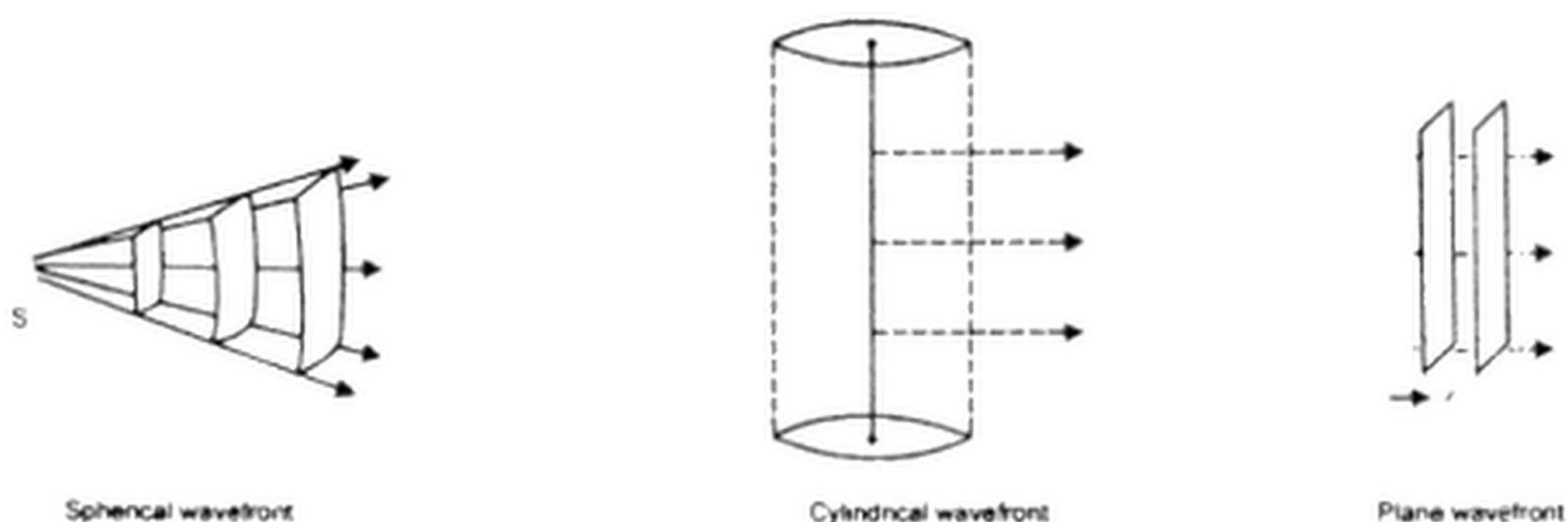


## Unit 9

# PHYSICAL OPTICS

**Q.1 What is wave front?****Answer****Wave Fronts**

The surface on which all the points of waves have same phase of vibration is known as wave front.

**Explanation**

Suppose the light emitted from a point source propagates outward in all direction with speed  $c$ . After time  $t$ , the waves reach the surface of an imaginary sphere with center as  $S$  and radius as  $ct$ . As the distance of all these points from the source is same so all the points on the surface of the sphere have the same phase of vibration. Such surface is known as wave front.

**Note**

The wave front from a point source are spherical. Thus, wave propagates in space by the motion of wave fronts.

The distance between two consecutive wave fronts is one wave length.

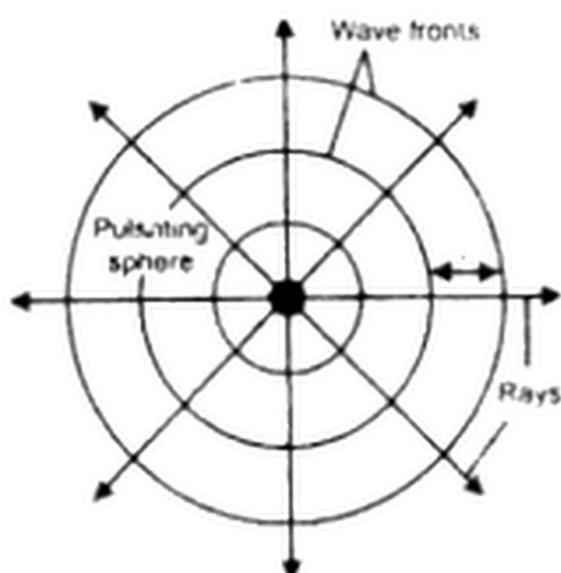
**Ray of Light**

The line normal to the wave front which shows the direction of propagation of light is called a ray of light.

### 1. Spherical wave front

The wave front in which the light waves are propagated in spherical form with the source is called spherical wave front.

For a point source of light in a homogeneous medium, the wave fronts are the concentric spheres of increasing radii.



### 2. Plane wave front

At very large distance (i.e. at infinity) from the source, a small portion of spherical wave front will become very nearly plane. Such a wave front is known as plane wave front as shown in figure.



For example, the sun light reaches the earth in plane wave fronts.

**Q.2 How can you obtain plane waves from a point source? State and explain the Huygens' principle?**

**Answer**

In order to obtain plane wave from a point source, it is placed at the focus of convex lens.

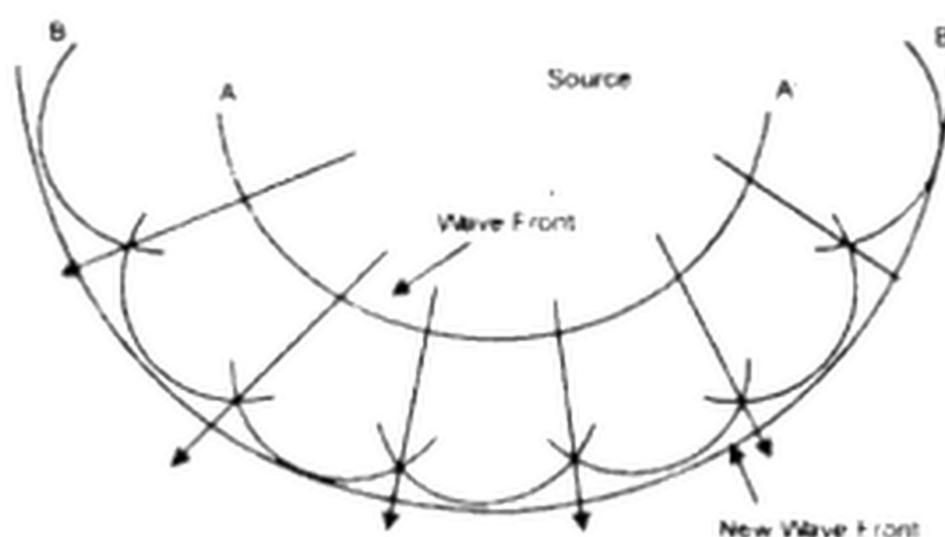
**Huygens' Principle**

If the location of the wave front at any instant  $t$  is known then Huygens' Principle enables us to determine shape and location of the new wave front at a later time

$t + \Delta t$ .

This principle has two parts:

- i) Every point of a wave front may be considered as a source of secondary wavelets which spread out in forward direction with a speed equal to the speed of propagation of the wave.
- ii) The new position of the wave front after a certain interval of time can be found by constructing a surface that touches all the secondary wavelets.



**Explanation**

Let AB is the wave front at time  $t$ .

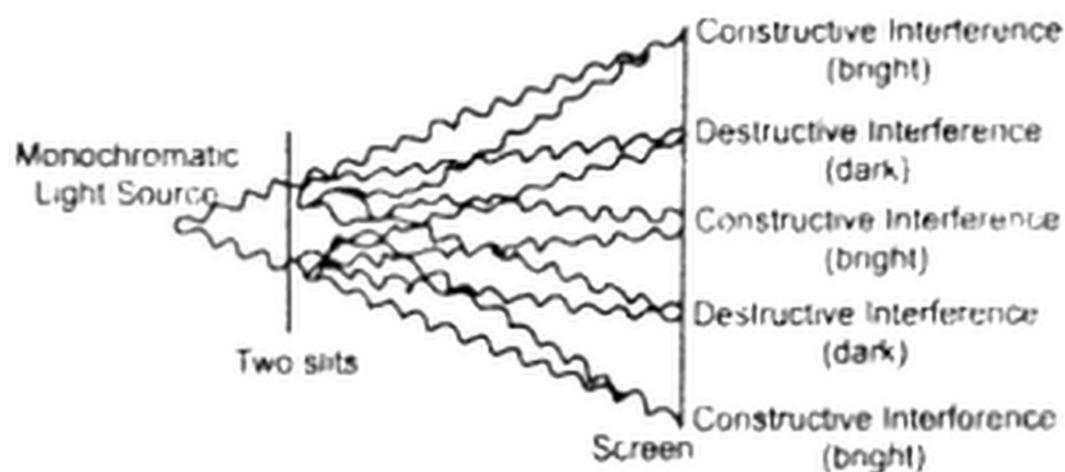
To determine the wave front at time  $t + \Delta t$ , draw secondary wavelets with center at various points on the wave front  $A'B'$  and radius  $c\Delta t$ , where  $c$  is the speed of propagation of wave. The new wave front at time  $t + \Delta t$  is  $A''B''$  which is a tangent envelope to all the secondary wavelets.

**Q.3 Discuss the interference of light. Discuss its different types and conditions for detectable interference.**

**Answer**

### Interference of Light Waves

When two identical light waves travelling in the same direction are superimposed to each other in such a way that they reinforce each other at some points (constructive interference). While at some points they cancel the effect of each other (destructive interference). Such phenomenon is called interference of light.



A two-point source interference pattern creates an alternating pattern of bright and dark lines when it is projected onto a screen

### Types of Interference

There are two types of interference.

#### 1) Constructive Interference

If crest of one wave falls on the crest of other or trough of one wave falls on the trough of other waves, they support each other. This phenomenon is called constructive interference.

Whenever the path difference between the two waves is an integral multiple of wavelength, then the both waves reinforce each other. This effect is called constructive interference.

If  $\Delta S$  is the path difference between two waves having wavelength  $\lambda$ , then condition of constructive interference can be described as:

$$\Delta S = n\lambda$$

Where  $n = 0, \pm 1, \pm 2, \pm 3, \dots$

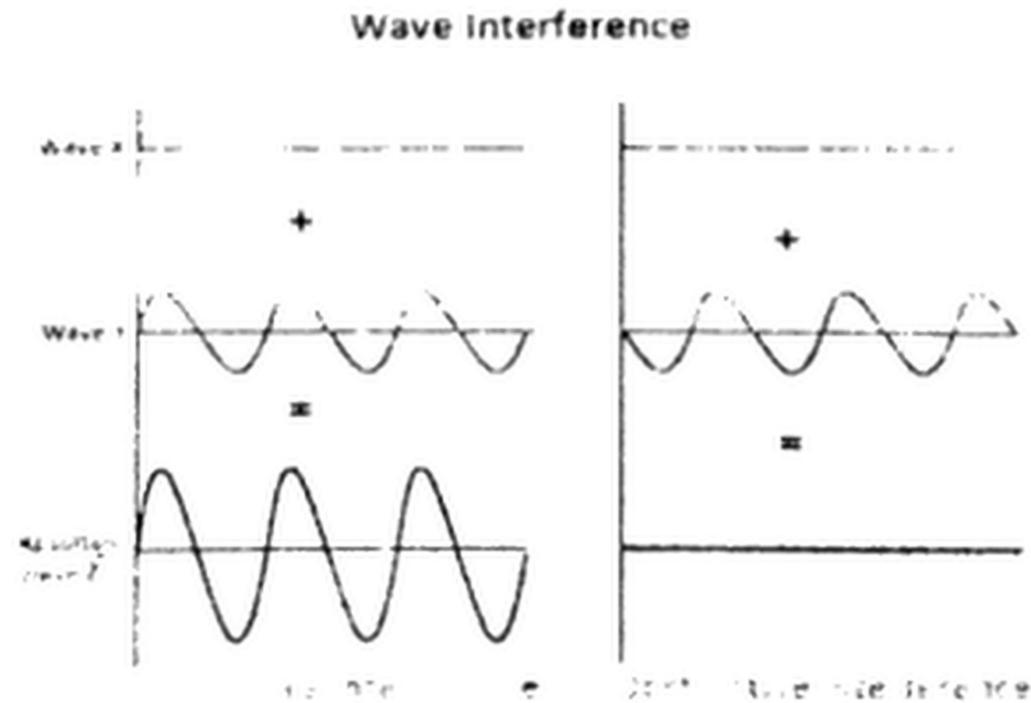
## 2) Destructive Interference

If crest of one wave fall on the trough of the other wave, then they cancel each other. Such an interference is known as destructive interference.

Whenever the path difference between the two waves is an odd integral multiple of half of wavelength, then the both waves cancel each other's effect. This effect is called destructive interference.

If  $\Delta S$  is the path difference between two waves having wavelength  $\lambda$ , then condition of destructive interference can be described as:

$$\Delta s = (2n+1)\frac{\lambda}{2} \quad \text{Where } n = 0, \pm 1, \pm 2, \pm 3, \dots$$



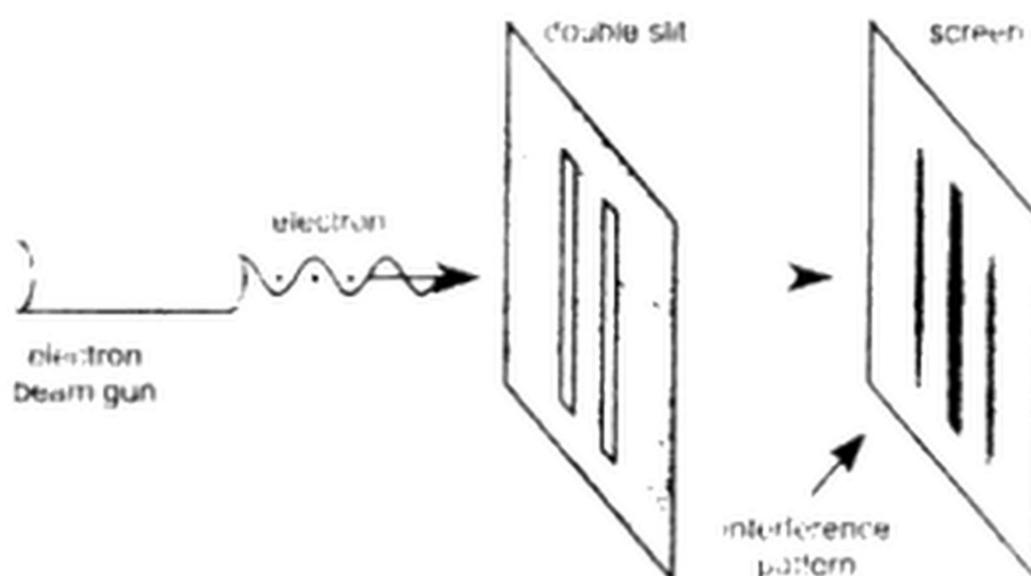
### Conditions for detectable interference pattern

The following conditions must be met, in order to observe the interference phenomenon.

- 1) The interfering beams must be monochromatic.
- 2) The interfering beams of light must be coherent.
- 3) The sources should be narrow and very close to each other.
- 4) The intensity of the two sources be comparable.

### Monochromatic Source

The sources which should emit the light of single wave length are called monochromatic sources.



### Coherent Sources

The monochromatic sources of light which emit waves, having a constant phase difference are called coherent source.

### How to obtain coherent sources

A common method to obtain the coherent light beam is to use a monochromatic source to illuminate a screen containing two small closely spaced holes, usually in the shape of slits. The light emerging from the two slits is coherent because a single source produces the original beam and two slits serve only to split it into two parts. The points on a Huygens' wave front which send out secondary wavelength are also coherent sources of light.

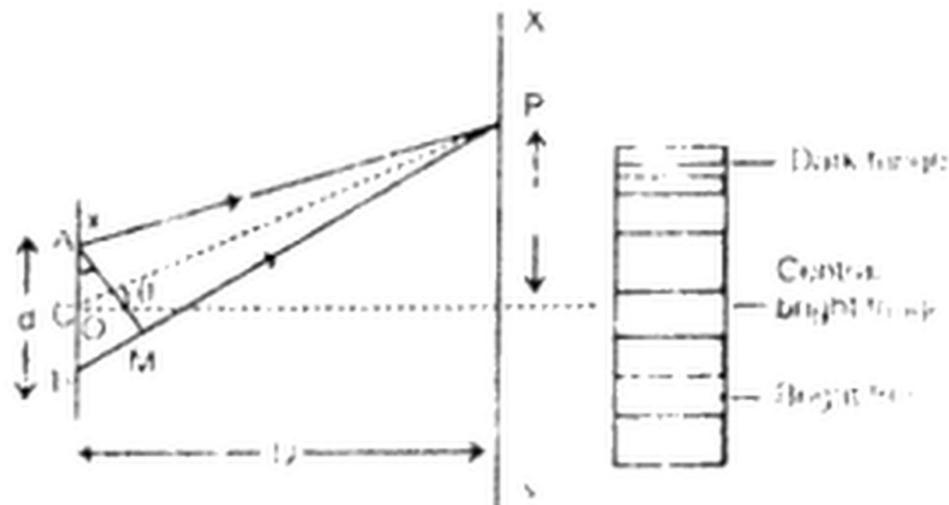
**Q.3 Describe the Young's double slit experiment for demonstration for interference of light. Derive an expression for fringe spacing.**

**Answer**

### Young's double Slit Experiment

In 1801, Thomas Young performed the interference experiment to prove the wave nature of light. A screen having two narrow slits is illuminated by a beam of monochromatic light.

The portion of wave front incident on the slit behaves like the source of secondary wavelets. The wavelets leaving the slits are coherent. Superposition of these wavelets results into the series of bright and dark bands which are observed on the second screen placed at some distance parallel to the first screen.



### Conditions for Maxima and Minima

In order to derive the equations for maxima and minima, an arbitrary point  $P$  is taken on the screen on one side of the central point  $O$  as shown in figure.  $AP$  and  $BP$  are the parts of the rays reaching  $P$ . The line  $AD$  is drawn such that  $AP = DP$ . The separation between the centers of the two slits is  $AB = d$ .

The distance of the second screen from the slits is  $CO = L$ . The angle between  $CP$  and  $CO$  is  $\theta$ . It can be proved that the angle  $BAD = \theta$  by assuming that  $AD$  is nearly normal to  $BP$ . The path difference between the wavelets, leaving slits and arriving at  $P$  is  $BD$ . From right angled triangle  $ADB$ , we can write

$$\frac{BD}{AB} = \sin\theta$$

Or  $BD = AB \sin\theta$

$$AB = d$$

$$\text{Path difference} = BD = d \sin\theta \quad (1)$$

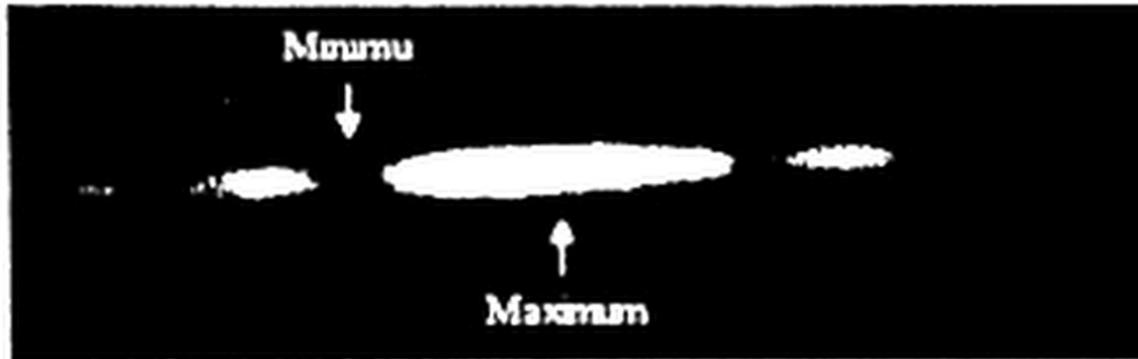


Fig 1 The bright spots are the maxima the dark spots between them are the minima

### Constructive Interference

If the point P is to have bright fringe, the path difference BD must be an integral multiple of wavelength. So,

$$BD = m\lambda$$

Thus  $d \sin \theta = m\lambda$  (2)

Where  $m = 0, 1, 2, 3,$

Where m is called the order of the fringe. At central point O, the path difference  $BP-AP=0$ , so there will be a bright fringe at O corresponding to  $m=0$ . This is called Zeroth Order fringe.

### Destructive Interference:

If a dark fringe is formed at P, the path difference BD must contain half integral multiple of wavelengths. According to the condition for dark fringe.

$$BD = \left[ m + \frac{1}{2} \right] \lambda$$

Thus  $d \sin \theta = \left[ m + \frac{1}{2} \right] \lambda$

Where  $m = 0, 1, 2, 3, \dots$

### Position of Dark and Bright Fringe:

Let  $y$  is the distance of point  $P$  from the central point  $O$  and a bright fringe is formed at  $P$ .

$$\begin{aligned} \text{As} \quad \text{Path diff} &= d \sin \theta \\ &= d \tan \theta \end{aligned}$$

(for smaller angle  $\sin \theta = \tan \theta$ )

$$\begin{aligned} &= d \left( \frac{y}{L} \right) \\ &= \frac{yd}{L} \end{aligned}$$

### Position of Bright Fringe

From equation (2)

$$\begin{aligned} \frac{yd}{L} &= m\lambda \\ y &= m \frac{yL}{d} \\ m &= 0, 1, 2, 3, \dots \end{aligned}$$

### Position of Dark Fringe:

$$\begin{aligned} \frac{yd}{L} &= \left( m + \frac{1}{2} \right) \lambda \\ y &= \left( m + \frac{1}{2} \right) \frac{yL}{d} \\ m &= 0, 1, 2, 3, \dots \end{aligned}$$

### Fringe Spacing:

The distance between the centers of two consecutive bright or dark fringes is called fringe spacing.

OR

It is the distance between two adjacent bright fringes (or dark fringes on screen).

### DOUBLE SLIT INTERFERENCE

#### Fringe width ( $\Delta y$ )

The distance between two consecutive bright or dark fringes (for small  $\theta$ ) is known as fringe width  $\Delta y$ .



The spacing between the adjacent minima is same the spacing between adjacent maxima.

#### For Two Bright Fringes:

In order to find the distance between two adjacent bright fringes on the screen  $m^{\text{th}}$  and  $(m+1)^{\text{th}}$  fringes are considered.

$$\text{Position of the } m^{\text{th}} \text{ fringe } y_m = (m) \left( \frac{\lambda L}{d} \right)$$

$$\text{Position of the } (m+1)^{\text{th}} \text{ fringe} = y_{m+1} = (m+1) \left( \frac{\lambda L}{d} \right)$$

Then

$$\begin{aligned} \Delta y &= y_{m+1} - y_m \\ &= (m+1) \left( \frac{\lambda L}{d} \right) - (m) \frac{\lambda L}{d} \\ &= (m+1-m) \frac{\lambda L}{d} \\ &= \frac{\lambda L}{d} \end{aligned}$$

#### For Two Dark Fringes:

In order to find the distance between two adjacent dark fringes on the screen

$\left(m + \frac{1}{2}\right)$ th and  $\left(m + \frac{3}{2}\right)$ th fringes are considered.

$$\text{Position of } \left(m + \frac{1}{2}\right)\text{th fringe} = y_m = \left(m + \frac{1}{2}\right)\left(\frac{\lambda L}{d}\right)$$

$$\text{Position of } \left(m + \frac{3}{2}\right)\text{th fringe} = y_{m+1} = \left(m + \frac{3}{2}\right)\left(\frac{\lambda L}{d}\right)$$

Then

$$\Delta y = y_{m+1} - y_m$$

$$\Delta y = \left(m + \frac{3}{2}\right)\left(\frac{\lambda L}{d}\right) - \left(m + \frac{1}{2}\right)\left(\frac{\lambda L}{d}\right)$$

$$\Delta y = \left(m + \frac{3}{2} - m - \frac{1}{2}\right)\left(\frac{\lambda L}{d}\right)$$

$$\Delta y = \left(\frac{\lambda L}{d}\right)$$

Hence the bright and dark fringes are of equal width and equally spaced. The fringe spacing varies directly with distance 'L' between the slits and screen and inversely with the separation 'd' of the slits.

The formula for the fringe spacing can be used for the determination of the wavelength.

#### Q.4 Explain the phenomenon of interference of light in a thin film?

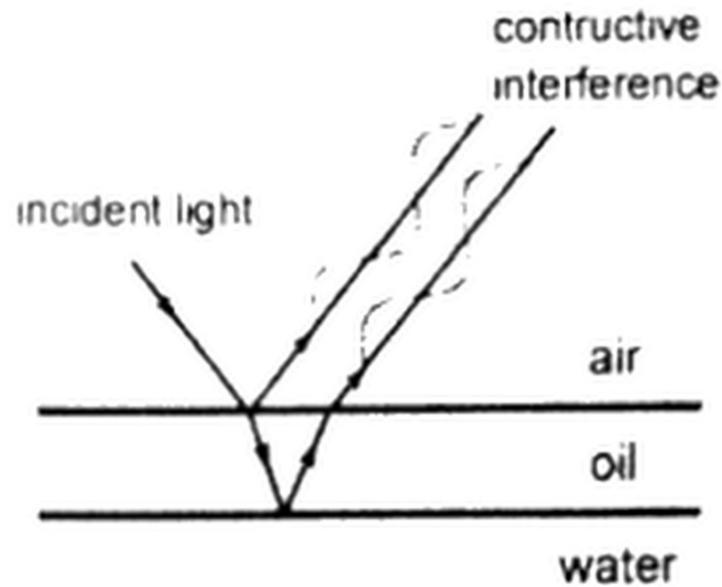
**Answer**

##### Interference in a Thin Film

"A transparent medium whose thickness is very small (Comparable with the wavelength of light) is called thin film."

**Examples:**

- (i) Oil film on the surface of water.
- (ii) Surface of soap bubble.
- (iii) Cracks in glass plate.



### Explanation

Consider a thin film of a refracting medium. A beam AB of monochromatic light of wavelength  $\lambda$  is incident on its upper surface. It is partly reflected along BC and partly refracted into the medium along BD. At D it is again partly reflected inside the medium along DE and then along EF as shown in fig. The distance between the beams BC and EF will be very small, and they will superpose and the result of their interference will be detected by the eye.

It can be seen from fig. that the original beam splits into two parts BC and EF due to thin film which enters the eye after covering different lengths of path. The path difference depends upon;

1. Thickness of the film.
2. Nature of the film.
3. Angle of incidence.

If the two reflected waves reinforce each other, then the film will look bright. However, if the thickness of the film and the angle of incidence are such that the two reflected waves cancel each other, the film will look dark.

### Film of irregular thickness

If white light is incident on a film of irregular thickness at all possible angles, we should consider the interference pattern due to each spectral colour separately.

But if the thickness of the film and the angle of incidence are such that the destructive interference takes place from one colour. Then the remaining colour of the white light will make appearance on the film.

**Peacock Feathers & Hummingbirds have tiny ridges.  
Reflected Light of different  $\lambda$  interferes constructively or destructively**



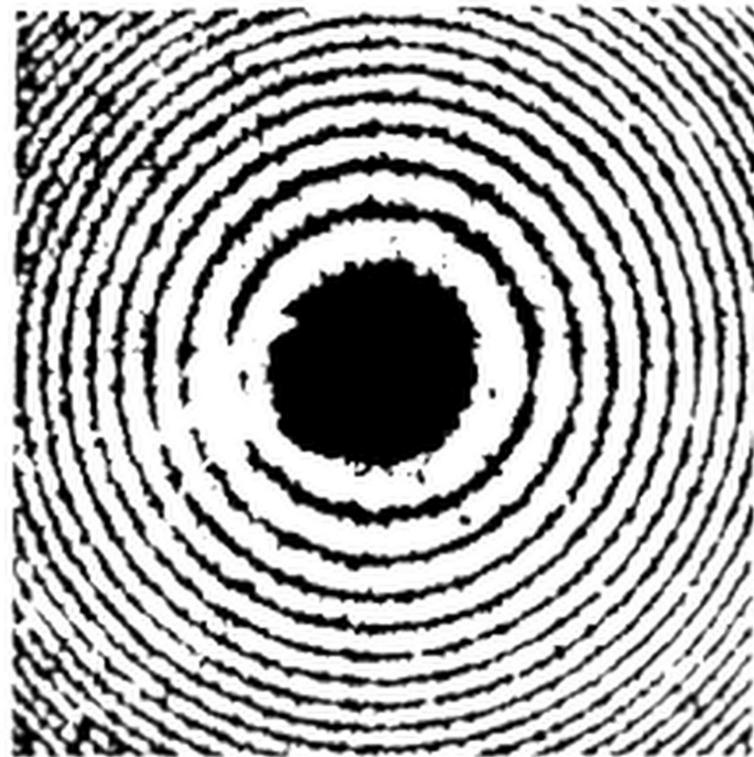
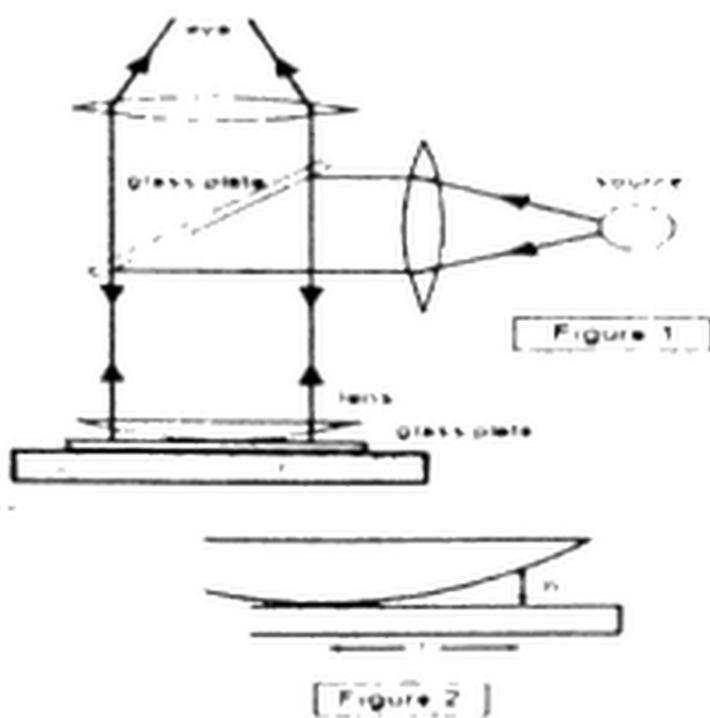
Figure 27.20 Interference in thin films

**Q.5 Discuss the formation of Newton's rings. Why does the central spot of Newton's ring look dark?**

**Answer**

**Newton's Ring**

“When a plano-convex lens of long focal length is placed in contact with a plane glass plate, a thin air film is enclosed between them to form circular dark and bright fringes known as Newton's rings.”



### Experimental arrangement

The thickness of the air film between plano-convex lens and glass slit is almost zero at the point of contact 'O' and it increases gradually as we proceed towards the periphery of the lens. Thus, the point where the thickness of the air film is constant will lie on the circle with O as center. Light beam from a monochromatic source 'S' becomes parallel after passing through the convex lens 'L'. This beam of light falls on the glass plate G. Some rays are partly reflected normally towards the air film and partly refracted through G. When light rays fall normally on the lens, these rays are reflected by the top and bottom surfaces of the air film. As these rays are coherent and interfere each other constructively or destructively.

When the light reflected upward is observed through a microscope. "M" focused at the glass plate G, a series of dark and bright circular rings are observed, as shown in figure. These concentric rings are called Newton's rings.

**Dark Central Spot:**

At the point of contact of the lens and the glass plate, the thickness of the film is effectively zero but due to reflection at the lower surface of air film from denser medium, an additional path difference of  $\lambda/2$  is (or phase change of  $180^\circ$ ) introduced. Consequently, the center of Newton's rings is dark due to destructive interference.

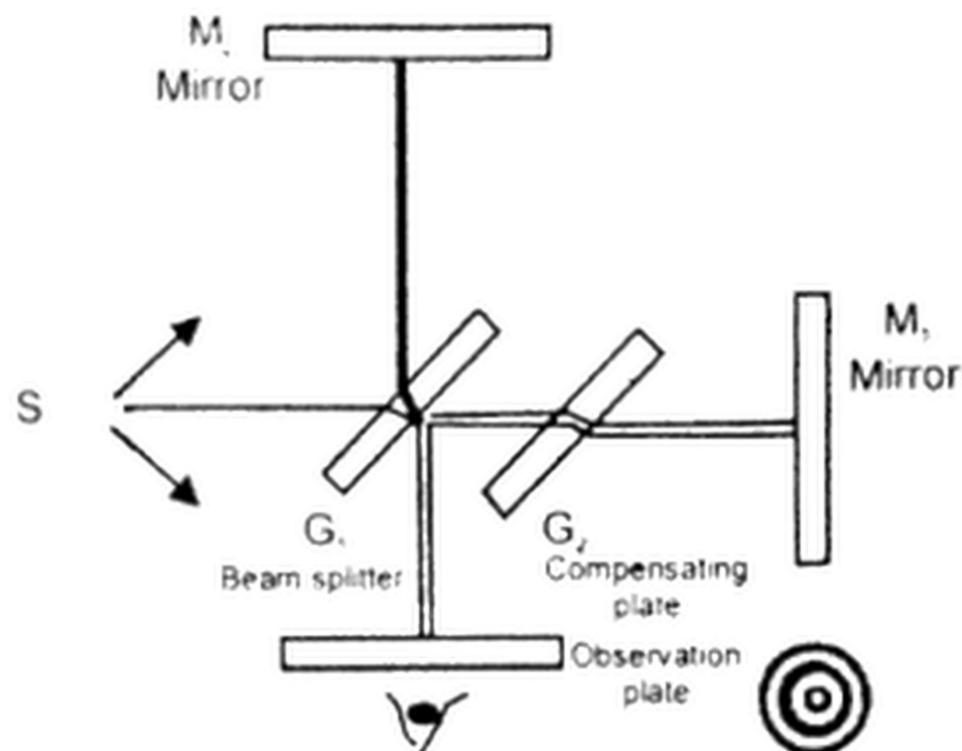
**Q.6. Describe the principle, construction and working of Michelson's interferometer. How can you find the wave length of light used?**

**Answer**

**Michelson's Interferometer**

Michelson's interferometer is an instrument that can be used to measure distance with extremely high precision.

Albert A Michelson devised this instrument in 1881, using the idea of interference of light rays.

**Experiment Principle**

## Principle

Its working is based on interference. When light from a single source is split into two parts and then interferes it, forms an interference pattern.

## Construction and working

The essential features of a Michelson's interferometer are shown schematically in figure.

## Working

Monochromatic light from an extended source falls on a half-silvered glass plate  $G_1$  that partially reflects it and partially transmits it. The reflected portion labelled as I in the figure travels a distance  $L_1$  to mirror  $M_1$ , which reflects the beam back towards  $G_1$ .

The half-silvered plate  $G_1$  partially transmits this portion that finally arrives at the observer's eye. The transmitted portion of the original beam labelled as II, travels a distance  $L_2$  to mirror  $M_2$  which reflects the beam back towards  $G_2$  cut from the same piece of glass as  $G_1$  is introduced in the path of beam II as a compensator plate.  $G_2$  therefore equalizes the path length of the beam I and II in glass. The two beams having their different paths are coherent. They produce interference effects when they arrive at observer's eyes.

The observer then sees a series of a parallel-interference fringes. In a practical interferometer, the mirror  $M_1$  can be moved along the direction perpendicular to its surface by means of a precision screw. As the length  $L_1$  is changed, the pattern of interference fringes is observed to shift.

If  $M_1$  is displaced through a distance equal  $\lambda/2$ , a path difference of double of this displacement (i.e.  $\frac{\lambda}{2} + \frac{\lambda}{2} = \lambda$ ) is produced, i.e. equal to  $\lambda$ . Thus a fringe is seen shifted forward across the line of reference of cross wire in the eye piece of the telescope used to see the fringes. A fringe is shifted each time the mirror is

displaced through  $\lambda/2$ . Hence, by counting the number  $m$  of the fringes which are shifted by the displacement  $L$  of the mirror. We can write the equation,

$$L = m \frac{\lambda}{2}$$

Or 
$$\lambda = \frac{2L}{m}$$

Very precise length measurements can be made with an interferometer.

### Uses

Michelson's interferometer is used for the following purposes:

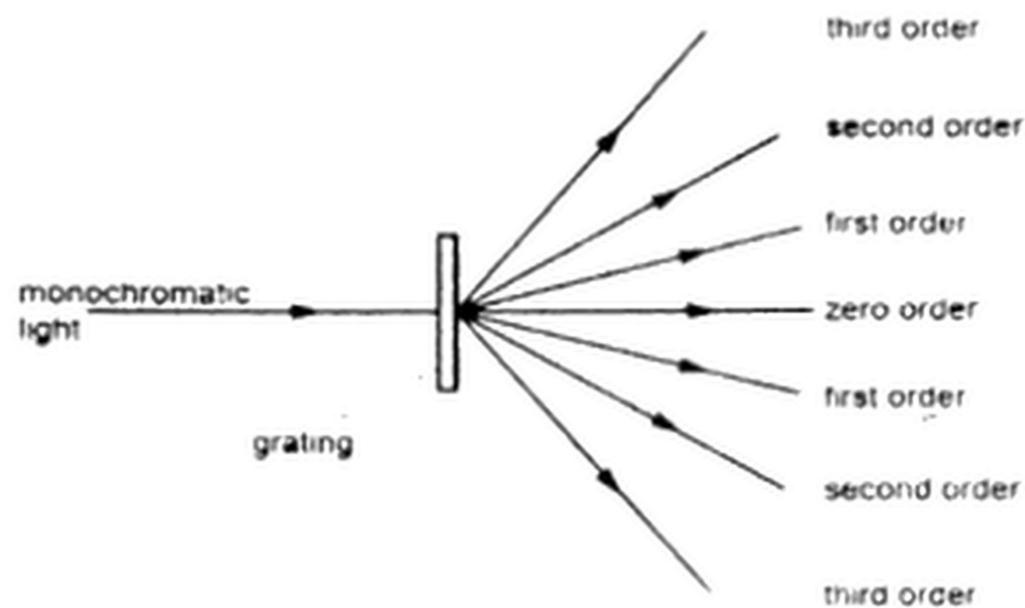
- 1) It is used for the determination of wavelength of light.
- 2) Michelson measured the length of the standard meter in terms of wavelength of red cadmium light and proved that Standard meter = 1553163.5 wavelength of light.
- 3) If light of wavelength  $\lambda=400$  nm is used, then it can measure the thickness up to  $10^{-4}$  nm (or 100 nm).
- 4) If it is used to observe the interference of light.

**Q.7 What is meant by diffraction of light? Also discuss the diffraction of light through a narrow slit?**

**Answer**

### Diffraction of Light

The property of bending of light around obstacles and spreading of light waves into the geometrical shadow of an obstacle is called diffraction.



### Explanations:

Consider a small and smooth steel ball of about 3 mm in diameter is illuminated by a point source of light 'S', the shadow of the object is received on a screen as shown in figure. The shadow of the spherical object is not completely dark but has a bright spot at its center. It happens only if the light bends around the obstacle.

### Conclusion

This phenomenon becomes prominent when the wavelength of light is large as compared with the size of the obstacle or aperture of the slit.

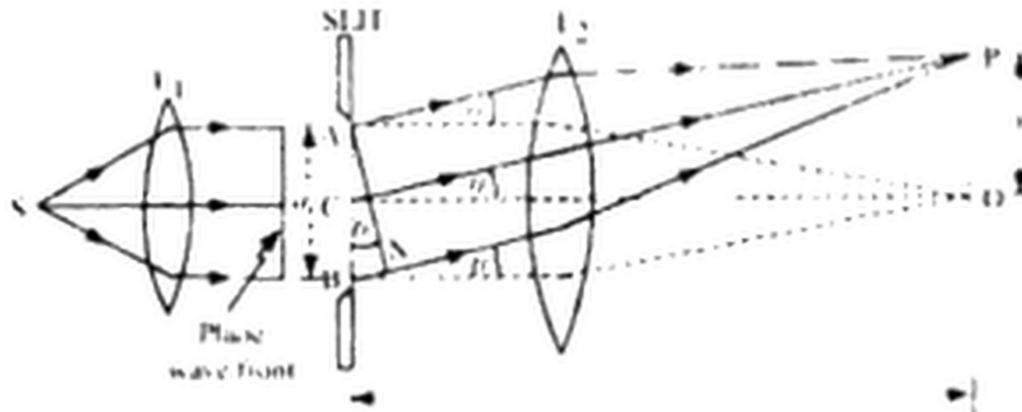
The diffraction of light occurs, in effect, due to the interference between rays coming from different parts of the same-wave front.

### Diffraction of light through a narrow slit:

The experimental arrangement for studying diffraction of light due to narrow slit is shown in figure.

Let us consider a slit AB of width  $d$  is illuminated by a parallel beam of monochromatic light of wavelength ' $\lambda$ '. A small portion of the incident wavefront passes through the narrow slit. Each point of this section of wave front sends out secondary wavelets to the screen. These wavelets then interfere to produce the diffraction pattern. It becomes simple to deal with rays instead of

wave fronts. Only nine rays have been drawn whereas actually there are a large number of rays.



Let us consider ray 1 and 5 which are in phase when in the wave front AB. After these reach the wave front AC, ray 5 would have a path difference 'ab' say equal by  $\lambda/2$ . Thus, when these two rays reach point P on the screen, they will interfere destructively. Similarly, each pair 2 and 6, 3 and 7, 4 and 8 differ in path by  $\lambda/2$  and will do the same.

In order to find the value of path difference ab, we consider the right-angle triangle aAb, as shown in figure.

$$\sin \theta = \frac{ab}{AB/2}$$

or  $ab = \frac{AB}{2} \sin \theta$       But  $AB = d$

thus  $ab = \frac{d}{2} \sin \theta$

For destructive interference (first minimum),  $ab = \frac{\lambda}{2}$

Hence equation for first minimum can be written as

$$\frac{d}{2} \sin \theta = \frac{\lambda}{2}$$

or  $d \sin \theta = \lambda$

Where  $m = \pm 1, \pm 2, \pm 3, \dots$

The region between any two consecutive minima both above and below the centre by bright i.e. maxima. In this way we may obtain series of alternate dark and bright fringes with central bright.

**Q.8 What is diffraction grating and obtain the grating equation to find the wavelength of light?**

**Answer**

### Diffraction Grating

"A diffraction grating consists of glass plate on which very fine equidistant parallel line (scratches) are drawn by mean of ruling engine with fine diamond point. The transparent spacing between the scratches on the glass plate acts as slits."

A typical diffraction grating has about 400 to 5000 lines per centimeter.



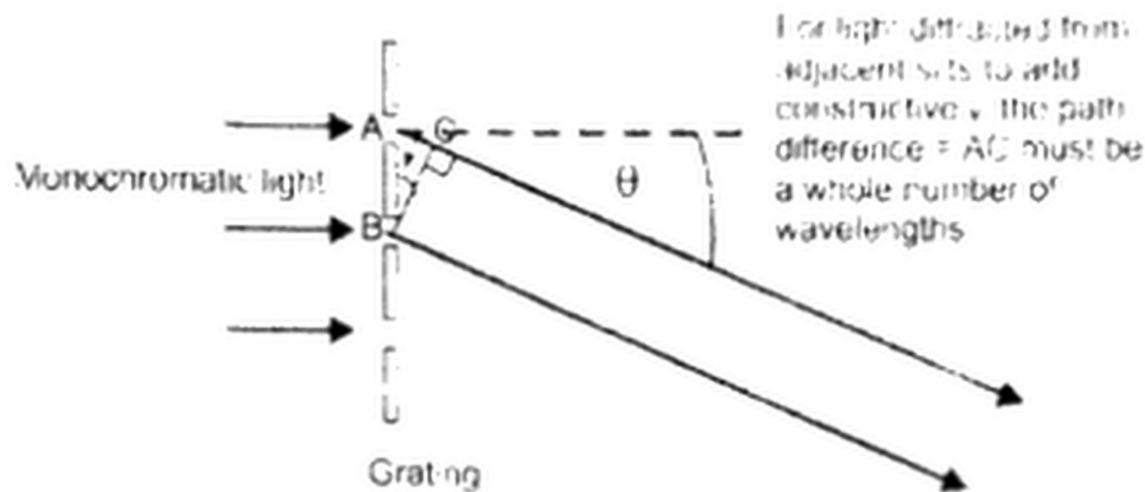
### Grating element

"The distance between the centers of two adjacent lines is called grating element."

Its value is obtained by dividing the length  $L$  of the grating by the total number  $N$  of the line's rules on it.

So, the grating element =  $d = L/N$ .

If we consider the unit length of the diffraction grating then  $d = 1/N$ .



$$AC = AB \sin \theta \text{ and } AB \text{ is the grating element } = d$$

**Hence**  $d \sin \theta = n\lambda$   $d =$  grating element

$$d = \frac{1}{\text{number of lines per metre}}$$

### Working and Theory

Consider the parallel beam of monochromatic light illuminating the grating at normal incidence. The parts of the wave front that pass through the slits behaves as source of secondary wave lets according to Huygens' principle.

Consider the parallel rays which make an angle  $\theta$  with  $AB$  after diffraction. They are then brought to focus on the screen at  $P$  by convex lens. If the path difference between ray 1 and 2 is one wavelength  $\lambda$ , they will reinforce each other at  $P$ . As the incident beam consists of the parallel rays, the rays from any two consecutive slits will differ in path by  $\lambda$ , when they arrive at  $P$ . They will therefore, interfere constructively.

### Grating Equation

The path difference for constructive interference between two consecutive rays should be integral multiple of  $\lambda$  i.e.

$$\text{Path diff} = ab = \lambda \quad (1)$$

From figure, acb is a right-angle triangle

$$ab/ac = \sin\theta$$

Or  $ab = ac \sin\theta$

$$ab = d \sin\theta \quad (2)$$

Comparing (1) and (2)

$$\lambda = d \sin \theta \quad (3)$$

According to equation (2), if  $\theta=0^\circ$ , then path difference = 0, so we will get a bright fringe. This is known as zero order image formed by the grating. If we increase  $\theta$  on either side of this direction, a value of  $\theta$  will be arrived at which  $\lambda = d \sin\theta$  and we again get bright image. If path difference is the integral multiple of  $\lambda$ , we will get second, third order etc. images.

Therefore, in general we can write

$$d \sin\theta = n \lambda \quad \text{Where } n = 0, 1, 2, 3, \dots$$

This is called the equation of grating and 'n' is called the order of diffraction  $n=0$ , is the central maxima,  $n=1$  is the maxima and so on. The separate images are obtained corresponding to each wavelength or colour.

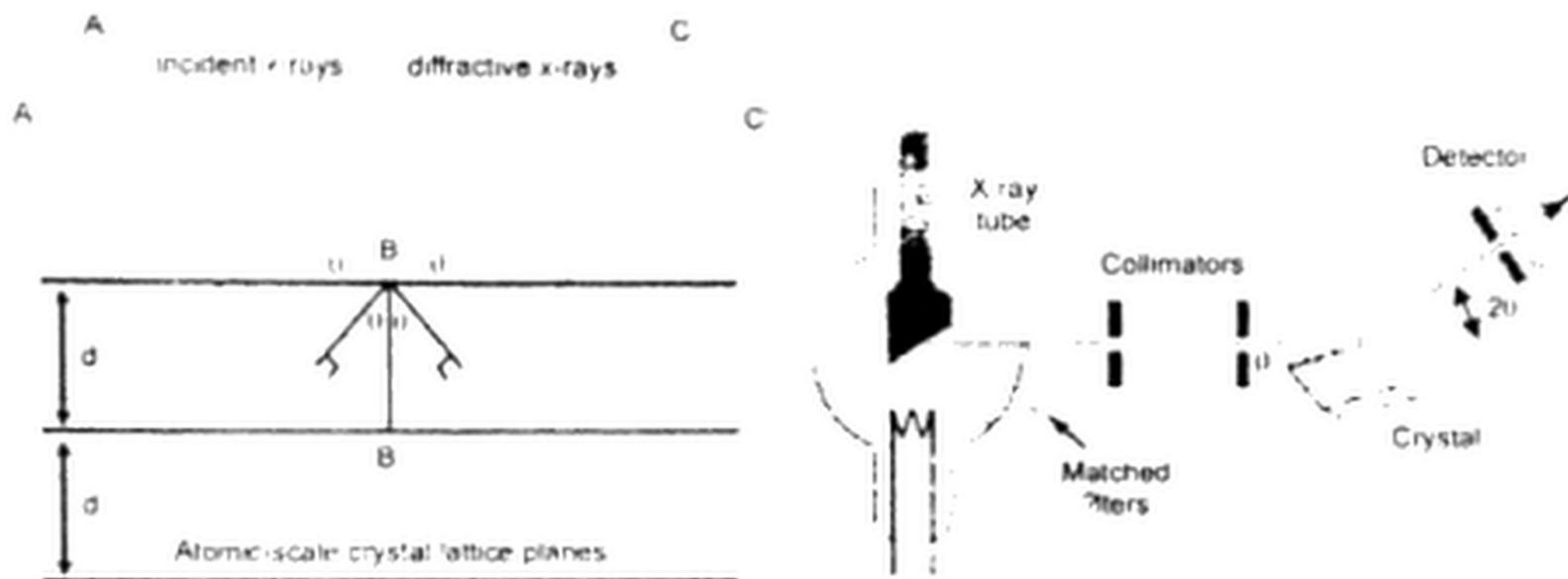
**Q.9 Describe the diffraction of x-rays through crystals? Also describe the Brags equation and its different uses?**

**Answer.**

**Diffraction of x-Rays by Crystals**

X-rays is type of electromagnetic radiation of much shorter wavelength, of the order of  $10^{-10}$  m.

In order to observe the effect of diffraction, the grating spacing must be of the order of the wavelength of the radiation used. The regular array of atoms in a crystal forms a natural diffraction grating.



The study of atomic structure of crystals by X-rays was initiated in 1914 by W.H. Bragg and W.L Bragg with remarkable achievements. They found that a monochromatic beam of X-rays was reflected from a crystal plane as if it acted like mirror. To understand this effect, a series of atomic planes of constant inter planar spacing 'd' parallel to a crystal face are shown by lines PP', P<sub>1</sub>P<sub>1</sub>', P<sub>2</sub>P<sub>2</sub>' shown in fig. and so on.

### Bragg's equation:

Suppose an x-ray beam is incident at an angle  $\theta$  on one of the planes. The beam reflected from the lower plane travels some extra distance (BC+CB') as compare between the two reflected beams in BC+CB'.

From triangle ABC, we have

$$\frac{BC}{AC} = \sin \theta$$

Or  $BC = AC \sin \theta$

Or  $BC = d \sin \theta$  As  $AC = d$

Similarly, from triangle  $ACB'$ , we have

$$\frac{CB'}{AC} = \sin \theta$$

$$CB' = AC \sin \theta$$

$$CB' = d \sin \theta$$

Thus, path difference =  $BC + CB'$

$$= d \sin \theta + d \sin \theta \quad \dots\dots\dots(1)$$

$$= 2 d \sin \theta$$

Both reflected beams will reinforce (constructive interference) if path difference is equal to integral multiple of wavelength. Hence for constructive integral multiple of wavelength. Hence for constructive interference

$$\text{Path difference} = n \lambda \quad \dots\dots\dots (2)$$

Comparing 1 and 2, we get

$$2d \sin \theta = n \lambda \quad \text{where } n = 1, 2, 3, \dots\dots\dots$$

Where  $n$  is the order of reflection. This is known as Bragg's equation, or Bragg's law.



## Uses

- 1) Bragg's equation can be used to determine the interplanar spacing between similar parallel planes of a crystal i.e.  $d = \frac{n\lambda}{2\sin\theta}$
- 2) X-rays diffraction is very useful in determining the structure of biologically important molecules such as hemoglobin, which is an important constituent of blood, and double helix structure of DNA.
- 3) Bragg's equation can be used to determine the wave length of light  
[i.e.  $\lambda = \frac{2d\sin\theta}{n}$ ]

**Q10. Explain the phenomenon of polarization. How plane polarized light is produced and detected?**

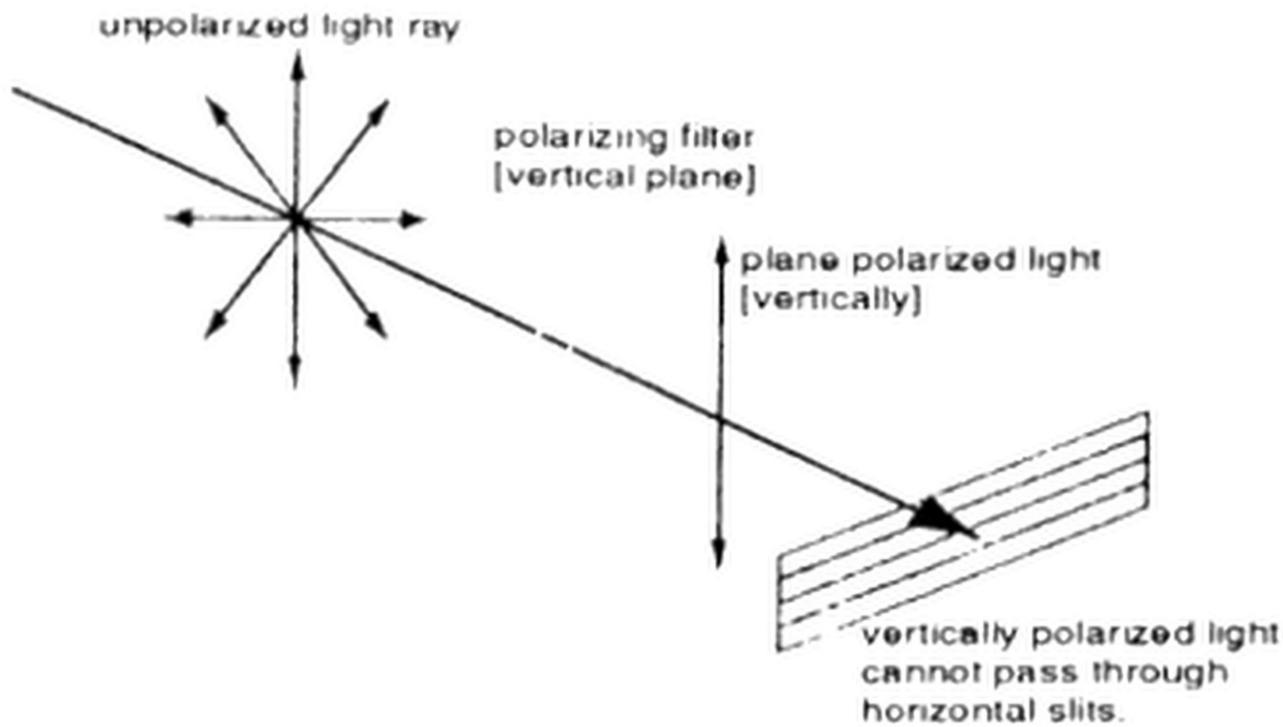
**Answer**

**Polarization**

The phenomenon of interference and diffraction have proved that light has wave nature but these phenomena do not show whether light waves are longitudinal transverse.

In transverse mechanical waves, the vibration can be oriented along vertical, horizontal or any other direction. In each of these cases, the wave is said to be polarized.

The plane of polarization is the plane containing the direction of vibration of the particles of the medium and the direction of propagation of wave.



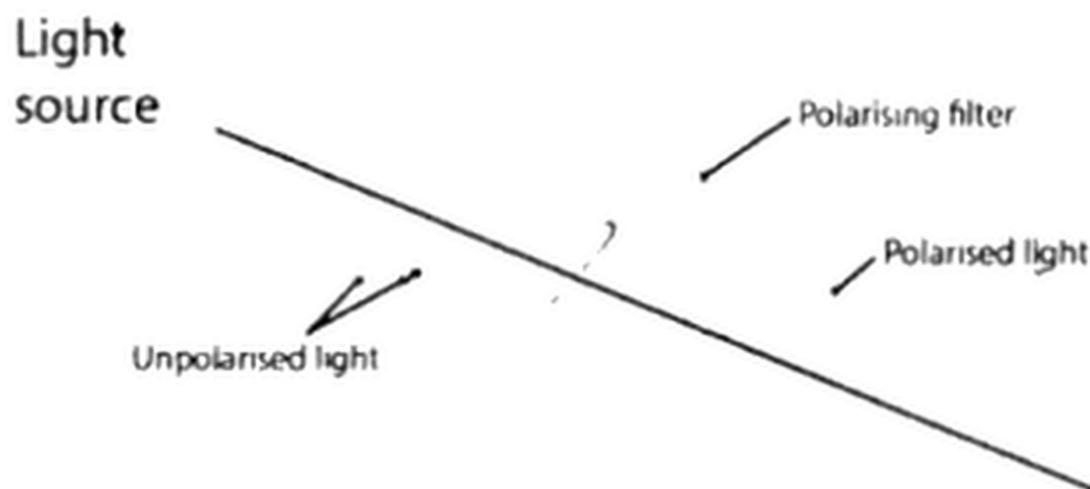
A light wave produced by oscillating charge consists of a periodic variation of electric field vector along with magnetic field vector at right angle to each other. The direction of polarization in a plane polarized light wave is taken as the direction of electric field vector.

### Unpolarized light

A beam of ordinary light consisting of large number of planes of vibration is called unpolarized light.

### Polarized light

The beam of light in which all vibrations are confined to a single plane of vibration is called polarized light.





If the un-polarized light is made incident on the sheet of Polaroid, the transmitted light will be plane polarized. If a second sheet of Polaroid is placed in such a way that the axes of the Polaroid, as shown by the straight lines drawn on them, are parallel, the light is transmitted through the second Polaroid also. If the second Polaroid is slowly rotated about the beam of light, as axis of rotation, the light emerging out of the second Polaroid gets dimmer and dimmer and disappears when the axes become mutually perpendicular. The light reappears on further rotation and become brightest when the axes are again parallel to each other.

### **Transverse Nature of Light**

This experiment proves that light waves are transverse waves. If the light waves were longitudinal, they would never disappear even if the two Polaroids were mutually perpendicular. Sunlight also becomes partially polarized because of scattering by air molecules of the Earth's atmosphere or by reflection we can obtain the partially polarized light instead of glare of light.

### **Reflection from different surfaces:**

Reflection of light from water, glass, snow and rough road surfaces, for larger angles of incidences, produces glare. Since the reflected light is partially polarized, glare can considerably be reduced by using polarized sunglasses.

### **Scattering by small particles:**

Reflection of light from water, glass, snow and rough road surfaces, for larger angles of incidences, produces glare. Since the reflected light is partially polarized, glare can considerably be reduced by using polarized sunglasses.

### **Scattering by small particles:**

Sunlight also becomes partially polarized due to scattering by air molecules of earth's atmosphere. This effect can be observed by looking directly up through

a pair of sunglasses made of polarizing glass. A certain direction of the lens, less light passes through it than at others.

### Polaroid:

A synthetic doubly refracting substance, that strongly absorbs polarized light in one plane, while easily passing polarized light in another plane of right angles.

### Q.11 What is meant by optical rotation?

#### Answer

#### Optical Rotation

When a plane polarized light is passed through certain crystals. They rotate the plane of polarization. Quartz and sodium chlorate crystals are typical examples, which are termed optically active crystals.

A few millimeter thicknesses of such crystals will rotate the plane of polarization by many degrees. Certain organic substances, such as sugar and tartaric acid, show optical rotation when they are in solution, this property of optical active substances can be used to determine the concentration in the solutions.

