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WAVE OPTICS

PHYSICS - VOL 2 **UNIT - 7**

NAME :

STANDARD : 12 SECTION :

SCHOOL :

EXAM NO :

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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?

Corpuscular theory :

- ***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.

Wave theory of light :

- ***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 .

Electromagnetic wave theory of light :

- ***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.

Quantum theory of light :

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

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.

Wave nature of light :

- 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.

Huygen's principle :

- 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 $2\,\pi$
- 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

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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 Fresnel and Fraunhofer diffraction.

Fresnel diffraction	Fraunhofer diffraction
Spherical or cylindrical wave front undergoes diffracion	Plane wavefront undergoes diffraction
The source of light is finite distance from the obstacle	The source of light is infinite distance from the obstacle
Convex lenses need not be used	Convex lenses are to be used
Difficult to observe and analyse	Easy to observe and analyse

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

- The equation for first minimum in single slit diffraction is $a\,sin\theta = \lambda$

Case (1) :If $a < \lambda$ then $sin\theta > 1$ which is not possible. Hence diffraction does not takes place.

Case (2) : If $a = \lambda$ then $sin\theta = 1$ (or) $\theta = 90°$. **(i.e.)** The first minimumis at **90°**

Case (3) : If $a > \lambda$ (i.e.) $a = 2\lambda$ then, $sin\theta = \frac{1}{2}$ or $\theta = 30°$ The diffraction is observed with a measurable spread. Hence, it is concluded that for observing the diffraction pattern, essentially the width of the slit a must be just few times greater than the wavelength of light λ

Case(4) : If $a >> \lambda$ then $sin\theta << 1$. The first minimum falls within the width space of the slit itself. Hence, the phenomenon of diffraction is not observed at all.

26. What is diffraction grating?

- Grating is a plane sheet of transparent material on which opaque rulings are made with a fine diamond pointer.
- Thus gratting has multiple slits with equal widths of size comparable to the wavelength of light
- The modern commercial grating contains about 6000 lines per centimeter.

27. Define grating element and corresponding points.

- The combined width of a ruling (b) and a slit (a) is called grating element (e = a + b)
- Points on successive slits separated by a distance equal to the grating element are called corresponding points.

28. 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.

29. 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.

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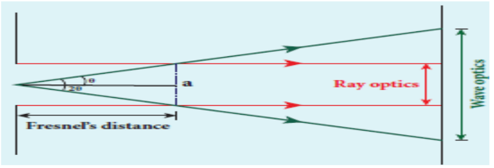
Expression :



- 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,

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

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

30. Give the reason for colourful appearance of the compact disc.

- On the read or writable side of the disc, there are many narrow circular tracks whose width are comparable to the wavelength of visible light.
- Hence the diffraction takes place after reflection for incident white light to give colourful appearance.
- Thus tracks act as ***reflecting grating***.

31. 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.

32. 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.

33. Define polarization.

- The phenomenon of restricting the vibrations of light to a particular direction perpendicular to the direction of wave propagation motion is called polarization.

34. Distinguish between unpolarized and plane polarized light.

Unpolarized light	Plane polarized light
A transverse wave which has vibrations in all directions in a plane perpendicular to the direction of propagation is said to be unpolarized light	A transverse wave which has vibrations in only one direction in a plane perpendicular to the direction of propagation is said to be planepolarized light
Symmetrical about the ray direction	Asymmetrical about the ray direction
Produced by conventional light sources	It is obtained from unpolarized light with help of polarizers

35. Define plane of vibration and plane of polarization.

Plane of vibration:

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

Plane of polarization:

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

36. How an unpolarized light can be polarized?

- The unpolarized light can be polarized by following techniques.
  (1) Polarization by selective absorption
  (2) Polarization by reflection
  (3) Polarization by double refraction
  (4) Polarization by scattering

37. Discuss polarization by selective absorption.

Polarization by selective absorption (Polaroids) :

- Selective absorption is the property of a material which transmits waves whose electric field vibrate in a plane parallel to a certain direction of orientation and absorbs all other waves.
- The ***polroids*** or ***polarizer*** using this property of selective absorption to produce intense plane polarized light.
- Selective absorption is also called as ***dichroism***.
- Edwin Land developed polarizer in the form of thin sheets.
- ***Tourmaline*** is a natural polarizing material. But polaroids are made artificially.
- A number of needle shaped crystals of ***quinine iodosulphate*** with their axes parallel to one another packed in between two transparent plastic sheets serve as a good polaroid.
- Recently new type of polaroids are prepared in which thin film of polyvinyl alcohol (colour less crystals) is used.

38. What is polarizer and analyser?

Polariser :

- The polaroid which plane polarizes the unpolarized light passing through it is called a polarizer.

Analyser :

- The polaroid which is used to examine whether a beam of light is polarized or not is called analyser.

39. Discuss how a plane polarized and partially polarized light will be analysed using analyser?

Plane polarized light :

- If the intensity of light varies from ***maximum to zero*** for every rotation of 90° of the analyser, the light is said to be plane polarized

Partially polarized light :

- If the intensity of light varies from ***maximum to mimimum*** for every rotation of 90° of the analyser, the light is said to be partially polarized.

40. State and prove Malus' law.

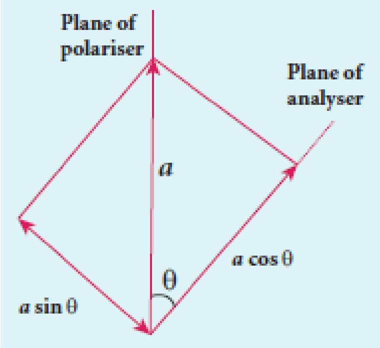
Malus's law :

- When a beam of plane polarized light of intensity I_o is incident on an analyser, 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 polarizer and analyser. This is known as Malus' law.

$$\boldsymbol{I = I_o \cos^2\theta}$$

Proof :

- Let the angle between plane of polarizer and analyser = θ
  Intensity of electric vector transmitted by the polarizer = I_o
  Amplitude of this electric vector = a



- The amplitude of the incident light was resolved in to two components,
  (1) $a\cos\theta$ - parallel component to the axis of transmission of the analyser
  (2) $a\sin\theta$ - perpendicular component to the axis of transmission of the analyser
- Here only the parallel component $(a\cos\theta)$ will be transmitted by the analyser.
- Hence ht intensity of the transmitted light is,

$$I \propto (a\cos\theta)^2$$
$$I = k(a\cos\theta)^2$$
$$I = k\,a^2\cos^2\theta$$
$$\boldsymbol{I = I_o\cos^2\theta}$$

  (1) When $\theta = 0°$, $\boldsymbol{I = I_o}$
  (2) When $\theta = 90°$, $\boldsymbol{I = 0}$

41. List the uses of polaroids.

<u>Uses of polaroids</u> :

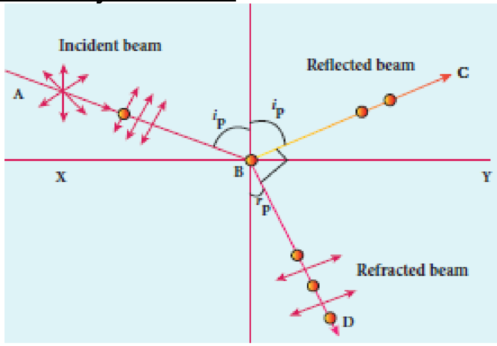
- Used in goggles and cameras to avoid glare of light
- Used in holography (three dimensional motion pictrure)
- Used to improve contrast in old oil paintings
- Used in optical stress analysis.
- Used as window glasses to control the intensity of incoming light
- Polarised needle beam acts as needle to read/write in compact discs (CDs)
- Polaroid produce polarized lights to be used in liquid crystal display (LCD)

42. Defined angle of polarization.

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

43. Explain polarization by reflection.

<u>Polarization by reflection</u> :

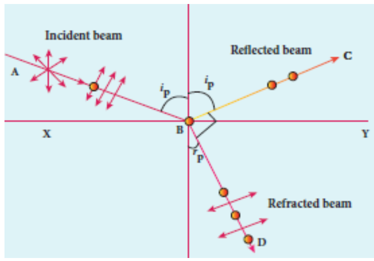


- It is the simplest method to produce plane polarized light.
- It is discovered by ***Malus.***
- Here, XY - reflecting surface
  AB - incident unpolarized light beam
  BC - reflecting light beam
  BD - refracted light beam
- On examining the reflected beam 'BC' with an analyser, it is found that the 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*** ($\boldsymbol{i_P}$)

44. State and prove Brewster's law

<u>Brewste' s law</u> :

- 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,

$$i_P + 90° + r_P = 180°$$
$$\boldsymbol{r_P = 90° - i_P} \quad ----(1)$$

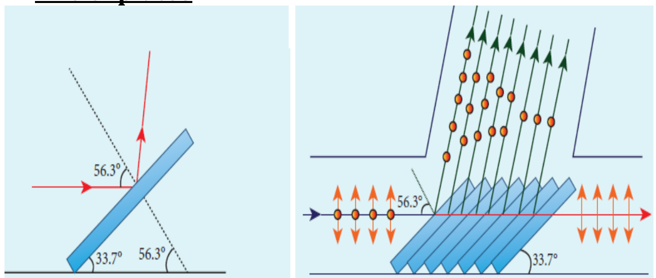
- From Snell's law

$$\frac{\sin i_P}{\sin r_P} = n$$
$$\frac{\sin i_P}{\sin(90° - i_P)} = n$$
$$\frac{\sin i_P}{\cos i_P} = n$$
$$\boldsymbol{\tan i_P = n}$$

- 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.***

45. Write a note on pile of plates.

<u>Pile of plates</u> :



- 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.

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46. **Define double refraction.**
- When a ray of unpolrized 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.
- The obtained images are called as,
  (1) Ordinary image
  (2) Extra ordinary image
- Double refraction is also called ***bi refringence***.

47. **Distinguish between ordinary ray and extra ordinary ray.**

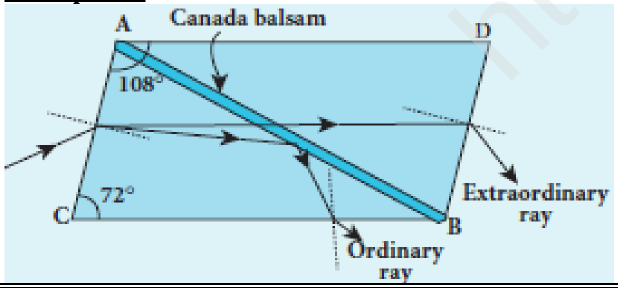
Ordinary ray	Extraordinary ray
They obey the laws of refraction	They do not obey the laws of refraction
Inside the crystal, they travel with same velocity in all directions	Inside the crystal, they travel with different velocities along different directions
A point source inside the crystal produces spherical wavefront for ordinary ray	A point source inside the crystal produces elliptical wavefront for extra ordinary ray

48. **Define Optic axis.**
- Inside the double refracting crystal, there is a particular direction in which both the ordinary and extraordinary rays travel with same velocity. This direction is called optic axis.
- Along optic axis, the refractive index is same for both rays.

49. **Define uniaxial crystal and biaxial crystal.**
- 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. **Discuss about Nicol prism.**

<u>**Nicol prism**</u> :



- Nicol prism is made by calcite crystal which is double refracting crystal.
- ABCD is the principal section of a calcite crystal with its length is three times of its breadth.
- The face angles are **72°** and **108°**
- It is cut in to two halves along the diagonal AB and joined together by a layer of ***canada balsam***, a transparent cement.
- Let an unpolarized light from monochromatic source is incident on the face AC of the Nicol prism.
- Here double refraction takes place, and the ray split in to ordinary ray and extraordinary ray.
- For this calcite crystal.
  refractive index for the ordinary ray = 1.658
  refractive index for the extraordinary ray = 1.486
- The refractive index of canada balsam = 1.523
  Here canada balsam does not polarize light
- The ordinary ray is totally internally reflected at the layer of canada balsam.
- The extraordinaty ray alone is transmitted through the crystal which is plane polarized.

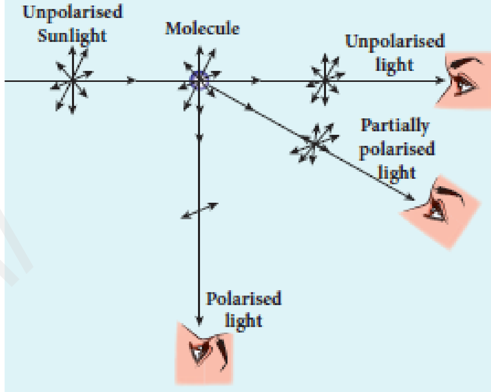
51. **What are the uses and drawbacks of Nicol prism?**

<u>**Uses**</u> :
- It produces plane polarized light and funcitons as a polarizer.
- It can also used as an analyser.

<u>**Drawbacks**</u> :
- It cost is very high due to scarity of large and flawless calcite crystal.
- 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 polarized.

52. **Explain polarization by scattering.**

<u>**Polarization by scattering**</u>:
- 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 on encountering the molecules of the earth's atmosphere.
- The electric field of light interact with the electrons present in the air molecules.



- Under the influence of the electric field of the incident wave the electrons in the molecules acquire components of motion in both these directions.
- We have shown an observer looking at 90 to the direction of the sun.
- Clearly, charges accelerating paralled do not radiate energy towards this observer since their acceleration has no transverse component.
- The radiation scattered by the molecule is therefore polarized perpendicular to the plane of the paper.
- This explains the reason for polarization of sunlight by scattering.

53. **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 $\boldsymbol{m = \frac{D}{f}}$

54. **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)***

55. 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.

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

- A terrestrial telescope is used to see object at long distance on the surface of earth. Hence image should be erect.
- So an additional erecting lens is used to make the final image enlarged and erect.

57. What is the use of collimator inspectrometer?

- The collimator is an arrangement to produce a parallel beam of light.

58. What are the uses of spectrometer?

- Spectrometer is an optical instrument used to,
  (1) study the spectra of different sources of light
  (2) measure the refractive indices of materials

59. What is myopia? What is its remedy?

- A person suffering from myopia or nearsightedness cannot see distant objects clearly.
- It occurs when the eye lens has too short focal length due to thickening of the lens or larger diameter of the eyeball than usual.
- Using ***concave lens*** this defect can be rectified.

60. What is hypermetopia? What is its remedy?

- A person suffering from hypermetopia or farsightedness cannot see objects close to the eye.
- It occurs when the eye lens has too long focal length due to thinning of eye lens or shortening of the eyeball than normal.
- Using ***convex lens*** this defect can be rectified.

61. What is presbyopia?

- The least distance for clear vision for aged people is appreciably more than 25 cm and the person has to keep the object inconveniently away from the eye.
- Thus reasing or viewing smaller things held in the hands is difficult for them.
- This kind of farsightedness arising due to aging is called ***presbyopia***.

62. What is astigmatism?

- 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 planes called ***cylindrical lens*** is used to rectify astigmatism defect.

63. Whar are called Airy's discs?

- When a circular aperture like a lens or the iris of eye forms an image of a point object, the image formed will not be a point, but a diffraction pattern of concentric circles that becomes fainter while moving away from the centre.
- These are known as Airy's discs.

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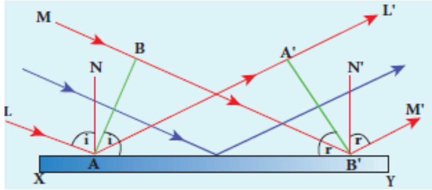
5 - Mark Question & Answer

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,

$$\angle B = \angle A^1 = 90°$$

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

hypotenuse AB^1 *is common*

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

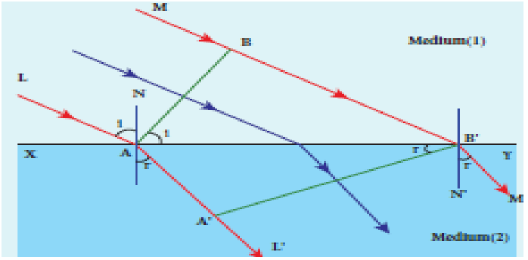
$$\angle BAB^1 = \angle A^1B^1A$$

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

- 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 ,

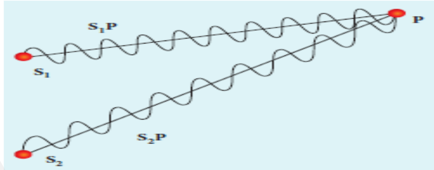
$$\frac{\sin i}{\sin r} = \frac{\left(\frac{BB^1}{AB^1}\right)}{\left(\frac{AA^1}{AB^1}\right)} = \frac{BB^1}{AA^1} = \frac{v_1}{v_2} = \frac{\left(\frac{c}{n_1}\right)}{\left(\frac{c}{n_2}\right)} = \frac{n_2}{n_1}$$

- 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.

$$I \propto A^2$$

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

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

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

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

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

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

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

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

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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, $I \propto A^2$

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

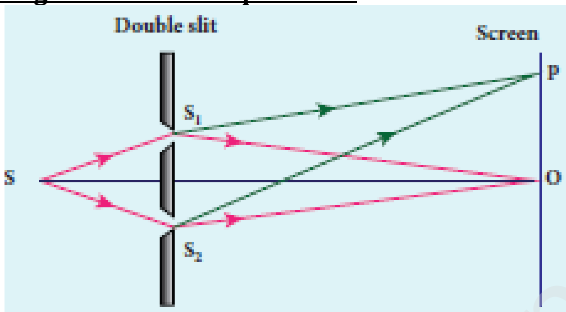
When, $\phi = 0, \pm 2\pi, \pm 4\pi, \ldots ....,$ $\quad \boldsymbol{I_{max} = 4\,I_O}$

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

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

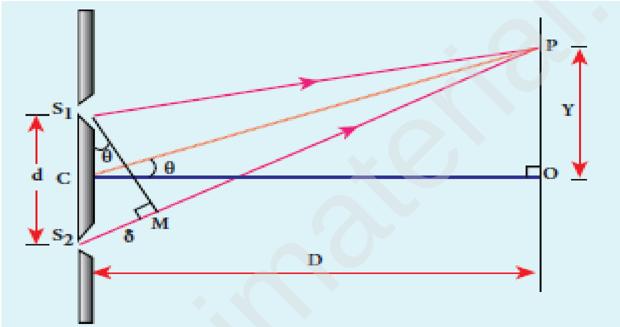
4. Explain Young's double slit experimental set up and obtain equation for path difference.

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

$$\sin\theta = \frac{S_2M}{S_1S_2} = \frac{\delta}{d}$$
$$\therefore \quad \delta = \sin\theta \,.\, d$$

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

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

- Also, in ΔOCP,

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

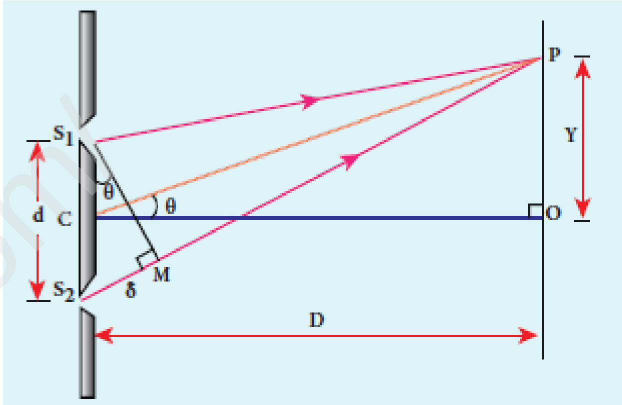
- Put this in eqn (1)

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

- 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,

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

- 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,

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

- 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.

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- The distance between (n+1)th and nth consecutive bright fringes from 'O' is

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

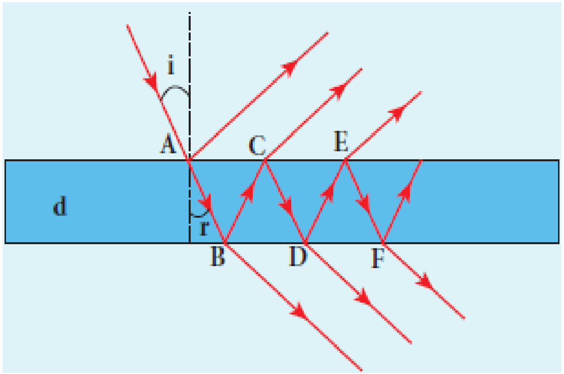
- Similarly the distance between (n+1)th and nth consecutive dark fringes from 'O' is

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

- 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,

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

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

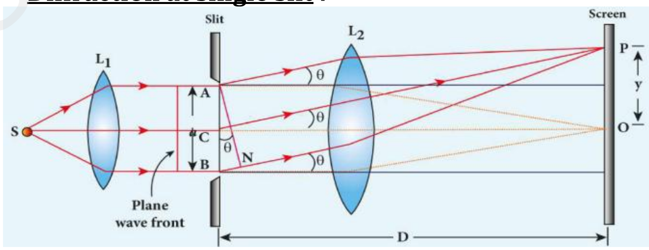
$$\delta = n\,\lambda$$
$$(or) \qquad 2\,\mu\,d + \frac{\lambda}{2} = n\,\lambda$$
$$(or) \qquad \boldsymbol{2\,\mu\,d = (2n-1)\frac{\lambda}{2}} \qquad ---(5)$$

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

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

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,

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

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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

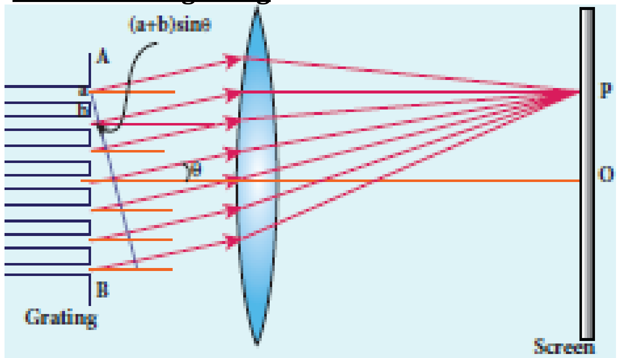
$$\frac{a}{5}\sin\theta = \frac{\lambda}{2} \quad (or) \quad \boldsymbol{a\sin\theta = 5\,\frac{\lambda}{2}}$$

- In general, for n[th] 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 the diffraction at a grating and obtain the condition for m[th] maximum.

Diffraction in grating :



- Let 'AB' represent the plane transmission grating.
- It has number of slits of equal width (a) and equal number of opaque rulings of equal width (b)
- Lte a plane wavefornt of monochromatic light of wavelength 'λ' be incident normally on the grating.
- As the slit size is comparable to that of wavelength, the incident light diffracts at the grating.
- Using convex lens, the diffracted waves are focused on the screen.
- Consider a point 'P' on the screen, at an angle 'θ' with the normal drawn from the centre of the grating to the screen.
- The path difference (δ) between the diffracted waves from one pair of corresponding points is,

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

- The point 'P' will be bright, when

$$\delta = m\,\lambda \qquad [m = 0,1,2,3\,\ldots]$$

- Hence,

$$\boldsymbol{(a+b)\sin\theta = m\,\lambda} \qquad ----(1)$$

where $m \rightarrow$ order of diffraction

(1) **Condition for zero order maximum :**

- When, $(a+b)\sin\theta = 0$, then, $\theta = 0$; $m = 0$

It is ***zero order diffraction*** or ***central maximum***

(2) **Condition for first order maximum :**

- When, $(a+b)\sin\theta_1 = \lambda$, then, $\theta = \theta_1$; $m = 1$

It is ***first order diffraction***

(3) **Condition for second order maximum :**

- When, $(a+b)\sin\theta_2 = 2\lambda$, then, $\theta = \theta_2$; $m = 2$

It is ***second order diffraction***

(4) **Condition for higher order maxima :**

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

- If 'N' be the number of rulings drawn per unit width (1 m), then , $N\,a + N\,b = 1$ (or)

$$N\,(a+b) = 1$$

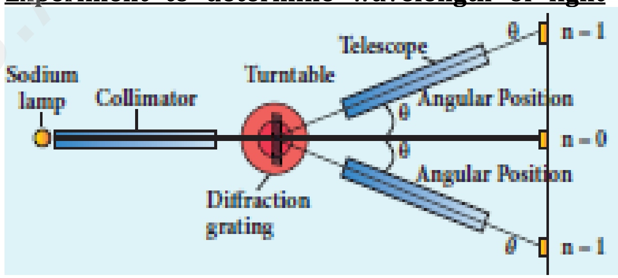
$$a+b = \frac{1}{N}$$

$$\therefore \quad \frac{1}{N}\sin\theta = m\,\lambda$$

$$(or) \qquad \boldsymbol{\sin\theta = N\,m\,\lambda} \qquad -----(2)$$

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

Experiment to determine wavelength of light :



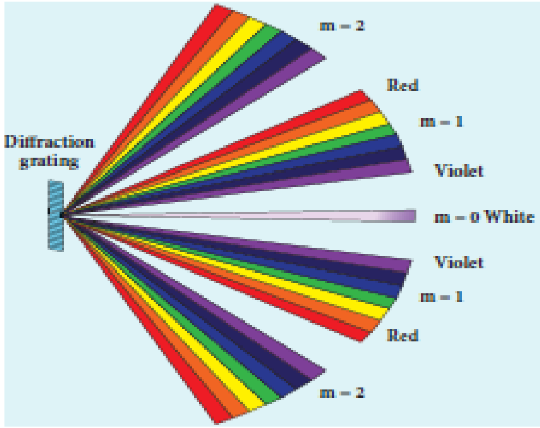
- The wavelength of a spectral line can be very accurately determined with help of a diffraction grating and a spectrometer.
- Let all the preliminary adjustments are made on the spectrometer.
- The slit of the spectrometer is illuminated by a monochromatic light, whose wavelength to be determined.
- The telescope is brought in line with collimator to view the direct image of the slit.
- The given transmission grating is then mounted on the prism table with its plane perpendicular to the incident beam of light coming from collimator.
- The telsescope is turn 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 vertical cross wire and corresponding reading is noted.
- The difference between two positions gives $2\,\theta$
- Half of its value gives θ, the diffraction angle for first order maximum.
- The wavelength of light is calculated from,

$$\boldsymbol{\lambda = \frac{\sin\theta}{N\,m}}$$

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

Determination of wavelength of different colours :

- White light is a composite light which contains all wavlengths from violet to red in visible region.
- When white light is used, the diffraction pattern consists of a white central maximum and on both sides continuous coloured diffraction patterns are formed.



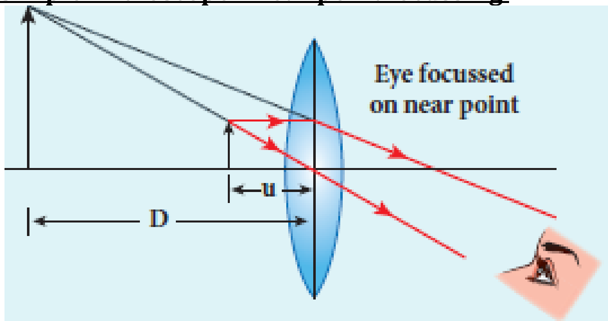
- The central maximum is white as all the colours meet here constructively with no phase difference.
- It produces a spectrum of diffraction pattern from violet to red on either side of central maximum.
- By measuring the angle ($\boldsymbol{\theta}$) at which these colours appear for various order (m) of diffraction, the wavelength of different colours could be calculated using the formula,

$$\boldsymbol{\lambda = \frac{\sin\theta}{N\,m}}$$

where, $\boldsymbol{N} \rightarrow$ number of rulings drawn per unit width of grating

11. 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,

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

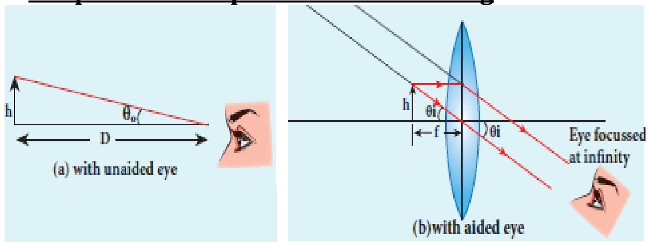
-

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

- 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,

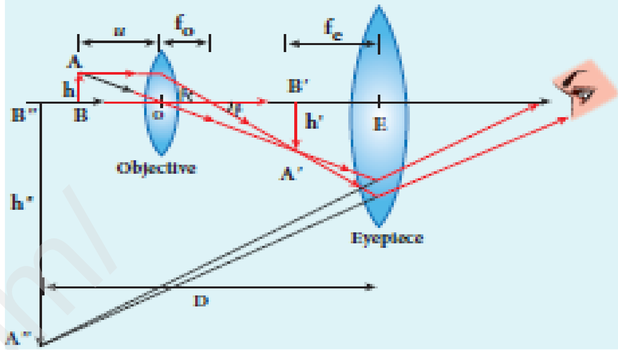
$$m = \frac{\theta_O}{\theta_i} = \frac{\left(\frac{h}{D}\right)}{\left(\frac{h}{f}\right)}$$

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

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

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.

Magnification (m) :

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

$$m_o = \frac{h^1}{h} = \frac{L}{f_o} \qquad ----- \ (1)$$

Here 'L' is the distance between the first focal point of the eye piece to the second focal point of the objective. This is called the ***tube length***.

- The magnification of the eyepiece,

$$m_e = 1 + \frac{D}{f_e} \qquad ----- \ (2)$$

- The total magnification 'm' in near point focusing ,

$$\boldsymbol{m = m_o m_e = \left[\frac{L}{f_o}\right]\left[1 + \frac{D}{f_e}\right]}$$

- If the final image is formed at infinity (normal focusing), the magnification if eye piece is,

$$m_e = \frac{D}{f_e} \qquad ----- \ (3)$$

- The total magnification 'm' in normal focusing is,

$$\boldsymbol{m = m_o m_e = \left[\frac{L}{f_o}\right]\left[\frac{D}{f_e}\right]}$$

13. 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.

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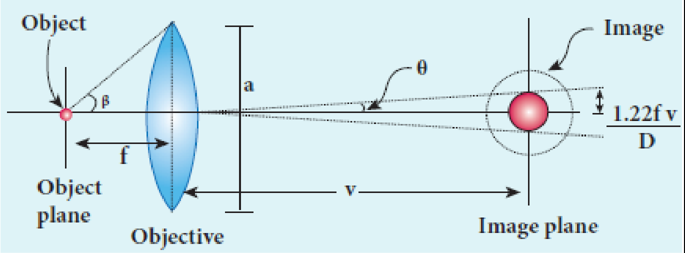


- The spatial resolution (radius of central maximum) is

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

- 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,

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

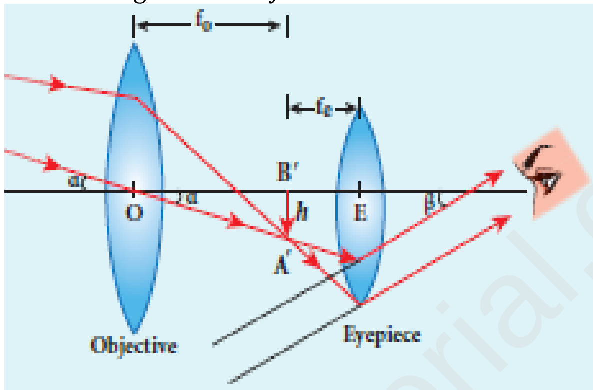
- Then the resolving power of microscope is,

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

14. 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,

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

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

Spectrometer :

- The spectrometer is an optical instrument used to analise the spectra of different sources of light, to measure the wavelength of different colours and to measure the refractive indices of materials of prisms.
- It basically consists of three parts namely
  (i) collimator (ii) prism table and (iii) telescope.

(1) **<u>Collimator:</u>**

- The collimator is used for producing parallel beam of light.
- It has a convex lens and a vertical slit of adjustable width which faces the source.
- The position of slit can be adjusted so that it is kept at the focus of the lens.
- The collimator is rigidly fixed to the base.

(2) **<u>Prism table</u>:**

- The prism table is used for mounting the prism, grating etc. It consists of two circular discs provided with three levelling screws.
- It can be rotated and its position can be read from two verniers V_1 and V_2 .
- The prism table can be fixed at any desired height.

(3) **<u>Telescope</u> :**

- The telescope is an astronomical type.
- It consists of an eyepiece provided with cross wires at one end and an objective at its other end.
- The distance between the objective and the eyepiece can be adjusted so that the telescope forms a clear image at the cross wires.
- The telescope is attached to a circular scale and both can be rotated together.
- The telescope and prism table are provided with ***radial screws*** for fixing them at a desired position and ***tangential screws*** for fine adjustments.

Preliminary adjustments of the spectrometer

(1) **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.

(2) **Adjustment of the telescope:** The telescope is adjusted to receive parallel rays by focusing it to a distant object to get a clear image on the cross wire.

(3) **Adjustment of the collimator :** The telescope is brought in line with the collimator. The distance between the illuminated slit and the lens of the collimator is adjusted until a clear image of the slit is seen at the cross wire.

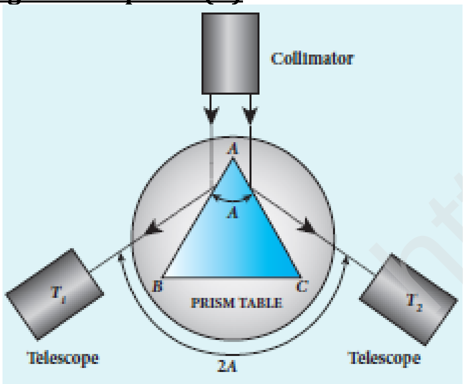
(4) **Levelling of the prism table :** The prism table is brought to the horizontal level by adjusting the levelling screws and it is ensured by using sprit level.

16. Explain the experimental determination of material of the prism using spectrometer.

Determination of refractive index :

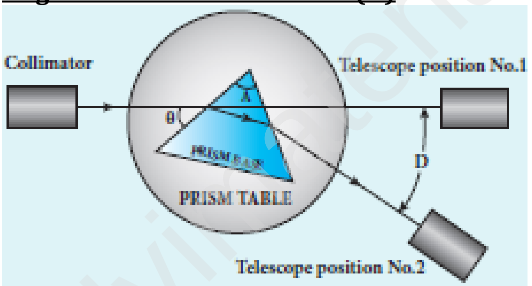
- The preliminary adjustments of the telescope, collimator and the prism table of the spectrometer are made.
- The refractive index (μ) of the prism is determined by knowing the angle of the prism (A) and the angle of minimum deviation (D)

(1) Angle of the prism (A) :



- The prism is placed on the prism table with its refracting edge facing the collimator.
- The slit is illuminated by a sodium 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 coincides with the vertical cross wire of the telescope.
- The corresponding vernier readings 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 with the vertical cross wire of the telescope. The corresponding vernier 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)

(2) 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.
- 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 telescope is made to coincide with the image of the slit, where it turns back. This gives the minimum deviation position.
- The vernier readings corresponding to this position is noted.
- Now the prism is removed and the telescope is turned to receive the direct ray and the vernier readings are again noted.
- The difference between the two readings gives the angle of minimum deviation (D)

Refractive index (μ) of the prism :

- The refractive index of the material of the prism is calculated using the formula,

$$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

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