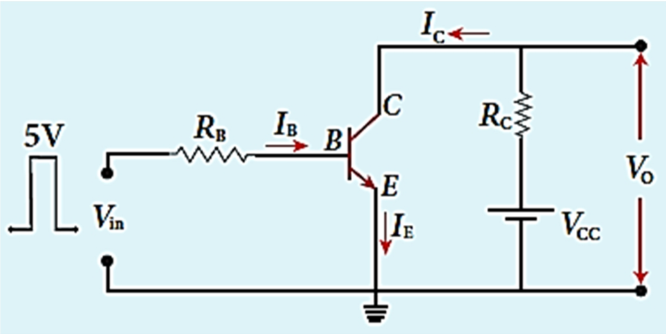
- The ratio of the change in collector current (ΔI_C) to the change in base current (ΔI_B) at constant collector-emitter voltage (V_{CE}) is called forward current gain (β).

$$\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}}$$

- Its value is very high and it generally ranges from 50 to 200.
- It depends on the construction of the transistor and will be provided by the manufacturer.
- There are transistors with β as high as 1000 as well.

11) Transistor functions as a switch. Explain.

- A transistor in saturation region acts as a closed switch while in cut-off region; it acts as an open switch.
- It functions like an electronic switch that helps to turn ON or OFF a given circuit by a small control signal which keeps the transistor either in saturation region or in cut-off region. The circuit is shown in Figure



(a) When the input is low:

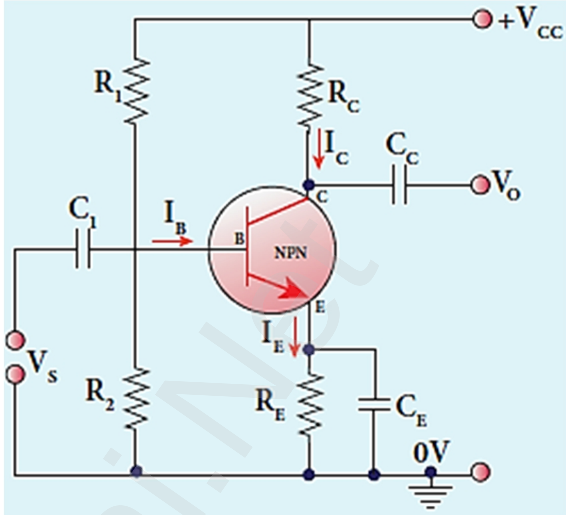
- When the input is low (say 0V), the base current is zero and transistor is not properly forward biased. It is in cut off region.
- As a result, the collector current is zero and correspondingly the voltage drop across R_C also becomes nearly zero.
- The output voltage is high and is equal to V_{CC}.
- It means that there is no current flows through the transistor and it is said to be switched off. The transistor acts as an open switch.

(b) When the input is high:

- When the input voltage is increased to a certain high value (say +5 V), the base current (I_B) increases and in turn increases the collector current to its maximum. The transistor will move into the saturation region.
- The increase in collector current (I_C) increases the voltage drop across R_C, thereby lowering the output voltage, close to zero ($\because$ $V_0 = V_{CC} - I_C R_C$).
- It means that maximum current flows through the transistor and it is said to be switched on. The transistor acts as a closed switch.
- It is manifested that a high input to the transistor gives a low output and a low input gives a high output.
- In addition, we can say that the output voltage is opposite to the applied input voltage.
- Therefore, a transistor can be used as an inverter (NOT gate) in computer logic circuitry.

12) Describe the function of a transistor as an amplifier with the neat circuit diagram. Sketch the input and output wave form.

- A single stage transistor amplifier as shown in Figure.



- Single stage indicates that the circuit consists of one transistor with the allied components.
- An NPN transistor is connected in the common emitter configuration.
- To start with, the Q point or the operating point of the transistor is fixed so as to get the maximum signal swing at the output (neither towards saturation point nor towards cutoff).
- A load resistance, R_C is connected in series with the collector circuit to measure the output voltage.
- The capacitor C_1 allows only the ac signal to pass through.
- The emitter bypass capacitor C_E provides a low reactance path to the amplified ac signal.
- The coupling capacitor C_C is used to couple one stage of the amplifier with the next stage while constructing multistage amplifiers.
- V_S is the sinusoidal input signal source applied across the base-emitter.
- The output is taken across the collector-emitter.

$$Collector\ current,\ \ I_C = \beta\, I_B \qquad \left[\because \beta = \frac{I_C}{I_B}\right]$$

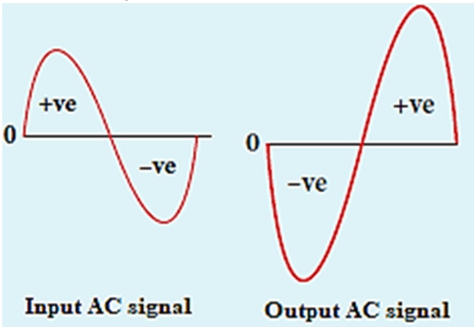
- Applying Kirchhoff 's voltage law in the output loop, the collector-emitter voltage is given by,

$$V_{CE} = V_{CC} - I_C\, R_C$$

Working of the amplifier:

(a) During the positive half cycle:

- Input signal (V_s) increases the forward voltage across the emitter-base.
- As a result, the base current (I_B) increases. Consequently, the collector current (I_C) increases β times.
- This increases the voltage drop across R_C (I_C R_c) which in turn decreases the collector-emitter voltage (V_{CE}) .
- Therefore, the input signal in the positive direction produces an amplified signal in the negative தன்irection at the output.
- Hence, the output signal is reversed by 180^0 as shown in Figure below.

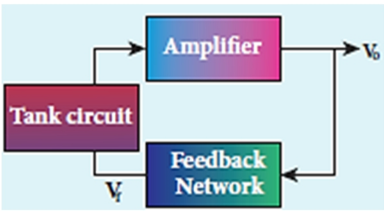


(b) During the negative half cycle:

- Input signal (V_s) decreases the forward voltage across the emitter-base.
- As a result, base current (I_B) decreases and in turn increases the collector current (I_C).
- The increase in collector current (I_C) decreases the potential drop across R_C and increases the collector-emitter voltage (V_{CE}).
- Thus, the input signal in the negative direction produces an amplified signal in the positive direction at the output.
- Therefore, 180^0 phase reversal is observed during the negative half cycle of the input signal as well as shown in Figure above.

13) Transistor functions as an oscillator. Explain.

- An oscillator circuit consists of a tank circuit, an amplifier and a feedback circuit as shown in Figure.



- The tank circuit generates electrical oscillations and acts as the ac input source to the transistor amplifier. Amplifier amplifies the input ac signal.
- The feedback circuit provides a portion of the output to the tank circuit to sustain the oscillations without energy loss.
- Hence, an oscillator does not require an external input signal. The output is said to be self-sustained.

(a) Amplifier:

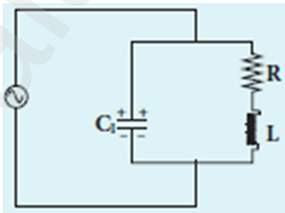
- The transistor amplifier circuit is amplifies the input signal.

(b) Feedback network:

- The circuit used to feedback a portion of the output to the input is called the feedback network.
- If the portion of the output fed to the input is in phase with the input, then the magnitude of the input signal increases. It is necessary for sustained oscillations.

(c) Tank circuit :

- The LC tank circuit consists of an inductance and a capacitor connected in parallel. as shown in Figure.



- Whenever energy is supplied to the tank circuit from a DC source, the energy is stored in inductor and capacitor alternatively.
- This produces electrical oscillations of definite frequency.
- But in practical oscillator circuits there will be loss of energy across resistors, inductor coils and capacitors.
- A small amount of energy is used up in overcoming these losses during every cycle of charging and discharging of the capacitor.
- Due to this, the amplitude of the oscillations decreases gradually.
- Hence, the tank circuit produces damped electrical oscillations.
- Therefore, in order to produce undamped oscillations, a positive feedback is provided from the output circuit to the input circuit.
- The frequency of oscillations is determined by the values of L and C using the equation.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

14.State Boolean laws. Elucidate how they are used to simplify Boolean expressions with suitable example.

(a) Complement law:

A	$Y=\overline{A}$
0	$Y=\overline{0}=1$
1	$Y=\overline{1}=0$

The complement law can be realised as,

$$\overline{\overline{A}} = A$$

(b) OR laws:

A	B	Y = A+B
0	0	Y = 0+0 = 0
0	1	Y = 0+1 = 1
1	0	Y = 1+0 = 1
1	1	Y = 1+1 = 1

The OR laws can be realised as

1st law	A + 0 = A
2nd law	A + 1 = 1
3rd law	A + A = A
4th law	$A + \overline{A} = 1$

(c) AND laws:

A	B	Y = A.B
0	0	Y = 0.0 = 0
0	1	Y = 0.1 = 0
1	0	Y = 1.0 = 0
1	1	Y = 1.1 = 1

The AND laws can be realised as

1st law	A . 0 = 0
2nd law	A . 1 = A
3rd law	A . A = A
4th law	$A . \overline{A} = 0$

(d) Commutative laws:

$$A + B = B + A$$
$$A \cdot B = B \cdot A$$

(e) Associative laws:

$$A + (B + C) = (A + B) + C$$
$$A \cdot (B \cdot C) = (A \cdot B) \cdot C$$

(f) Distributive laws:

$$A(B + C) = AB + AC$$
$$A + BC = (A + B) + (A + C)$$

Elucidation with an example:

- Simplify the Boolean identity,

$$AC + ABC = AC$$

- Solution:

$$\textbf{Step 1}: AC(1 + B) = AC.1 \quad [\textbf{OR law} - \textbf{2}]$$

$$\textbf{Step 2}: AC.1 = AC \quad [\textbf{AND law} - \textbf{2}]$$

$$Therefore, \quad AC + ABC = AC$$

15. State and proove De Morgan's theorems.

(a) First theorem:

The complement of the sum of two logical inputs is equal to the product of its complements.

$$\overline{A + B} = \overline{A} \cdot \overline{B}$$

(b) Second theorem:

The complement of the product of two inputs is equal to the sum of its complements.

$$\overline{A \cdot B} = \overline{A} + \overline{B}$$

Proof:

(a) First theorem:

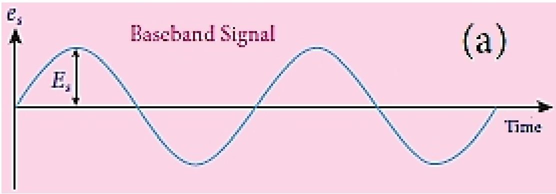
A	B	A+B	$\overline{A+B}$	$\overline{A}$	$\overline{B}$	$\overline{A}.\overline{B}$
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0

(b) Second theorem:

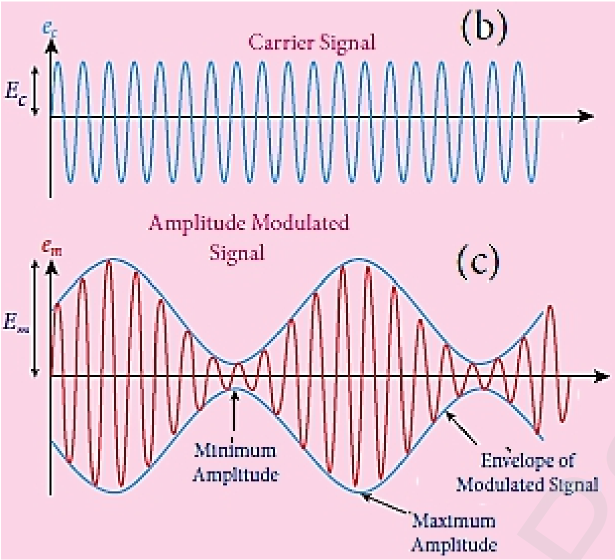
A	B	A.B	$\overline{A.B}$	$\overline{A}$	$\overline{B}$	$\overline{A}+\overline{B}$
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0

16.Explain the amplitude modulation(AM) with necessary diagrams.

- ❖ If the amplitude of the carrier signal is modified in proportion to the instantaneous amplitude of the baseband , then it is called amplitude modulation.
- ❖ Here the frequency and the phase of the carrier signal remain constant.
- ❖ Amplitude modulation is used in radio and TV broadcasting.
- ❖ The signal shown in Figure (a) is the baseband signal that carries information.



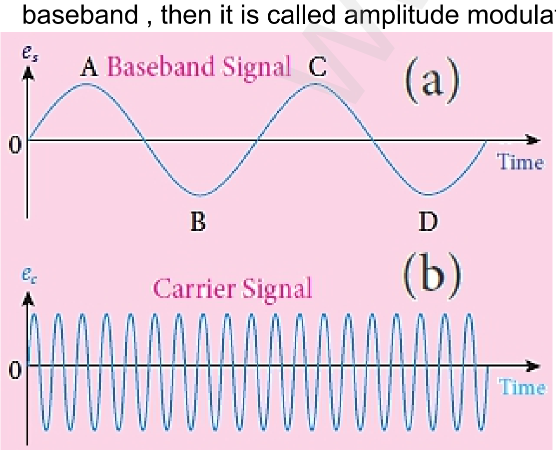
- ❖ Figure (b) shows the high-frequency carrier signal and Figure (c) gives amplitude modulated signal.



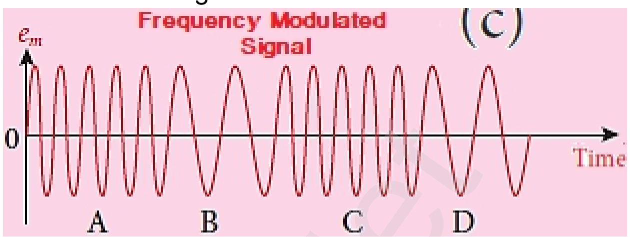
- ❖ We can see that amplitude of the carrier is modified in proportion to the amplitude of the baseband signal.

17.Explain the frequency modulation(FM) with necessary diagrams.

- ❖ If the frequency of the carrier signal is modified in proportion to the instantaneous amplitude of the baseband , then it is called amplitude modulation.



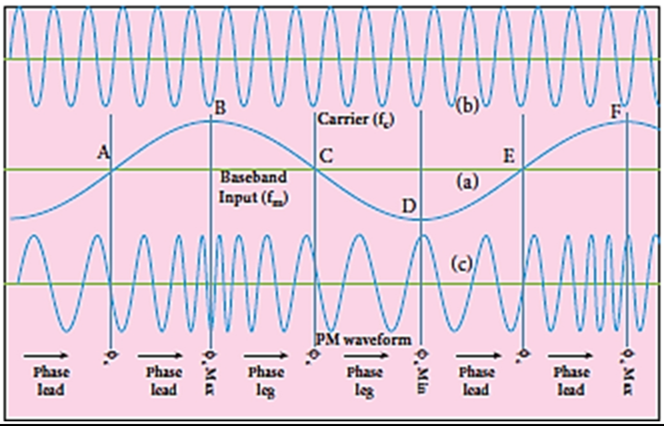
- ❖ Here the amplitude and the phase of the carrier signal remain constant.
- ❖ Increase in the amplitude of the baseband signal increases the frequency of the carrier signal and vice versa.
- ❖ This leads to compressions and rarefactions in the frequency spectrum of the modulated wave as shown in Figure.



- ❖ Louder signal leads to compressions and relatively weaker signals to rarefactions.
- ❖ When the amplitude of the baseband signal is zero in Figure (a), the frequency of the modulated signal is the same as the carrier signal.
- ❖ The frequency of the modulated wave increases when the amplitude of the baseband signal increases in the positive direction (A, C).
- ❖ The increase in amplitude in the negative half cycle (B, D) reduces the frequency of the modulated wave (Figure (c)).
- ❖ When the frequency of the baseband signal is zero (no input signal), there is no change in the frequency of the carrier wave.
- ❖ It is at its normal frequency and is called as centre frequency or resting frequency.
- ❖ Practically this is the allotted frequency of the FM transmitter.
- ❖ Internationally alloted frequency shift of broadcasting stations is 75 kHz.

18.Explain the phase modulation(PM) with necessary diagrams.

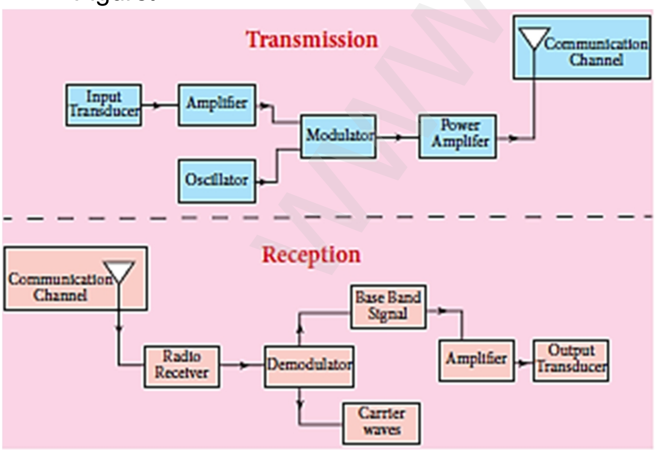
- ❖ If the phase of the carrier signal is modified in proportion to the instantaneous amplitude of the baseband , then it is called phase modulation.



- This modulation is used to generate frequency modulated signals.
- It is similar to frequency modulation except that the phase of the carrier is varied instead of varying frequency.
- The carrier phase changes according to increase or decrease in the amplitude of the baseband signal.
- When the modulating signal goes positive, the amount of phase lead increases with the amplitude of the modulating signal.
- Due to this, the carrier signal is compressed or its frequency is increased.
- On the other hand, the negative half cycle of the baseband signal produces a phase lag in the carrier signal.
- This appears to have stretched the frequency of the carrier wave.
- Hence similar to frequency modulated wave, phase modulated wave also comprises of compressions and rarefactions.
- When the signal voltage is zero (A, C and E) the carrier frequency is unchanged.
- The frequency shift in carrier wave frequency exists in phase modulation as well.
- The frequency shift depends on (i) amplitude of the modulating signal and (ii) the frequency of the signal.

19) Explain the basic elements of communication system with the necessary block diagram.

- The elements of the basic communication system are explained with the block diagram shown in Figure.



(i) Information (Baseband or input signal):

- Information can be in the form of speech, music, pictures, or computer data.
- This information is given as input to the input transducer.

(ii) Input transducer :

- A transducer is a device that converts variations in a physical quantity (pressure, temperature, sound) into an equivalent electrical signal or vice versa.
- In communication system, the transducer converts the information which is in the form of sound, music, pictures or computer data into corresponding electrical signals.
- The electrical equivalent of the original information is called the baseband signal.
- The best example for the transducer is the microphone that converts sound energy into electrical energy.

(iii) Transmitter :

- It feeds the electrical signal from the transducer to the communication channel.
- It consists of circuits such as amplifier, oscillator, modulator and power amplifier.
- The transmitter is located at the broadcasting station.
  - **Amplifier:** The transducer output is very weak and is amplified by the amplifier.
  - **Oscillator:** It generates high-frequency carrier wave (a sinusoidal wave) for long distance transmission into space. As the energy of a wave is proportional to its frequency, the carrier wave has very high energy.
  - **Modulator:** It superimposes the baseband signal onto the carrier signal and generates the modulated signal.
  - **Power amplifier:** It increases the power level of the electrical signal in order to cover a large distance.

(iv) Transmitting antenna :

- It radiates the radio signal into space in all directions.
- It travels in the form of electromagnetic waves with the velocity of light (3 ஒ 108 m s–1).

(v) Communication channel:

- Communication channel is used to carry the electrical signal from transmitter to receiver with less noise or distortion.
- The examples for communication medium are wires, cables and optical fibers in wireline communication and free space in wireless communication.

(vi) Receiver:

- The signals that are transmitted through the communication medium are received by a receiving antenna which converts em waves into RF signals and are fed into the receiver.
- The receiver consists of electronic circuits like demodulator, amplifier, detector etc.
- The demodulator extracts the baseband from the modulated signal.
- Then the baseband signal is detected and amplified using amplifiers. Finally, it is fed to the output transducer.

(vii) Repeaters:

- Repeaters are used to increase the range or distance through which the signals are sent. It is a combination of transmitter and receiver.
- The signals are received, amplified and retransmitted with a carrier signal of different frequency to the destination.
- The best example is the communication satellite in space.

(viii) Output transducer:

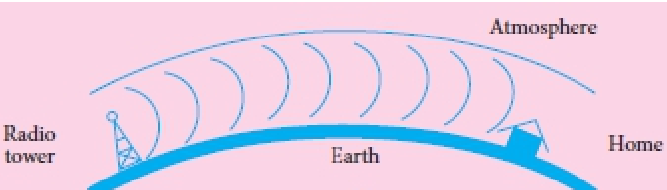
- It converts the electrical signal back to its original form such as sound, music, pictures or data.
- Examples of output transducers are loudspeakers, picture tubes, computer monitor, etc.

20) Explain the three modes of propagation of electromagnetic waves through space.

- The electromagnetic wave transmitted by the transmitter travels in three different modes to reach the receiver according to its frequency range:
  - Ground wave propagation (or) surface wave propagation. **(2 kHz to 2 MHz)**
  - Sky wave propagation (or) ionospheric propagation. **(3 MHz to 30 MHz)**
  - Space wave propagation. **(30 MHz to 400 GHz)**

(a) Ground Wave Probagation:

- If the electromagnetic waves transmitted by the transmitter glide over the surface of the earth to reach the receiver, then the propagation is called ground wave propagation.
- The pictorial representation is shown in Figure (a).

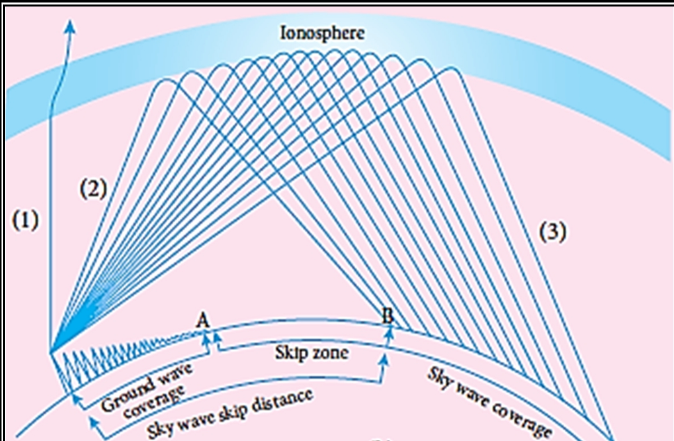


(a)

- Here both transmitting and receiving antennas must be close to the earth surface.
- It is mainly used in local broadcasting, radio navigation, for ship-to-ship, shipto- shore communication and mobile communication.

(b) Sky Wave Probagation:

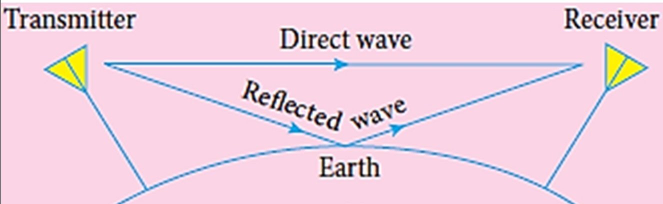
- The mode of propagation in which the electromagnetic waves radiated from an antenna, directed upwards at large angles, gets reflected by the ionosphere back to earth is called sky wave propagation or ionospheric propagation. The corresponding waves are called sky waves.
- Ionosphere acts as a reflecting surface. It is at a distance of approximately 50 km and spreads up to 400 km above the Earth surface.
- Due to the absorption of ultraviolet rays, cosmic ray, and other high energy radiations like α, β rays from sun, the air molecules in the ionosphere get ionized.
- This produces charged ions and these ions provide a reflecting medium for the reflection of radio waves or communication waves back to Earth within the permitted frequency range.
- The phenomenon of bending the radio waves back to earth is nothing but the total internal reflection.
- When the angle of incidence at the ionosphere is large, the sky wave returns to the ground at a long distance from the transmitter.
- As this angle is reduced, the wave returns closer and closer to the transmitter.
- If the angle of incidence is reduced further, the radio waves penetrate through the ionosphere.
- For a particular angle of incidence, the point of reception (B) is at the minimum distance from transmitter.
- The shortest distance between the transmitter and the point of reception of the sky wave along the surface is called as the skip distance.
- The ground waves get attenuated as they move away from the transmitter.
- At a particular point (A), there is no reception ground wave.
- The zone (in between A and B) where there is no reception of electromagnetic waves neither ground nor sky is known as skip zone or skip area



(b)

(c) Space Wave Probagation:

- The process of sending and receiving information signal through space is called space wave communication (Figure (c)).

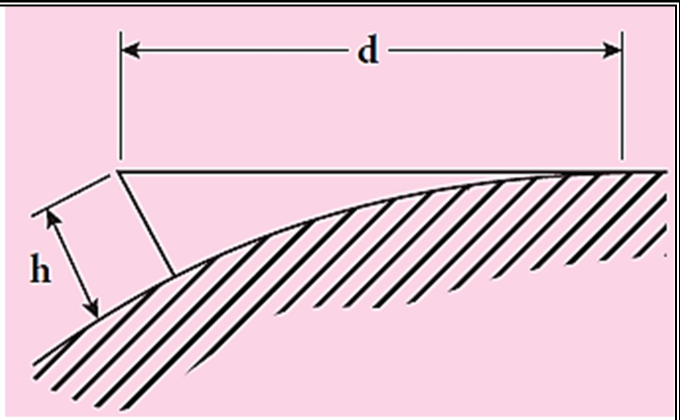


(c)

- The electromagnetic waves of very high frequencies above 30 MHz are called as space waves.
- These waves travel in a straight line from the transmitter to the receiver. Hence, it is used for a line of sight communication (LOS).
- The communication systems like television telecast, satellite communication and RADAR are based on space wave propagation.
- Microwaves having high frequencies (super high frequency band) are used against radio waves due to certain advantages:
  - Larger bandwidth,
  - High data rates,
  - Better directivity,
  - Small antenna size,
  - Low power consumption, etc.
- The range or distance (d) of coverage of the propagation depends on the height (h) of the antenna given by the equation,

$$d = \sqrt{2Rh}$$

  Where R is the radius of the Earth and it is 6400 km.
- The distance of coverage is shown pictorially in Figure below.



21) Fiber optic communication is gaining popularity among the various transmission media -justify.

- Fiber optic cables provide the fastest transmission rate compared to any other form of transmission.
- It can provide data speed of 1 Gbps for homes and business.
- Multimode fibers operate at the speed of 10 Mbps.
- Recent developments in optical communication provide the data speed at the rate of 25 Gbps.
- Fiber cables are very thin and weigh lesser than copper cables.
- This system has much larger band width. This means that its information carrying capacity is larger.
- Fiber optic system is immune to electrical interferences.
- Fiber optic cables are cheaper than copper cables.
- Hence, Fiber optic communication is gaining popularity among the various transmission media.

11. Recent Developments In Physics

1. What is Nanoscience?

Nanoscience is the study of structures and materials on the scale of nanometers(10^{-9} m).

2. What is Nanotechnology?

Nanotechnology is a technology involving the design, production, characterization and applications of nano structured materials.

3. What is Nanoparticles or nano solid?

If the particles of solid is of size less than 100nm, it is called nanoparticles or nano solid.

4. What is bulk solid?

If the particle size is greater than 100nm, it is called bulk solid.

5. What are the two important phenomena which govern nano properties?

- Quantum confinement effects.
- Surface effects.

6. What are the fields involving nanotechnology?

- Electrical and mechanical engineering.
- Material science.
- Molecular biology.
- Applied mathematics and computer science.
- Physics
- Chemistry.

7. What are the two approaches in synthesis of nanoparticles?

- Top down approach.
- Bottom up approach.

8. How nanomaterials are synthesised in top down approach? Give some examples.

In this approach, nanomaterials are synthesised by breaking down bulk solids into nano sizes.

Ex: Ball milling, Sol-gel, Lithography.

9. How nanomaterials are synthesised in bottom up approach? Give some examples.

In this approach, nanomaterials are synthesised by asembling the atoms or molecules together.

Ex: Plasma etching, Chemical vapour deposition.

10. What are applications of nanomaterial in automotive industry?

- Lightweight construction.
- Painting(fillers, base coat, clear coat).
- Catalysts.
- Tires (fillers).
- Sensors.
- Coatings for wind-screen and car bodies.

11. What are applications of nanomaterial in chemical industry?

- Fillers for paint systems.
- Coating systems based on nanocomposites.
- Impregnation of papers.
- Switchable adhesives.
- Magnetic fluids.

12. What are applications of nanomaterial in engineering?

- Wear protection for tools and machines(anti blocking coatings, scratch resistant coatings on plastic parts,etc.)
- Lubricant-free bearings.

13. What are applications of nanomaterial in electronic industry?

- Data memory.
- Displays.
- Laser diodes.
- Glass fibres.
- Optical switches.
- Filters (IR-blocking)
- Conductive, antistatic coatings.

14. What are applications of nanomaterial in construction?

- Construction materials.
- Thermal insulation.
- Flame-retardants.
- Surface-functionalised building materials for wood, floors, stone, facades, tiles, roof tiles, etc.
- Facade coatings.
- Groove mortar.

15. What are applications of nanomaterial in medicine?

- Drug delivery systems.
- Active agents.
- Contrast medium.
- Medical rapid tests.
- Prostheses and implants.
- Antimicrobial agents and coatings.
- Agents in cancer therapy.

16. What are applications of nanomaterial in textile and fabrics and non-wovens?

- Surface-processed textiles.
- Smart clothes.

17. What are applications of nanomaterial in energy?
- ❖ Fuel cells.
- ❖ Solar cells.
- ❖ Batteries.
- ❖ Capacitors.

18. What are applications of nanomaterial in Cosmetics?
- ❖ Sun protection.
- ❖ Lipsticks.
- ❖ Skin cream.
- ❖ Tooth paste.

19. What are applications of nanomaterial in food and drinks?
- ❖ Package materials.
- ❖ Storage life sensors.
- ❖ Additives.
- ❖ Clarification of fruit juices.

20. What are applications of nanomaterial in household?
- ❖ Ceramic coatings for irons.
- ❖ Odors catalyst.
- ❖ Cleaner for glass, ceramic, floor , windows.

21. What are applications of nanomaterial in sports and outdoor?
- ❖ Ski wax.
- ❖ Antifogging of glasses and goggles.
- ❖ Antifouling coatings for ships and boats.
- ❖ Reinforced tennis rackets and balls.

22. What is robotics?

Robotics is an integrated study of mechanical engineering, electronic engineering, computer engineering, and science.

23. What is robot?

Robot is a mechanical device designed with electronic circuitry and programmed to perform a specific task.

24. What are fields in which robotics involved?
- ❖ Security.
- ❖ Services.
- ❖ Logistics.
- ❖ Manufacture and automation macro.
- ❖ Manufacture and automation micro and nano.
- ❖ Medical surgery.
- ❖ Rehabilitate orthotics prosthetics.
- ❖ Unmanned vehicles.
- ❖ Intelligent transportation.
- ❖ Monitoring inspection.

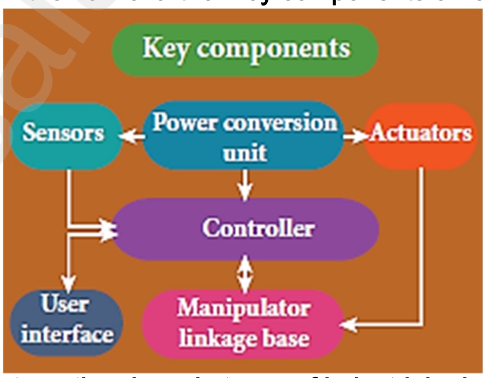
25. What are the components of robotic system?

The robotic system mainly consists of sensors, power supplies, control systems, manipulators and necessary software.

26. What are the three main parts of robots?
- ❖ **The Controller** - also known as the "brain" which is run by a computer program. It gives commands for the moving parts to perform the job.
- ❖ **Mechanical parts** - motors, pistons, grippers, wheels, and gears that make the robot move, grab, turn, and lift.
- ❖ **Sensors** - to tell the robot about its surroundings. It helps to determine the sizes and shapes of the objects around, distance between the objects, and directions as well.

27. What are the types of robots?
- ❖ **HUMAN ROBOTS -** Certain robots are made to resemble humans in appearance and replicate the human activities like walking, lifting, and sensing, etc.
- ❖ **INDUSTRIAL ROBOTS** – Certain robots are made for industrial purpose.

28. Draw the flow chart for key components of robotics.



29. What are the six main types of industrial robots?
- ❖ Cartesian
- ❖ SCARA - Selective Compliance Assembly Robot Arm.
- ❖ Cylindrical.
- ❖ Delta.
- ❖ Polar.
- ❖ Vertically articulated.

30. What are the purposes six-axis robots are used?
- ❖ Arc welding.
- ❖ Spot welding.
- ❖ Material handling.
- ❖ Machine tending.
- ❖ Other applications.

31. What is artificial intelligence(AI)?

Artificial intelligence is a technology which brings human like behavior in robots.

32. What are the functions of artificial intelligence?
- ❖ Face recognition.
- ❖ Providing response to player's actions in computer games

- Taking decisions based on previous actions
- To regulate the trafic by analyzing the density of trafic on roads.
- Translate words from one language to another.

33. What are the applications of robotics?

- **Outer space:** Exploring stars, planets etc., investigation of the mineralogy of the rocks and soils on Mars, analysis of elements found in rocks and soils.
- **Other applications:** Little robot, welding, cutting, assembling, vacuum cleaner, packing, transport, surgery, weaponry, lawn mowing, laboratory, underwater, hospitals, agriculture, pool cleaning.
- **Nano robots:** perform small surgical procedures through blood stream, fight against bacteria, repairing cell in the body, autonomous DNA robots to combat cancer tumours.

34. What are the materials used to make robots?

Aluminium and steel are commonly used to make robots in the form of sheet, bar, rod, channel and other shapes.

35. Why steel is preferred in making Robots?

Robots are used for doing hardworks which is not possible by normal human. Due to this reason, long living very strong steel is preferred in making Robots.

36. What is particle physics?

Particle physics deals with the theory of fundamental particles of nature.

37. What are sub atomic particles?

Particles that are smaller than the atom are called subatomic particles. The three main subatomic particles are protons, neutrons and electrons.

38. What is cosmology?

Cosmology is the branch that involves the origin and evolution of the universe. It deals with formation of stars, galaxy etc.

39. What are gravitational waves?

Gravitational waves are the disturbances in the curvature of space-time and it travels with speed of light. Any accelerated mass emits gravitational waves.

40. Write a short note on black hole.

- Black holes are end stage of stars which are highly dense massive object.
- Its mass ranges from 20 times mass of the sun to 1 million times mass of the sun. It has very strong gravitational force such that no particle or even light can escape from it.
- The existence of black holes is studied when the stars orbiting the black hole behave differently from the other stars.
- Every galaxy has black hole at its center. Sagittarius A* is the black hole at the center of the Milky Way galaxy.

5 Marks Q & A:

1. **Tabulate the Nano objects in nature and their corresponding mimic in laboratories.**

Object	Nano action	Mimic in Laboratory
Single strand of DNA	It is 3nm wide and is building block of all living things.	-
Morpho butterfly	Nanostructure in wings makes interaction of light waves and produces brilliant metallic blue and green hues in the wings.	Manipulation of colours by adjusting the size of nano particles of the material.
Peacock feathers	10nm photonic crystal interacts with light and gives iridescent coloration in feathers.	Nanostructures are made to glow in different colours.
Parrot fish	Nanostructured flurapatite chain mail-like interwoven fibre crystal gives incredible durability to teeth. So that it crunches up coral all day.	Nano structured ultra-durable synthetic materials are useful for mechanical components in electronics and in other devices which undergo repitative movement,abrasion and contact stress.
Lotus leaf surface	Nanostructure on the surface is the reason for self cleaning process in lotus leaf.	Water repellant paints are made to give durability, stain and dust protection and also give fuel efficiency in ships.

2. **Explain the key components of robotics.**
   - **Power conversion unit:** Robots are powered by batteries, solar power, and hydraulics.
   - **Actuators:** Converts energy into movement. The majority of the actuators produce rotational or linear motion.
   - **Electric motors:** ey are used to actuate the parts of the robots like wheels, arms, fingers, legs, sensors, camera, weapon systems etc. Different types of electric motors are used. The most often used ones are AC motor, Brushed DC motor, Brushless DC motor, Geared DC motor, etc.
   - **Pneumatic Air Muscles:** They are devices that can contract and expand when air is pumped inside. It can replicate the function of a human muscle. They contract almost 40% when the air is sucked inside them.
   - **Muscle wires:** They are thin strands of wire made of shape memory alloys. They can contract by 5% when electric current is passed through them.
   - **Piezo Motors and Ultrasonic Motors:** Basically, we use it for industrial robots.
   - **Sensors:** Generally used in task environments as it provides information of real-time knowledge.
   - **Robot locomotion:** Provides the types of movements to a robot. The different types are
     (a) Legged.
     (b) Wheeled.
     (c)Combination of Legged and Wheeled Locomotion.
     (d) Tracked slip and skid.

3. **What are the advantages of robotics?**
   - The robots are much cheaper than humans.
   - Robots never get tired like humans. It can work for 24 x 7. Hence, absenteeism in work place can be reduced.
   - Robots are more precise and error free in performing the task.
   - Stronger and faster than humans.
   - Robots can work in extreme environmental conditions: extreme hot or cold, space or underwater. In dangerous situations like bomb detection and bomb deactivation.
   - In warfare, robots can save human lives.
   - Robots are significantly used in handling materials in chemical industries especially in nuclear plants, which can lead to health hazards in humans.

4. **What are the disadvantages of robotics?**
   - Robots have no sense of emotions or conscience.
   - They lack empathy and hence create an emotionless workplace.
   - If ultimately, robots would do all the work, and the humans will just sit and monitor them, health hazards will increase rapidly.
   - Unemployment problem will increase.
   - Robots can perform defined tasks and cannot handle unexpected situations
   - The robots are well programmed to do a job and if a small thing goes wrong it ends up in a big loss to the company.
   - If a robot malfunctions, it takes time to identify the problem, rectify it, and even reprogram if necessary.
   - This process requires significant time.
   - Humans cannot be replaced by robots in decision making.
   - Till the robot reaches the level of human intelligence, the humans in work place will exit.

5. **Explain the recent advancements in medical technology?**

(a)Virtual reality:

- It is used to stop the brain from processing pain and cure soreness in the hospitalized patients.
- Virtual reality has enhanced surgeries by the use of 3D models by surgeons to plan operations.
- It helps in the treatment of Autism, Memory loss, and Mental illness.

(b)Precision medine :

- Precision medicine is an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment, and lifestyle for each person.
- In this medical model it is possible to customise healthcare, with medical decisions, treatments, practices, or products which are tailored to the individual patient.

(c)Health wearables:

- A health wearable is a device used for tracking a wearer's vital signs or health and fitness related data, location, etc.
- Medical wearables with articial intelligence and big data provide an added value to healthcare with a focus on diagnosis, treatment, patient monitoring and prevention.

(d)Artificial organs:

- An articial organ is an engineered device or tissue that is implanted or integrated into a human. It is possible to interface it with living tissue or to replace a natural organ.
- It duplicates or augments a specific function or functions of human organs so that the patient may return to a normal life as soon as possible.

(e)3D printing:

- Advanced 3D printer systems and materials assist physicians in a range of operations in the medical field from audiology, dentistry, orthopedics and other applications.

(f)Wireless brain sensors:

- Wireless brain sensors monitor intracranial pressure and temperature and then are absorbed by the body.
- Hence there is no need for surgery to remove these devices.

(g)Robotic surgery:

- Robotic surgery is a type of surgical procedure that is done using robotic systems.
- Robotically-assisted surgery helps to overcome the limitations of pre-existing minimally-invasive surgical procedures and to enhance the capabilities of surgeons performing open surgery.

(h)Smart inhalers:

- Inhalers are the main treatment option for asthma.
- Smart inhalers are designed with health systems and patients in mind so that they can offer maximum benefit.
- Smart inhalers use bluetooth technology to detect inhaler use, remind patients when to take their medication and gather data to help guide care.