WAVE OPTICs

PHYSICS - VOL 2 | **UNIT - 7**

NAME :

STANDARD : 12 SECTION :

SCHOOL :

EXAM NO :

யாதானும் நாடாமால் ஊராமால் என்னொருவன்
சாந்துணையுங் கல்லாத வாறு

கற்றவனுக்கு எல்லா நாடும் சொந்த நாடாகும். எல்லா ஊரும் சொந்த ஊராகும். இதனை தெரிந்தும் ஒருவன் இறக்கும் வரை கூடப் படிக்காமல் இருப்பது ஏனோ ?

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2 & 3 mark questions and answers

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

<u>**Corpuscular theory**</u> :

- ***Sir Isaac Newton*** proposed corpuscular theory of light.
- According this theory, light is emitted as tiny, massless 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.
- They travel with high speed and they are unaffected by the force of gravity. So their path is a straight line.
- The energy of light is the kinetic energy of these corpuscles.
- When they 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.
- The reflection of light is due to repulsion of the corpuscles by the medium and refraction of light is due to the attraction of the courpuscles by the medium.
- This theory could not explain, why speed of light is lesser in denser medium than rarer medium and also interference, diffraction and polarization.

2. Write a note on wave theory of light.

<u>**Wave theory of light**</u> :

- ***Christian Huygens*** proposed the wave theory of light.
- According to wave theory, light is a disturbance from a source that travels as longitudinal mechanical wave through the ether medium that was presumed to pervade in all space.
- This theory could successfully explain reflection, refraction, interference, and diffraction.
- But polarization could not explain by this theory as it is the property of only transverse waves.
- Later the existence of ether in all space was proved to be wrong.

3. Write a note on electromagnetic wave theory .

<u>**Electromagnetic wave theory of light**</u> :

- ***Maxwell*** proposed electromagnetic theory of light.
- According to electromagnetic wave 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 electromagnetic theory.
- But the interaction of light with matter like photoelectric effect, Compton effect could not be explained by this theory.

4. Write a short note on quantum theory of light.

<u>**Quantum theory of light**</u> :

- By extending Max Plank quantum ideas, ***Albert Einstein*** proposed quantum theory of light.
- According to quantum theory, light is not continuous but it propagated in the form of discrete packets of energy called ***photon***.
- Each photon has energy 'E' of

$$E = h\nu$$

Here $h \rightarrow$Plank's constant($h = 6.625 X\ 10^{-34}\ Js$)

5. What is Dual nature of light ?

- A light has both wave as well as particle nature and hence it is said to have dual nature.
  (1) Light propagated as a waves
  (2) Light interacts with matter as a particle

6. Write a note on wave nature of light.

<u>**Wave nature of light**</u> :

- Light is transverse electromagnetic wave.
- The wave nature of light was confirmed by the experiments on interference and diffraction.
- Like electromagnetic wave, light can travel through vacuum.
- The transverse nature of light was proved by polarization.

7. Define wave front.

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

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

(1) A point source located at a finite distance gives spherical wavefront.
(2) A point source located at infinite distance gives plane wavefront.
(3) A line source gives cylindrical wavefront.

9. State Huygen's principle.

<u>**Huygen's principle :**</u>

- Each point of the wavefront is the source of secondary wavelets which spreading out in all directions with speed of the wave.
- The envelope to all this wavelets gives the position and shape of the new wavefront at a later time.

10. Define interference.

- The phenomenon of 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.

11. What is phase of a wave?

- Phase is the angular position of a vibration.

12. Give the relation between phase difference and path difference.

- In the path of the wave, one wavelength λ corresponds to a phase of 2π
- Hence the path difference δ corresponds to a phase difference ϕ is

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

13. Whar are called 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, same waveform and preferably same amplitude.

14. Can two independent monochromatic sources acts as coherent sources?

- Two independent monochromatic sources never be coherent, because they may emit waves of same frequency and same amplitude, but not with same phase.
- Due to thermal vibrations, the atoms while emitting light undergoes this change in phase.

15. Give the methods to obtain coherent light waves.

- Coherent waves are obtained by following three techniques.
  (1) Intensity or amplitude division
  (2) Wavefront division
  (3) Source and images

16. Write a note on intensity or amplitude division.

Intensity or amplitude division :

- If light is incident on a partially silvered mirror, both reflection and refraction takes place simultaneously.
- As the two light beams are obtained from the same light source, the two divided light beams will be coherent beams.
- They will be either in-phase or at constant phase difference. (e.g.) Michelson's interferometer

17. Write a note on wavefront division.

Wavefront division :

- It is the common method used for producing two coherent sources. We know all the points on the wavefront are at the same phase.
- If two points are chosen on the wavefront by using a doubl slit, the two points will act as coherent sources. (e.g.) Young's double slit method

18. Write a note on Source and images method.

Source and images :

- 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. (e.g.) Lloyd's mirror

19. What are called constructive and destructive interference?

Constructive interference :

- During superposition of two coherent waves, the points where the crest of one wave meets the crest of other (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 as bright.
- This type of interference is said to be ***constructive interference***.

Destructive interference :

- During superposition of two coherent waves, the points where the crest of one wave meets the trough of other (or) vice versa, the waves are ***out-of-phase***.
- Hence the displacement is minimum and these points appear as dark.
- This type of interference is said to be ***destructive interference***.

20. What is bandwidth of interference pattern?

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

21. What are the conditions for obtaining clear and broad interference bands?

(1) The screen should be as far away from the source as possible.
(2) The wavelength of light used must be larger.
(3) Two coherent sources must be as close as possible

22. Brilliant colours are exhibited by the surface of oil films and soap bubbles. Why?

- The colours exhibited by the surface of oil films and soap bubbles are due to ***interference of white light*** undergoing multiple reflections from the top and bottom surfaces of thin films.
- The colourd depends upon,
  (1) thickness of the film
  (2) refractive index of the film
  (3) angle of incidence of the light

23. What is diffraction?

- Diffraction is bending of waves around sharp edges into the geometrically shadowed region.
- We observe diffraction only when the size of the obstacle is comparable to the wavelength

24. Distinguish between interference and diffraction.

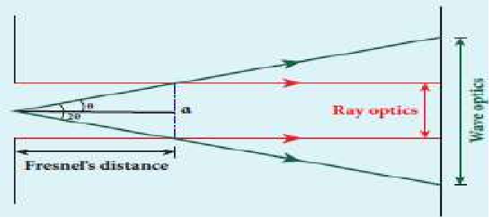
Interference	Diffraction
Superposition of two waves	Bending of waves around the edges
Superposition of waves from two coherent sources	Superposition of wavefronts emitted from various points of the same wavefront
Equally spaced fringes	Unequally spaced fringes
Intensity of all the bright fringes is almost same	Intensity falls rapidly for higher orders
Large number of fringes are obtained	Less number of fringes are obtained.

25. What is Fresnel's distance? Obtain an expression for it.

Fresnel's distance:

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

Expression :



- Let Fresnel distance = z
- From the diffraction equation for first minimum,

$$\sin\theta = \frac{\lambda}{a} \qquad (or) \qquad \theta = \frac{\lambda}{a}$$

- From the definition of Fresnel's distance,

$$\sin 2\theta = \frac{a}{z} \qquad (or) \qquad 2\theta = \frac{a}{z}$$

- Equating the above two equantion,

$$2\,\frac{\lambda}{a} = \frac{a}{z}$$

$$\boldsymbol{z = \frac{a^2}{2\,\lambda}}$$

26. What are resolution and resolving power?

- Two point sources must be imaged in such a way that their images are sufficiently far apart that their diffraction pattersn do not overlap. This is called ***resolution***.
- The inverse of resolution is called resolving power. The ability of an optical instrument to separate or distinguish small or closely adjacent objects through the image formation is said to be ***resolving power*** of the instrument.

27. What is Rayleigh's criterion?

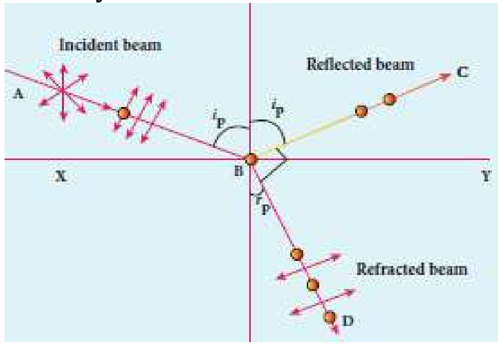
- According to Rayleigh's criterion, for tow point objects to be just resolved, the minimum distance between their diffraction images must be in such a way that the central maximum of one coincides with the first minimum of the other and vice versa.
- The Rayleigh's criterion is said to be limit of resolution.

28. Defined angle of polarization.

- The angle of incidence at which the reflected beam is plane polarized is called polarizing angle or Brewste's angle (i_P)
- The polarizing angle for glass is ; $\boldsymbol{i_P = 57.5°}$

29. Explain polarization by reflection.

Polarization by reflection :

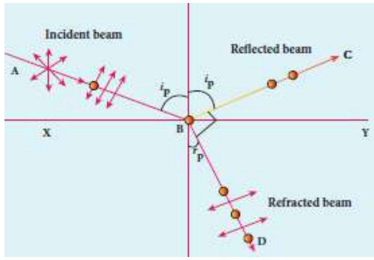


- It is the simplest method to produce plane polarized light.
- It is discovered by ***Malus.***
- Here, XY - reflecting surface
  AB - incident unpolarized light beam
  BC - reflecting light beam
  BD - refracted light beam
- On examining the reflected beam 'BC' with an analyser, it is found that the ray is is partially plane polarized.
- When the light is allowed to be incident on particular angle, the reflected beam is found to be plane polarized. That angle of incidence is called ***polarizing angle*** ($\boldsymbol{i_P}$)

30. State and prove Brewster's law

Brewste' s law :

- The angle of incidence at which a beam of unpolarized light falling on a transparent surface is reflected as a beam of plane polarized light is called polarizing angle or Brewster's angle (i_P)
- ***Sir David Brewster*** found that, at polarizing angle, the reflected and transmitted rays are perpendicular to each other.
- Let, incident polarizing angle $= i_P$
  Angle of refraction $= r$



- From the figure,

$$i_P + 90° + r_P = 180°$$

$$\boldsymbol{r_P = 90° - i_P} \quad ----(1)$$

- From Snell's law

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

$$\frac{\sin i_P}{\sin(90° - i_P)} = n$$

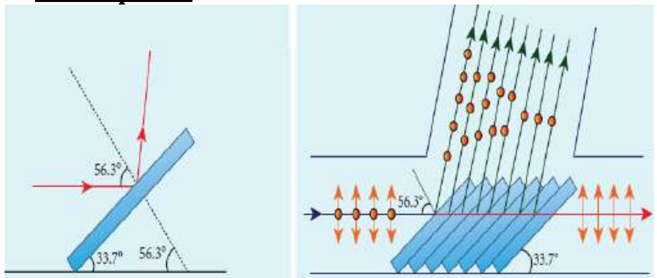
$$\frac{\sin i_P}{\cos i_P} = n$$

$$\boldsymbol{\tan i_P = n}$$

- This relation is known as Brewster's law.
- This law states that, ***the tangent of the polarizing angle for a transparent medium is equal to its refractive index.***

31. Write a note on pile of plates.

Pile of plates :



- It work on the principle of polarization by reflection.
- It consists of a number of glass plates placed one over the other in a tube.
- These plates are inclined at an angle $\boldsymbol{33.7°}$ to the axis of the tube.
- A beam of unpolarized 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 $\boldsymbol{56.3°}$**,** which is the polarizing 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 the intensity of the reflected plane polarized light.
- The pile of plates is used as a polrizer and also as an analyser.

32. Distinguish between near point focusing and normal focusing.

Near point focusing	Normal focusing
The image is formed at near point	The image is formed at infinity
In this position, the eye feel little strain	In this position, the eye is most relaxed to view the image
Magnification is high $\boldsymbol{m = 1 + \frac{D}{f}}$	Magnification is low $\boldsymbol{m = \frac{D}{f}}$

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

- 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 $\left(d_{min} = \frac{1.22\,\lambda}{2\sin\beta}\right)$
- That is, smaller the value of $'d_{min}'$ better will be the resolving power of the microscope.
- 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 containg oil of refractive index 'n'. $i.e.$ $\left(d_{min} = \frac{1.22\,\lambda}{2\,n\sin\beta}\right)$
- Such an objective is called ***oil immersed objective.***
- The term '$\boldsymbol{n\sin\beta}$' is called ***numerical aperture (NA)***

34. What are the merits and demerits of reflecting telescope?

Merits :

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

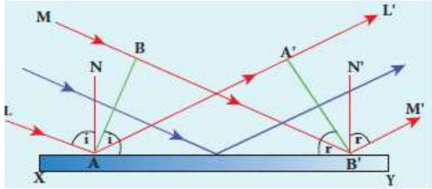
Demerits :

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

5 - Mark Question & Answer

1. Prove laws of reflection using Huygens principle.

Laws of reflection - Proof :



- XY – Reflecting surface
- AB –Incident plane wavefront.
- The incident rays from L and M are perpendicular to this incident wavefront.
- Initially the point 'A' reaches reflecting surface.
- Then the successive points between AB reaches the surface.
- Finally, by the time B reaches B^1, the point A would have reached A^1
- This is applicable to all the points on the wavefront AB. Thus the reflected wavefront A^1B^1 emanates as a plane wavefront.
- The line from L^1 *and* M^1 perpendiculars to A^1B^1 represent reflected rays.
- .As the reflection happens in the same medium, the speed of light is same before and after reflection. Hence, $AA^1 = BB^1$

Law (1) :

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

Law (2) :

- Angle of incidence,

$$\angle i = \angle NAL = 90° - \angle NAB = \angle BAB^1$$

- Angle of reflection,

$$\angle r = \angle N^1B^1M^1 = 90° - \angle N^1B^1A^1 = \angle A^1B^1A$$

- In ΔABB^1 and ΔB^1A^1A,

$$\angle B = \angle A^1 = 90°$$

$$AA^1 = BB^1 \text{ and}$$

hypotenuse AB^1 *is common*

- Thus the two triangles are congruent. (i.e)

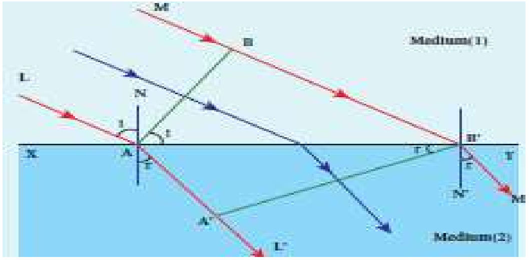
$$\angle BAB^1 = \angle A^1B^1A$$

$$\therefore \quad \boldsymbol{\angle i = \angle r}$$

- Hence laws of reflection are proved.

2. Prove laws of refraction using Huygen' principle.

Laws of refraction - Proof :



- Let XY be the refracting surface .
- The incident wavefront AB is in rarer medium (1)
- The incident rays from L and M are perpendicular to this incident wavefront.
- Initially the point 'A' reaches refracting surface.
- Then the successive points between AB reaches the surface.
- Finally, by the time B reaches B^1, the point A would have reached A^1 in the other medium.
- This is applicable to all the points on the wavefront AB. Thus the refracted wavefront A^1B^1 emanates as a plane wavefront.
- The line from L^1 *and* M^1 perpendiculars to A^1B^1 represent refracted rays.
- Let v_1 be the speed of light in medium (1) and v_2 be the speed of light in medium (2). Here $v_1 > v_2$
- The time taken for the ray to travel from B to $B^1$is same as the time taken for the ray to travel from A reaches A^1 . So $AA^1 = v_2\, t$ and $BB^1 = v_1\, t$

$$\therefore \quad \frac{BB^1}{AA^1} = \frac{v_1}{v_2} \qquad ------ \quad (1)$$

Law (1) :

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

Law (2) :

- Angle of incidence,

$$\angle i = \angle NAL = 90° - \angle NAB = \angle BAB^1$$

- Angle of refraction,

$$\angle r = \angle N^1B^1M^1 = 90° - \angle N^1B^1A^1 = \angle A^1B^1A$$

- From ΔABB^1 and ΔB^1A^1A ,

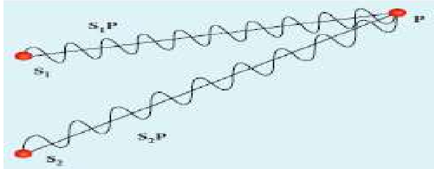
$$\frac{\sin i}{\sin r} = \frac{\left(\frac{BB^1}{AB^1}\right)}{\left(\frac{AA^1}{AB^1}\right)} = \frac{BB^1}{AA^1} = \frac{v_1}{v_2} = \frac{\left(\frac{c}{n_1}\right)}{\left(\frac{c}{n_2}\right)} = \frac{n_2}{n_1}$$

- In product form,

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

3. Obtain the equation for resultant intensity due to interference of light.

Resultant intensity due to interference :



- Let S_1 and S_2 are the two light waves meeting at a point 'P'
- At any instant 't', the displacement equations,

$$y_1 = a_1 \sin \omega t \qquad ---- \quad (1)$$

$$y_2 = a_2 \sin (\omega t + \phi) \qquad ---- \quad (2)$$

where, ϕ → phase difference between them

- Then the resultant displacement,

$$y = y_1 + y_2$$

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

- By solving this, we get,

$$\boldsymbol{y = A \sin (\omega t + \theta)} \qquad ---- \quad (3)$$

- where, $A = \sqrt{a_1^2 + a_2^2 + 2\, a_1 a_2 \cos\phi}$ and

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

(1) When , $\phi = 0, \pm 2\pi, \pm 4\pi, \ldots\ldots$ .the resultant amplitude becomes maximum

$$\boldsymbol{A_{max} = \sqrt{(a_1 + a_2)^2}}$$

(2) When, $\phi = \pm\pi, \pm 3\pi, \pm 5\pi \ \ldots\ldots$ the resultant amplitude becomes minimum

$$\boldsymbol{A_{min} = \sqrt{(a_1 - a_2)^2}}$$

- The intensity of light is directly proportional to the square of the amplitude.

$$I \propto A^2$$

$$I \propto a_1^2 + a_2^2 + 2\, a_1 a_2 \cos\phi$$

$$\boldsymbol{I \propto I_1 + I_2 + 2\sqrt{I_1 I_2}\ \cos\phi} \qquad --- (4)$$

(1) When, $\phi = 0, \pm 2\pi, \pm 4\pi, \ldots\ldots$ .the resultant intensity becomes maximum. This is called ***constructive interference***.

$$\boldsymbol{I_{max} \propto (a_1 + a_2)^2}$$

$$\boldsymbol{I_{max} \propto I_1 + I_2 + 2\sqrt{I_1 I_2}} \qquad --- (5)$$

(2) When, $\phi = \pm\pi, \pm 3\pi, \pm 5\pi \ \ldots\ldots$ the resultant intensity becomes minimum. This is called ***destructive interference***.

$$\boldsymbol{I_{min} \propto (a_1 - a_2)^2}$$

$$\boldsymbol{I_{max} \propto I_1 + I_2 - 2\sqrt{I_1 I_2}} \qquad --- (6)$$

Special case :

- If $a_1 = a_2 = a$, then resultant amplitude,

$$A = \sqrt{a^2 + a^2 + 2\,a^2\,cos\phi}$$
$$A = \sqrt{2\,a^2 + 2\,a^2\,cos\phi}$$
$$A = \sqrt{2\,a^2\,(1\;+\;cos\phi)}$$
$$A = \sqrt{2\,a^2\left[2\,cos^2\left(\frac{\phi}{2}\right)\right]}$$
$$\boldsymbol{A = 2\,a\,cos\left(\frac{\phi}{2}\right)} \qquad ------ \quad (7)$$

- If $I_1 = I_2 = I_O$, then the resultant intensity, $I\;\propto\;A^2$

$$I\;\propto\;4\,a^2\,cos^2\left(\frac{\phi}{2}\right)$$
$$\boldsymbol{I = \;4\,I_O\,cos^2\left(\frac{\phi}{2}\right)} \qquad ------ \quad (8)$$

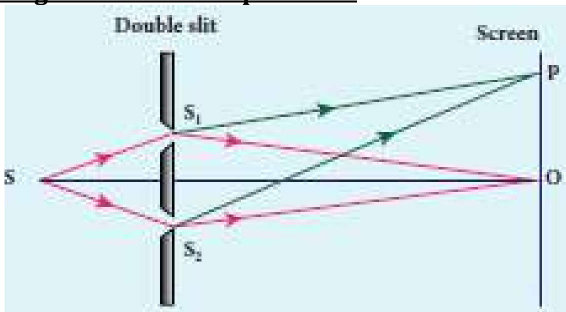
When, $\phi = 0, \pm 2\pi, \pm 4\pi, \dots \dots,$ $\quad \boldsymbol{I_{max} = \;4\,I_O}$

and $\quad \phi = \pm\pi, \pm 3\pi, \pm 5\pi\; \dots \dots,$ $\quad \boldsymbol{I_{min} = \;0}$

- Thus the phase difference (ϕ) between the two waves decides the intensity of light at the point, where the two waves meet.

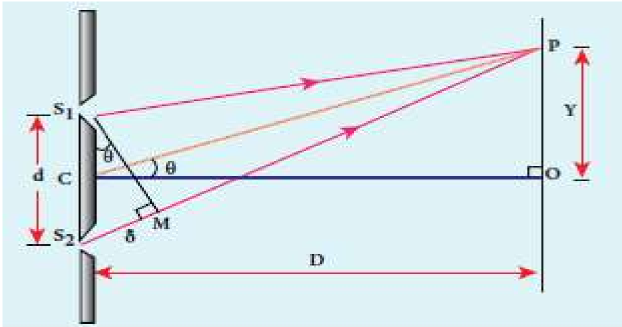
4. Explain Young's double slit experimental set up and obtain equation for path difference.

Young' s double slit experiment :



- Thomas Young used an opaque screen with two small openings called double slit S_1 and S_2 kept equidistance from a source 'S'
- 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.
- The wavefronts from S_1 and S_2 get superposed on the otherside of the double slit.
- When screen is placed at a distance of about 1 m from double slit, equally spaced alternate bright and dark fringes are appears on the screen. These are called interference fringes.
- At the point 'O' on the screen, the waves from S_1 and S_2 travels equal distances and arrive in-phase. Due to constructive interference, bright fringe is formed at point 'O' . This is called ***central bright fringe***.
- When one of the slit is covered, then the fringes disappear and there is uniform illumination observed on the screen. This clearly shows that the fringes are due to interference e.

Path difference (δ) :



- Let distance between S_1 *and* S_2 $= d$
  Distance of the screen from double slit $= D$
  Wavelength of coherent light wave $= \lambda$
- Hence path difference between the light waves from S_1 *and* S_2 to the point 'P' is

$$\delta = S_2P - S_1P = S_2P - MP = S_2M$$

- From the figure, $\angle OCP = \angle S_2S_1M = \theta$
- *In* ΔS_2S_1M

$$\sin\theta = \frac{S_2M}{S_1S_2} = \frac{\delta}{d}$$
$$\therefore \qquad \delta = \sin\theta\;.\;d$$

- Here θ is small. Hence, $\sin\theta \approx \tan\theta \approx \theta$

$$\delta = \theta\;.\;d \qquad ------ \quad (1)$$

- Also, in ΔOCP,

$$\theta \approx \tan\theta = \frac{OP}{OC} = \frac{y}{D}$$

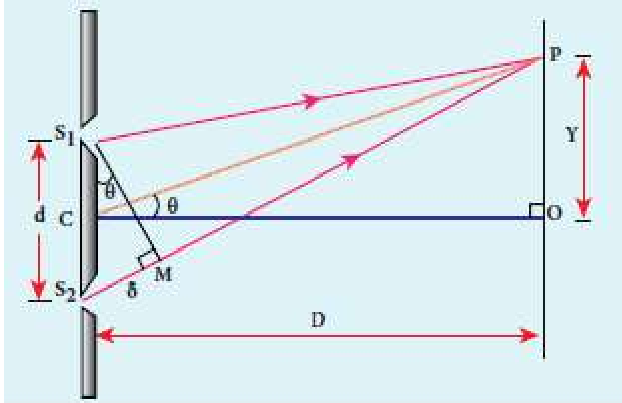
- Put this in eqn (1)

$$\boldsymbol{\delta = \frac{y}{D}\,d} \qquad ------ \quad (2)$$

- Point 'P' may be apper either bright or dark depending on the path differendce.

5. Obtain the equation for band width in young's double slit method.

Theory :



- Let distance between S_1 *and* S_2 $= d$
  Distance of the screen from double slit $= D$
  Wavelength of coherent light wave $= \lambda$
- Hence path difference between the light waves from S_1 *and* S_2 to the point 'P' is

$$\boldsymbol{\delta = \frac{y}{D}\,d}$$

Condition for bright fringe (maxima) :

- For constructive interference, the path difference will be,

$$\boldsymbol{\delta = \;n\,\lambda} \qquad [\,n = 0, 1, 2, \dots\,]$$
$$\frac{y}{D}\,d \;=\; n\,\lambda$$

- Thus the distance of the n th brigt fringe from 'O' is

$$\boldsymbol{y_n = \frac{D}{d}\,n\,\lambda} \qquad ----- \quad (3)$$

Condition for dark fringe (minima) :

- For destructive interference, the path difference will be,

$$\boldsymbol{\delta = \;(2\,n - 1)\frac{\lambda}{2}} \qquad [\,n = 1, 2, \dots\,]$$
$$\frac{y}{D}\,d \;=\; (2\,n - 1)\frac{\lambda}{2}$$

- Thus the distance of the n th darkt fringe from 'O' is

$$\boldsymbol{y_n = \frac{D}{d}\,(2\,n - 1)\frac{\lambda}{2}} \qquad ----- \quad (4)$$

Band width (β)

- The band width 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

$$\beta = y_{n+1} - y_n$$
$$\beta = \frac{D}{d}(n+1)\lambda - \frac{D}{d}n\lambda$$
$$\boldsymbol{\beta = \frac{D}{d}\lambda} \qquad -------- (5)$$

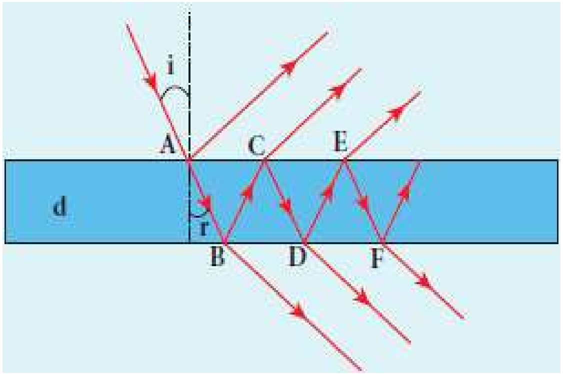
- Similarly the distance between (n+1)th and nth consecutive dark fringes from 'O' is

$$\beta = y_{n+1} - y_n$$
$$\beta = \frac{D}{d}[2(n+1)-1]\frac{\lambda}{2} - \frac{D}{d}(2n-1)\frac{\lambda}{2}$$
$$\boldsymbol{\beta = \frac{D}{d}\lambda} \qquad -------- (6)$$

- Eqn (5) and (6) shows 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.

Interference in thin films :



- Consider a thin film of transparent material of refractive index 'μ' and thickness 't'
- A parallel beam of light is incident on the film at an angle 'i'
- At upper surface, the light wave is divided in to two parts. One part is reflected and other part is refracted.
- The refracted part which enters in to the film, again gets divided at the lower surface in two parts. One is transmitted and the other is reflected back in to the film.
- Here interference is produced by both the reflected and transmitted light.

<u>Interference due to reflected light</u> :

- When light travelling in a rarer medium and getting reflected by a denser medium, undergoes a phase change of $\boldsymbol{\pi}$. Hence an additional path difference of $\frac{\lambda}{2}$ is introduced.
- Again for normal incidence ($i = 0$), the points 'A' and 'C' are very close to each other.
- The extra distance travelled by the wave coming out from 'C' is $(AB + BC)$
- Hence the path difference between the waves reflected at 'A' and 'C' is

$$\delta = \mu\,(AB + BC) = \mu\,(d + d) = 2\,\mu\,d$$

- Since additional path difference $\frac{\lambda}{2}$ is introduced due to reflection at A, the the total path difference,

$$\boldsymbol{\delta = 2\,\mu\,d + \frac{\lambda}{2}} \qquad --- \quad (4)$$

(1) The condition for constructive interference in reflected ray is,,

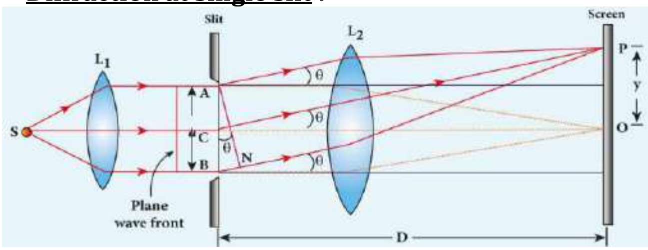
$$\delta = n\,\lambda$$
$$(or) \qquad 2\,\mu\,d + \frac{\lambda}{2} = n\,\lambda$$
$$(or) \qquad \boldsymbol{2\,\mu\,d = (2n-1)\frac{\lambda}{2}} \qquad --- (5)$$

(2) The condition for destructive interference in reflected ray is,

$$\delta = (2n+1)\frac{\lambda}{2}$$
$$(or) \qquad 2\,\mu\,d + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$
$$(or) \qquad \boldsymbol{2\,\mu\,d = n\,\lambda} \qquad --- \quad (6)$$

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

<u>Diffraction at single slit</u> :



- Let a parallel beam of light fall normally on a single slit AB. The centre of the slit is C
- A straight line through 'C' perpendicular to the plane of slit meets the centre of the screen at 'O'
- Let y be the distance of of point 'P' from 'O'
- The lines joining 'P' to the different points on the slit can be treated as parallel lines, making and angle θ with the normal 'CO'
- All the parallel waves from different points on the slits get interfere at 'P' to give resultant intensity.

<u>Condition for minima</u> :

- To explain minimum intensity, divide the slit in to even number of parts.

(1) **<u>Condition for P to be first minimum</u>** :

- Let us divide the slit AB in to two half's each of width $\frac{a}{2}$
- The various points on the slit which are separated by the same width $\left(\frac{a}{2}\right)$ called ***corresponding points***
- The path difference of light waves from different corresponding points meeting at 'P'

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

- The condition for 'P' to be first minimum,

$$\frac{a}{2}\sin\theta = \frac{\lambda}{2}$$
$$(or) \qquad \boldsymbol{a\sin\theta = \lambda}$$

(2) **<u>Condition for P to be second minimum</u>** :

- Let us divide the slit AB in to four equal parts of width $\frac{a}{4}$
- Here various corresponding points on the slit which are separated by the same width $\left(\frac{a}{4}\right)$
- The path difference of light waves from different corresponding points meeting at 'P'

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

- The condition for 'P' to be second minimum,

$$\frac{a}{4}\sin\theta = \frac{\lambda}{4}$$
$$(or) \qquad \boldsymbol{a\sin\theta = 2\,\lambda}$$

(3) **<u>Condition for P to be nth minimum</u>** :

- Let us divide the slit AB in to 2n equal parts of width $\frac{a}{2\,n}$
- The condition for 'P' to be nth minimum,

$$\frac{a}{2\,n}\sin\theta = \frac{\lambda}{2}$$
$$(or) \qquad \boldsymbol{a\sin\theta = n\,\lambda}$$

Condition for maxima :

- To explain maximum intensity, divide the slit in to odd number of parts.
- For first maximum, the slit is divided in to three equal parts each of width $\left(\frac{a}{3}\right)$. Hence

$$\frac{a}{3}\sin\theta = \frac{\lambda}{2} \quad (or) \quad \boldsymbol{a\sin\theta = 3\,\frac{\lambda}{2}}$$

- For secod maximum, the slit is divided in to five equal parts each of width $\left(\frac{a}{5}\right)$. Hence

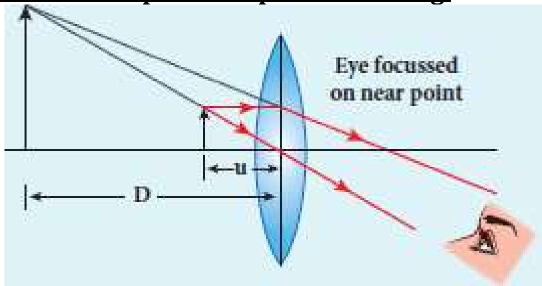
$$\frac{a}{5}\sin\theta = \frac{\lambda}{2} \quad (or) \quad \boldsymbol{a\sin\theta = 5\,\frac{\lambda}{2}}$$

- In general, for nth first maximum, the slit is divided in to (2n+1) equal parts each of width $\left(\frac{a}{2n+1}\right)$. Hence

$$\frac{a}{2n+1}\sin\theta = \frac{\lambda}{2} \quad (or) \quad \boldsymbol{a\sin\theta = (2n+1)\frac{\lambda}{2}}$$

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

Simple microscope - Near point focussing :



- A simple microscope is a single magnifying lens of small focal length.
- In near point focusing, object distance 'u' is less than 'f'
- The image is formed at near point or least distance 'D' of distinct vision.
- The magnification 'm' is given by,

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

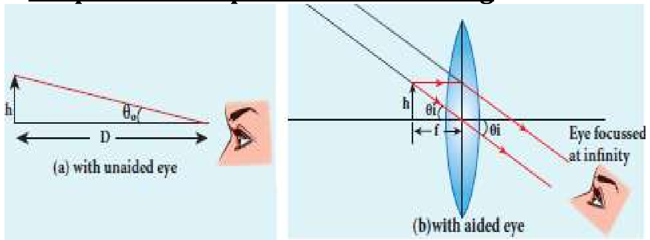
- Using lens equation,

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

- Substitute, $v = -D$

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

Simple microscope - Normal focussing :



- Here the image is formed at infinity.
- So we will not get direct practical relation for magnification. 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_O) subtended by the object with unaided eye. That is,

$$m = \frac{\theta_O}{\theta_i} \qquad ------ \ (1)$$

- For unaided eye,

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

- For aided eye,

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

- Thus eqn (1) becomes,

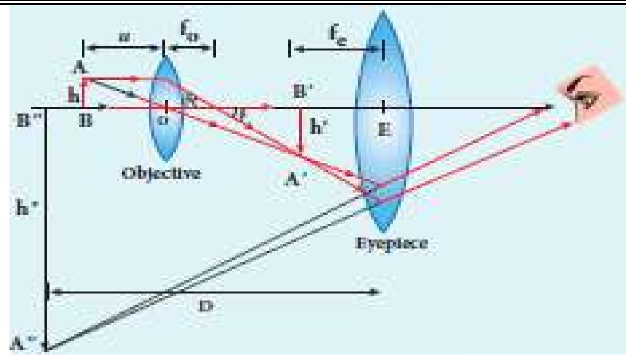
$$m = \frac{\theta_O}{\theta_i} = \frac{\left(\frac{h}{D}\right)}{\left(\frac{h}{f}\right)}$$

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

9. Explain about compound microscope.

Compound microscope :

- The lens near the object is 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***.
- Eye piece 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.

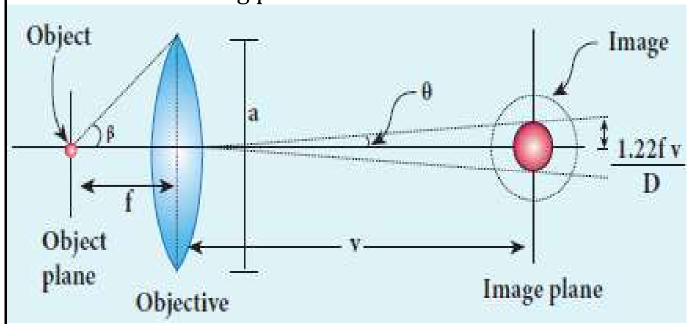


- The final image is inverted with respect to the original object.

10. Obtain the equation for resolving power of microscope.

Resolving power of microscope:

- A microscope is used to see the details of the object under observation.
- Good microscope should not only magnify the object but also resolve the two points on an object which are separated by the smallest distance d_{min}.
- Actually, d_{min} is the resolution and its reciprocal is the resolving power.



- The spatial resolution (radius of central maximum) is

$$r_o = \frac{1.22\,\lambda\,f}{a}$$

- In microscope, the object distance is just more than the focal length f and the image is formed at v as shown in the Figure. Hence,.

$$r_o = \frac{1.22\,\lambda\,v}{a}$$

- Here, 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,

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

$$(or) \quad d_{min} = \frac{r_o}{m} = \frac{1.22\,\lambda\,v}{m\,a} = \frac{1.22\,\lambda\,v}{\left(\frac{v}{u}\right)\,a}$$

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

- On the object side, $2\tan\beta \approx 2\sin\beta = \frac{a}{f}$

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

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

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

- Such an objective is called oil immersed objective. **The term *n sin β* is called *numerical aperture (NA)*.** Hence,

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

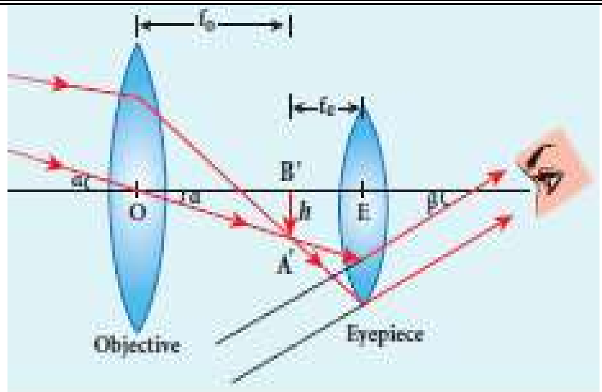
- Then the resolving power of microscope is,

$$\boldsymbol{R_M = \frac{1}{d_{min}} = \frac{2\,(NA)}{1.22\,\lambda}}$$

11. Discuss about astronomical telescope.

<u>Astronomical telescope</u> :

- An astronomical telescope is used to get the magnification of distant astronomical objects like stars, planets …
- The image formed by this will be inverted.



- It has an objective of long focal length and a much larger aperture than eye piece.
- Light from a distant object enters the objective and a real image is formed in the tube at its second focal point.
- The eye piece magnifies this image producing a final inverted image.

<u>Magnification (m)</u> :

- 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 figure,

$$m = \frac{\left[\frac{h}{f_e}\right]}{\left[\frac{h}{f_o}\right]}$$

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

- The length of the telescope is approximately,

$$\boldsymbol{L = f_o + f_e}$$

,