NATURE OF LIGHT 9

DUAL NATURE OF LIGHT:

Light is a form of energy which enables us to see different objects. Light energy can be changed to other forms of energies. There are many theories about the nature of light, which are:

- Newton's corpuscular theory of light.
- Huygen's wave theory of light.
- Maxwell's electromagnetic theory of light.
- Plank's quantum theory of light.

NEWTON'S CORPUSCULAR THEORY OF LIGHT:

According to this theory, *"light is emitted from a luminous body in the form of tiny particles called CORPUSCLES".*

These corpuscles move in straight lines with the velocity of light. Corpuscles of different size correspond to different colours. These corpuscles reach the eye & give the sensation of vision. The velocity of corpuscle increases in denser medium and also increases with the increase of temperature of the emitting body. But it was proved wrong.

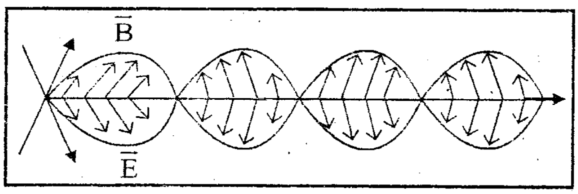
This theory explains the phenomenon of refraction, reflection & formation of images. This theory could not explain the phenomenon of interference & diffraction of light.

HUYGEN'S WAVE THEORY OF LIGHT:

According to this theory, *"light travels in the form of waves which require some medium for their propagation".* This medium was called *ETHER* & it was supposed that it filled all spaces, which was proved wrong. According to this theory velocity of light decreases in denser medium. This theory not only explains the phenomenon of reflection, refraction & formation of image but also explains the phenomenon of interference & diffraction.

MAXWELL'S ELECTROMAGNETIC THEORY OF LIGHT:

According to this theory, ***"light waves are electromagnetic which consists of varying electric & magnetic fields".*** Both electric & magnetic fields are perpendicular to each other & also perpendicular to the direction of propagation of light. These waves travel with the speed of light & require no medium for their propagation. This theory proves that light waves are transverse waves. This theory could not explain phenomenon of ***"PHOTOELECTRIC EFFECT".***



PLANK'S QUANTUM THEORY OF LIGHT:

According to this theory, ***"light is emitted from a luminous body in the form of groups or packets or bundles"***. These energy packets of light are called ***PHOTONS.*** The energy passed by a photon depends, upon its frequency. Greater the frequency of photon greater will be the energy passed by it. If "ν" be the frequency of a photon, then its energy "E" is given by.

$$E = h\nu$$

Where "h" is the plank's constant & its value is 6.626×10^{-34} Js

This theory explains the phenomenon of ***"PHOTOELECTRIC EFFECT"*** as well as ***"COMPTON EFFECT".***

CONCLUSION:

From the above theories we conclude that there are certain phenomenon of light, such as interference, diffraction & polarization which can be explained on the basis of wave theory of light. There are also some other effects such as photoelectric effect which can be explained on the basis of quantum theory of light. Hence it is concluded that light has dual nature, sometime it behaves like a wave and sometime like a particle.

WAVE FRONT:

All the points on the crest are in the same state of vibration i.e. they have same phase. The locus of all the point in a medium having the same phase is known as ***WAVE FRONT.***

SPHERICAL WAVE FRONTS:

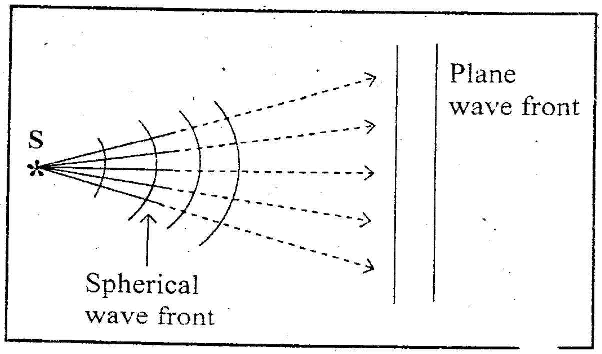
In case of a point source of light in a certain homogenous medium, the wave front will be concentric spheres with centre at the source, such type of wave front is known as ***SPHERICAL WAVE FRONT.***

PLANE WAVE FRONTS:

At a very large distance from the source, a small portion of a spherical wave front become nearly plane. Such portion of the wave front is called ***PLANE WAVE FRONT.***

RAYS OF LIGHT:

The direction of the motion of a wave front is denoted by lines known as RAYS which are always perpendicular to the wave front.



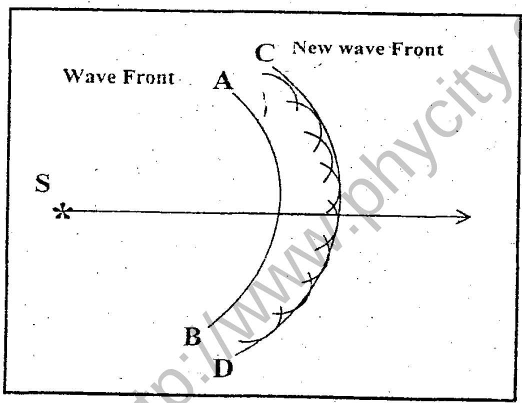
HUYGEN'S PRINCIPLE:

The position of the wave front at any instant can be determined by ***HUYGEN'S PRINCIPLE.*** This principle has two parts.

1) Every point on a wave front acts as source for secondary spherical wave-lets.
2) The new position of wave front after a time "t" can be found by drawing plane tangential to the secondary wave-lets.

EXPLANATION:

Consider a portion AB of a spherical wave front at a particular instant. For the position of new wave front after time "t", draw arcs (called WAVE-LETS) of radius "ct" with centre at wave front AB. (where "c" is the velocity of light). Now draw a plane CD which gives the new position of the wave front.



ORDINARY LIGHT:

Ordinary light consists of different colours. The colour of light depends upon the frequency. When this light is allowed to fall on a prism, various colours can be seen. Light coming from the sun is ordinary light.

MONOCHROMATIC LIGHT:

Light of single frequency is known as monochromatic light, but it is very difficult to get such light. Light emitted by sodium lamp is of yellow colour, but it consists of two waves of slightly different frequencies.

INTERFERENCE OF LIGHT:

The modification in the distribution of light energy due to superposition of two or more waves is called interference of light.

CONSTRUCTIVE INTERFERENCE:

When crests or troughs of two light waves reach at a point simultaneously, they support each other due to which brightness is seen or bright fringe is obtained on the screen. This phenomenon is called "constructive interference". In this phenomenon intensity of resultant wave increases.

DESTRUCTIVE INTERFERENCE:

When crest of one wave & trough of the other wave reach at a point simultaneously, they cancel the effect of each other due to which darkness is seen or dark fringe is obtained on the screen. This phenomenon is called "destructive interference". In this phenomenon intensity of the resultant wave decreases.

CONDITIONS FOR INTERFERENCE:

1) Light source should be monochromatic.
2) Light source should be coherent i.e. they should not be independent but should be subsidiary source & derived from a single source.
3) The light source should be narrow & have same intensity.
4) For constructive interference, path difference between light rays must be zero or integral multiple of wavelength of the light.

   Path difference = $0, \lambda, 2\lambda, 3\lambda$ ---------. $m\lambda$ where $m = 0, 1, 2, 3,$ ---------
5) For destructive interference, the path difference between the light rays should be odd integral multiple of half the wavelength of the light.

   Path difference = $\lambda/2, \frac{3\lambda}{2}, 5\frac{\lambda}{2}, 7\frac{\lambda}{2}$, ------$(m + \frac{1}{2})\lambda$ where $m = 0, 1, 2, 3$---

   OR where m = integers

   Path difference = $\lambda/2, \frac{3\lambda}{2}, 5\frac{\lambda}{2}, 7\frac{\lambda}{2}$, ------$(m - \frac{1}{2})\lambda$ where $m = 1, 2, 3, 4, 5$--

   where m = no. of fringes

YOUNG'S DOUBLE-SLIT EXPERIMENT:

The phenomenon of interference of light was first demonstrated by Thomas Young. His apparatus consists of a screen having a narrow slit, which is illuminated by a monochromatic light source "S". The waves emerging out from this slit is then allowed to incident on a second screen which has two narrow parallel slits S_1 & S_2. Light after passing through these slits interfere with each other. To see the interference fringes, a screen is placed at some distance from these slits as shown in figure (1).

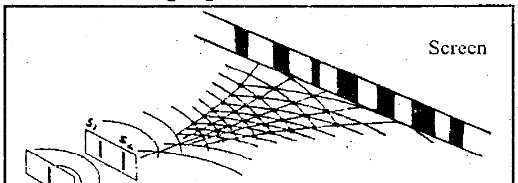


Figure (1)

DETERMINATION OF THE WAVELENGTH OF LIGHT:

Consider two narrow slits S_1 & S_2 separated by a small distance "d" from each other. The slits are illuminated by a monochromatic light of wavelength "λ". A screen is placed at a distance "L" from the slits to observe the interference pattern, as shown in fig (2).

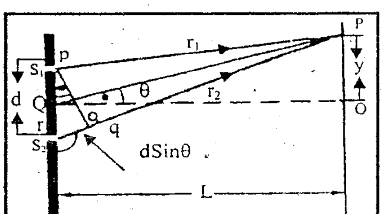


Figure (2)

Draw a perpendicular QO from the mid point Q of slits S_1 & S_2. On the screen at O, it will cover equal path and interfere constructively due to which brightness will be obtained at O. Now consider point P on the screen at a distance y_m from O where mth fringe is obtained. Light reaching from S_2 to P cover greater path as compared to that reaching from S_1 to P. The path difference between S_1P & S_2P can be found by drawing a perpendicular from S_1 on S_2 P & is given by

$$S_2P - S_1P = r_2 - r_1 = d \sin\theta$$

CONDITIONS FOR MAXIMA:

If the path difference between rays S_1P & S_2P is 0, λ, 2λ, -----, mλ then crests or troughs of both the rays will reach at P simultaneously due to which constructive interference will take place & P will be bright. Hence for brightness we can write:

$$d \sin\theta = m\lambda \text{ ----- (maxima)} \longrightarrow (1)$$

where **m = 0, 1, 2, 3, ------------**

When m = 0, the image will be obtained at O & is called *ZEROTH ORDER MAXIMUM.*

When m = 1, the image obtained is called 1st ORDER MAXIMUM and so on.

CONDITIONS FOR MINIMA:

If the path difference between rays S_1P & S_2P is $\frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \text{-------}, \left(m+\frac{1}{2}\right)\lambda$ then crest of one wave & trough of the other wave will reach at P simultaneously. Thus destructive interference will take place & P will be dark, hence for darkness we can write.

$$d \sin\theta = \left(m+\frac{1}{2}\right)\lambda \text{ --------- (minima)} \longrightarrow (2)$$

where m = 0, 1, 2, 3, -------

POSITION OF BRIGHT & DARK FRINGES:

The position of bright & dark fringes can be found by considering triangle QOP. Here

$$\textbf{Sin } \theta = \frac{\overline{OP}}{\overline{QP}} = \frac{y_m}{PQ}$$

In actual experiment PQ ≅ QO = L

$$\therefore \quad \text{Sin } \theta = \frac{y_m}{L}$$

Multiplying both sides by "d"

$$d \sin\theta = d\,\frac{y_m}{L} \longrightarrow (3)$$

For the position of BRIGHT FRINGE, comparing eq (1) & (3)

$$d\,\frac{y_m}{L} = m\lambda$$

$$\boxed{y_m = \frac{m\lambda L}{d}} \longrightarrow (4)$$

For the position of DARK FRINGE, comparing eq (2) & (3)

$$d\,\frac{y_d}{L} = \left(m+\frac{1}{2}\right)\lambda$$

$$y_d = \left(m+\frac{1}{2}\right)\frac{\lambda L}{d} \longrightarrow (5)$$

where m = 0, 1, 2, 3, --------

BRIGHT FRINGE SPACING:

The distance between two consecutive bright fringes is called "Bright Fringe Spacing". For first bright fringe put m = 1 in eq. (4)

$$y_1 = \frac{\lambda L}{d} \longrightarrow (6)$$

For second bright fringe put m = 2 in eq. (4)

$$y_2 = \frac{2\lambda L}{d} \longrightarrow (7)$$

Subtracting eq. (6) from eq. (7), we get Bright fringe spacing

$$\Delta y = y_2 - y_1 = \frac{2\lambda L}{d} - \frac{\lambda L}{d}$$

$$\boxed{\text{Bright Fringe Spacing} = \Delta y = \frac{\lambda L}{d}} \longrightarrow (8)$$

DARK FRINGE SPACING:

The distance between two dark fringes is called *"Dark Fringe Spacing"*. For first dark fringe put m = 0 in eq. (5)

$$y_1 = \left(0 + \frac{1}{2}\right)\frac{\lambda L}{d}$$

$$y_1 = \frac{\lambda L}{2d} \longrightarrow (9)$$

for second dark fringe put m = 1 in eq (5)

$$y_2 = \left(1 + \frac{1}{2}\right)\frac{\lambda L}{2d}$$

$$y_2 = \frac{3\lambda L}{2d} \longrightarrow (10)$$

Subtracting eq. (9) from eq. (10), we get Dark fringe spacing

$$\Delta y = y_2 - y_1 = \frac{3\lambda L}{2d} - \frac{\lambda L}{2d} = \frac{2\lambda L}{2d}$$

$$\textit{Dark Fringe Spacing} = \Delta y = \frac{\lambda L}{d} \longrightarrow (11)$$

FRINGE SPACING:

The distance between two consecutive bright or dark fringes is called "Fringe Spacing".

Form eq (8) & (11) it can be seen that

$$\text{Bright Fringe Spacing} = \text{Dark Fringe Spacing} = \frac{\lambda L}{d}$$

$$\therefore \quad \text{Fringe Spacing} = \frac{\lambda L}{d}$$

INTERFERENCE FROM THIN FILM:

"A soap bubble or layer of oil on water surface is known as thin film"

EXPLANATION:

When white light falls on these films various colours can be seen. These colours are the results of interference of light waves reflected from upper & lower surface of films.

To explain the phenomenon of interference from thin film, consider a thin film of refractive index "n" & thickness "t". Let a ray **ab** of monochromatic light of wavelength "λ" be incident on the film. This ray will be partially reflected along **bc** & partially refracted along **bd** and refract along **dg**. The reflected ray **de** will emerge out along **ef**. The rays **bc** & **ef** interfere with each other producing on phase relationship. It is clear from the figure that ray **ef** covers a greater path as compared to ray **bc**. The path difference between rays **bc** & **ef** depends upon the angle of incidence, refractive index of the film & thickness of the film. In a refracting medium wavelength of light changes. If "λ_n" be the wavelength of light in the film then it is given by $\lambda_n = \frac{\lambda}{n}$. For nearly normal incidence the path difference between interfering rays **bc** & **ef** is "2t". Moreover, ray upon reflection from a denser medium undergoes a phase change of 180° i.e. crest is reflected as trough & vice versa while no phase change occur when it is reflected from a denser medium. Under these situations the conditions for constructive interference changes & can be given by.

$$2t = \left(m + \frac{1}{2}\right) \lambda_n$$

Substituting $\lambda_n = \frac{\lambda}{n}$ we get

$$2t = \left(m + \frac{1}{2}\right) \frac{\lambda}{n}$$

$$2tn = \left(m + \frac{1}{2}\right) \lambda \text{ ---------- (maxima)}$$

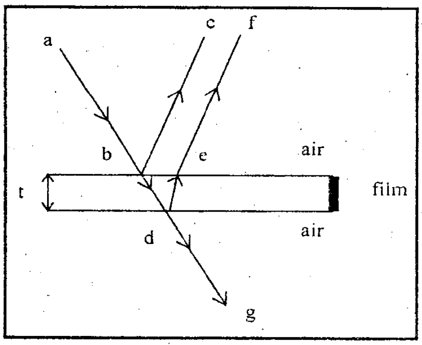
where m = 0, 1, 2, 3, ---------

for destructive interference we can write.

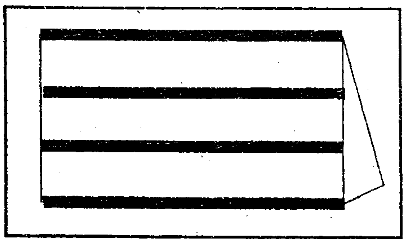
$$2tn = m\lambda \text{ -------- (minima)}$$

where m = 0, 1, 2, 3, ---------

"m" is called the order of the image .



When a wedge-shaped film is illuminated by a monochromatic light, alternate bright & dark bands are obtained, as shown in figure. At the edge of the film where thickness of the film is zero, dark band is obtained. As we go down the film its thickness changes gradually due to which alternate bright & dark bands are obtained.



NEWTON'S RING:

An air wedge film can be formed by placing a plano-convex lens on a flat glass plate. The thickness of film is zero where the lens & the plate are in contact with each other. The thickness of the film gradually increases in all directions as we go away from the centre. If such a film is illuminated by a parallel beam of monochromatic light from the top & also viewed from the same direction, dark & bright consecutive circles will be obtained. These rings are called "Newton's Rings". These rings are the result of constructive & destructive interference produced by thin (air) film in the region between eyes & lens.

At the point of contact there will be dark circle due to 180° change in phase of the light ray reflected from lower surface of the air film.

The radii of bright & dark circles can be found by considering the figure. In the figure consider a circle of radius "r" which is formed at thickness "t" of air film. If "R" be the radius of curvature of the lens then in the triangle ABC

$$(AB)^2 + (AC)^2 = (BC)^2 \text{-----------(By Pythagorous Theorem)}$$

$$r^2 + (R - t)^2 = R^2$$

$$r^2 = R^2 - (R-t)^2$$

$$r^2 = R^2 - (R^2 - 2Rt + t^2)$$

$$r^2 = R^2 - R^2 + 2Rt - t^2$$

As t^2 is very small as compared to R, therefore it can be neglected.

$$\therefore \quad r^2 = 2Rt$$

$$r^2 = 2t\,R \longrightarrow (1)$$

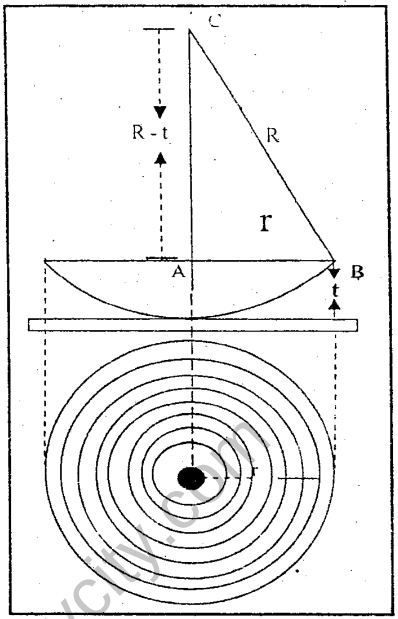
RADIUS OF BRIGHT RING:

The circle will be bright if the path difference between the interfering rays is odd integral multiple of $\frac{\lambda}{2}$ i.e.

$$2nt = \left(m + \frac{1}{2}\right)\lambda$$

for air $n = 1$

$$2t = \left(m + \frac{1}{2}\right)\lambda$$



For first bright ring m = 0

$$2t_1 = \left(0 + \frac{1}{2}\right)\lambda = \frac{1}{2}\lambda$$

For second bright ring m = 1

$$2t_2 = \left(1 + \frac{1}{2}\right)\lambda = \frac{3}{2}\lambda$$

For third bright ring m = 2

$$2t_3 = \left(2 + \frac{1}{2}\right)\lambda = \frac{5}{2}\lambda$$

Similarly for Nth bright ring m = N − 1

$$2t_N = [(N-1) + \frac{1}{2}]\lambda = (N - \frac{1}{2})\lambda$$

Substituting $2t_N$ in (1) we get

$$r_N^2 = (N - \frac{1}{2})\lambda R$$

$$r_N = \sqrt{R(N - \frac{1}{2})\lambda} \longrightarrow (2)$$

Where N = 1, 2, 3 --------- for 1st, 2nd, 3rd, ---------- bright rings respectively.

RADIUS OF DARK RING:

The circle will be dark if the path difference between interfering rays is integral multiple of λ, the wavelength of light, i.e.

$$2nt = m\lambda$$

For air, refractive index = n = 1

$$\therefore \quad 2t = m\lambda \longrightarrow (3)$$

Put the value of 2t from eq (3) in eq (1)

$$r^2 = m\lambda R$$

$$r = \sqrt{m\lambda R} \longrightarrow (4)$$

where m = 0, 1, 2, 3, -------- for zeroth, 1st, 2nd, 3rd, ------- dark rings respectively.

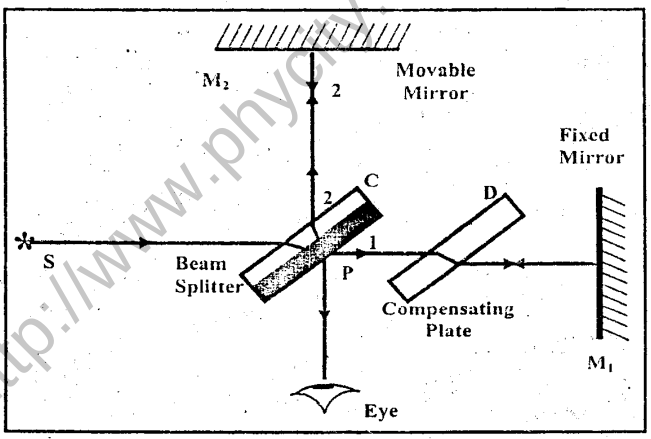
MICHELSON'S INTERFEROMETER:

CONSTRUCTION:

Michelson interferometer consists of two highly polished plane mirrors M_1 & M_2, a semi silvered glass plate C & a glass plate D. The mirror M_1 is fixed whereas the mirror M_2 is movable. The semi silvered glass plate C is called "beam splitter" & is inclined at an angle of 45° relative to the incident light **beam. The plate D** which is identical to the plate C is known as "Compensating plate". Its purpose is to ensure that the light rays pass through the same thickness of glass.

WORKING:

When a beam of monochromatic light (of wavelength "λ") from a source S falls on semi silvered plate C, it splits into two parts 1 & 2 at the point P. The part 1of light passes through the semi silver surface of the plate C continues its journey, passes through the compensating plate D & finally falls on the fixed mirror M_1.



It passes through the plate D on its return journey & finally it is incident on the silver surface of the plate C from where it is reflected to the observer's eye.

The part 2 of the light is reflected from the silvered surface of the plate C to the movable mirror M_2. After reflection from M_2, it returns to the observer's eye through the plate C. The two rays recombine between the plate C & eye to produce interference pattern which can be viewed.

EQUATION FOR WAVELENGTH:

If the distance covered by the light beam is zero, the rays will interfere constructively & brightness is seen. If the mirror M_2 is moved away through one quarter the wave length of light i.e. $\frac{\lambda}{4}$ $(\lambda/4 + \lambda/4 = \lambda/2)$ as compared to ray 1. Both rays will interfere destructively & darkness is seen. If M_2 is further moved away through $\lambda/4$ i.e. $\lambda/2$ from original position, the path difference between rays 1 & 2 will become $(\lambda/2 + \lambda/2 = \lambda)$. Both rays will interfere constructively & brightness is seen. Thus by moving mirror M_2 through $\lambda/2$ each time, alternate bright & dark fringes can be seen. The bright fringe will be obtained if the mirror M_2 is moved through $\lambda/2$ each time.

If for the "m" brightness the mirror M_2 moves through displacement "x" then.

$$x = m\,\lambda/2$$

OR

$$\boxed{\lambda = \frac{2x}{m}}$$

USES:

Michelson interferometer is used to determine the wavelength of light & to calibrate the scale.

DIFFRACTION OF LIGHT:

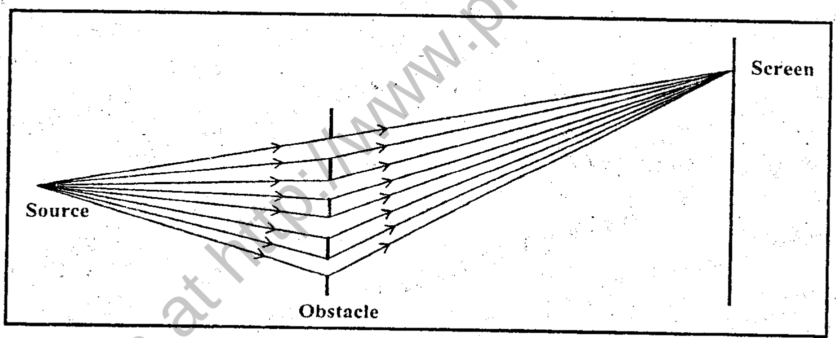
The bending of light around an obstacle is called ***"DIFFRACTION OF LIGHT".*** The bending of light i.e. the diffraction effect depends upon the size of obstacle. Diffraction effects are large if the edges of the obstacle are sharp & aperture are comparable in size of the wavelength of light i.e. of the order of 10^{-7}m.

Diffraction effects are classified in two types.

1. Fresnel Diffraction.
2. Fraunhofer Diffraction.

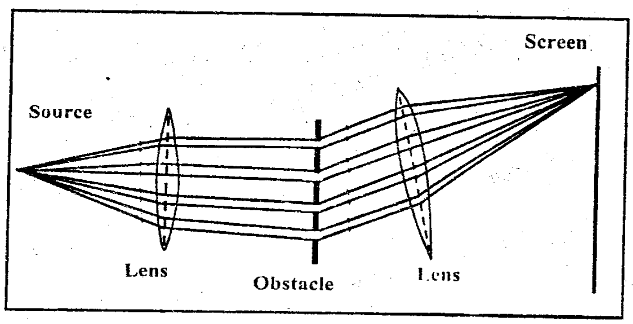
FRESNEL DIFFRACTION:

Fresnel diffraction can be observed if the source of light and the screen at which diffraction pattern is formed are kept at finite distance from the diffracting obstacle. In this situation the wave fronts falling on the obstacle are not plane. Similarly the wave fronts leaving the obstacle are not plane.



FRAUNHOFER DIFFRACTION:

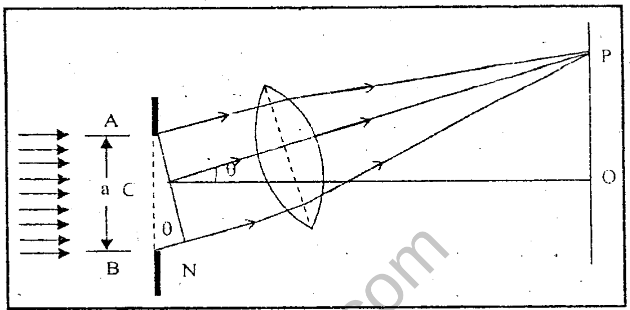
Fraunhofer diffraction can be observed if the source of light and screen at which diffraction pattern is formed are placed at infinite distance from the diffracting obstacle. This can be done by using two converging lenses. One lens is placed between the source of light & the obstacle while the other lens is placed between the obstacle & the screen. The lens between the source & obstacle makes the rays parallel to each other while the lens between the obstacle & screen, focus the parallel rays at a point on the screen.



DIFFRACTION BY SINGLE SLIT:

Slit is a rectangular aperture whose width is much smaller than its length.

Consider a slit of width "a" on which monochromatic light of wave length "λ" be incident. The light will diffract from the slit. This diffracted light can be focused by a convex lens on the screen. Depending upon the path difference between the diffracted rays, bright & dark bands can be obtained on the screen.



To find the value of path difference, draw a normal "CO" on the screen from the mid point "C" of the slit. If the diffracted light is focused at "O", brightness will be obtained because the rays reaching at "O", from all points of the slit will cover equal path.

Now consider the secondary wave, traveling in a direction making an angle "θ" with CO. These waves are brought to focus at P which will have a maximum or minimum intensity depending upon the path difference between the secondary waves front. Draw AN perpendicular to the direction of the diffracted rays from A. Path difference between the wavelets from the extreme of the slits A & B is "BN" & it can be found by considering triangle ABN.

Here $\sin\theta = \frac{BN}{AB}$

$BN = AB \sin\theta$

OR $BN = a \sin\theta$

If $BN = \lambda$, then P will be a point of minimum intensity . It is because the whole wave-front AB can be considered to be made up of the halves AC & BC. If the path difference between the secondary waves from A & B is λ, then the path difference between the secondary waves from A & C is λ/2. Thus for every point of the upper half CA, there is a corresponding point in the lower half CB between the secondary waves from which the path difference at P which has minimum intensity. Hence for first minimum

$a \sin\theta = \lambda$

If the path difference between the extreme wavelets from A & B is 2λ i.e.

$$BN = a \sin\theta = 2\lambda$$

The intensity will again be minimum, because the slit can now be supposed to be divided into four parts & the rays from the corresponding points separated by a distance $\frac{a}{4}$ in the two halves of the slit will have a path difference of $\lambda/2$, thus destroying each other's effect. Thus for second minimum intensity position

$$BN = a \sin\theta = 2\lambda$$

In general

$$a \sin\theta = m\lambda$$

when m = 1, 2, 3, -----------

In addition to the central maxima at O, there are secondary minima on either side of the central maxima. These are situated in a direction which the path difference BN is an odd multiple of $\lambda/2$. Hence for secondary maxima

$$a \sin\theta = (m + \frac{1}{2})\lambda$$

DIFFRACTION GRATING:

Diffraction grating is a glass plate on which thousands of equidistance parallel lines are ruled. The thin clear strip between the lines transmit light & acts as slits.

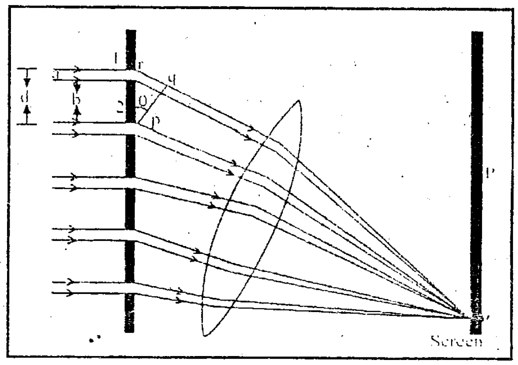
The width of a transparent space plus the width of an opaque space is called "GRATING ELEMENT" & it can be found by formula.

$$\text{Grating Element} = \frac{1}{\text{Number of lines per unit length of grating}}$$

$$\textbf{Grating Element} = \frac{\textbf{Length of grating}}{\textbf{Number of lines ruled}}$$

DETERMINATION OF WAVE LENGTH OF LIGHT BY DIFFRACTION GRATING:

Consider a diffraction grating having each slit of thickness 'a' and 'b' is the distance between two consective slits. A parallel beam of light rays falls on the grating plate and diffracted through it as shown in the figure.



Consider two rays 1 and 2 are diffracted from the edges 'r' and 'p' of the grating plate make an angle θ with OP, the normal to the grating. These rays are brought to focus on the screen at P′ by a convex lens. The ray 1 covers a longer distance than the ray 2. To find the path difference between the ray 1 and 2, a perpendicular is drawn from p, such that path difference = rq

According to constructive interference condition, path difference between the two rays should be equal to mλ.

Where $m = 0, 1, 2, 3, 4, \ldots\ldots$

$$rq = m\lambda \longrightarrow (i)$$

Consider Δrpq

$$\sin\theta = \frac{rq}{rp}$$

$$rq = rp \sin\theta$$

As $rp = (a + b) = d$ is called grating element

$$\therefore \quad rq = d \sin\theta \longrightarrow (ii)$$

By comparing equation (i) and (ii) we get

$$\boxed{m\lambda = d \sin\theta} \longrightarrow (iii)$$

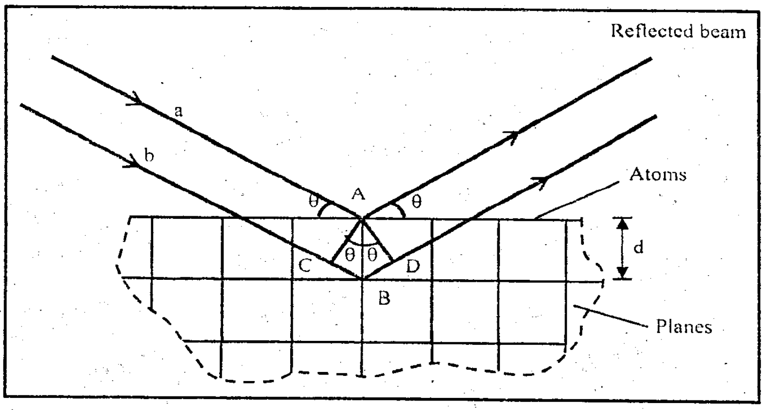
This is called grating equation.

By putting m = 0, 1, 2, 3, ... in equation (iii) we get zeroth order, first order, second order third order, etc.

DIFFRACTION OF X—RAYS THROUGH CRYSTALS (BRAGG'S LAW):

Consider two parallel X–Ray "a" & "b" of wavelength "λ" which are incident on salt crystal. The rays are reflected. Let "θ" be the angle made by rays with the layers, as shown in the figure. It can be seen in the figure that the ray "b" covers a greater path as compared to ray "a".

The path difference between rays "a" & "b" can be found by drawing perpendicular to AC & AD on the rays.



Now consider triangles ABC & ABD. In Δ ABC

$$\text{Sin}\ \theta = \frac{\overline{CB}}{\overline{AB}} \Rightarrow \overline{CB} = \overline{AB}\ \text{Sin}\ \theta$$

But AB = d = distance between the atomic layers.

$$\therefore \quad \overline{CB} = d\ \text{Sin}\ \theta \longrightarrow (1)$$

Similarly in Δ ABD

$$\text{Sin}\ \theta = \frac{\overline{BD}}{\overline{AB}} \Rightarrow \overline{BD} = \overline{AB}\ \text{Sin}\ \theta$$

$$\overline{BD} = d\ \text{Sin}\ \theta \longrightarrow (2)$$

Adding eq (1) & eq (2)

$$\overline{CB} + \overline{BD} = d \sin\theta + d \sin\theta$$
$$\overline{CB} + \overline{BD} = 2d\ \text{Sin}\ \theta$$

The rays "a" & "b" interfere constructively if path difference between them is 0, λ, 2λ, ----------------, mλ

i.e. $\overline{CB} + \overline{BD} = \lambda m$

OR $2d\ \text{Sin}\ \theta = \lambda m \longrightarrow (3)$

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

Eq (3) is known as BRAGG'S LAW.

This law is used to study the structure of crystals if wavelength is known.

Conversely if "d" is known, λ can be determined.

POLARIZATION OF LIGHT:

The orientation of the vibration pattern of light waves in a singular plane

Unpolarized Light:

Ordinary light from a normal source spread in all directions is unpolarized. This light consist of electric and magnetic fields which are perpendicular to each other and perpendicular to propagation of light. (Fig.) a

Polarized Light:

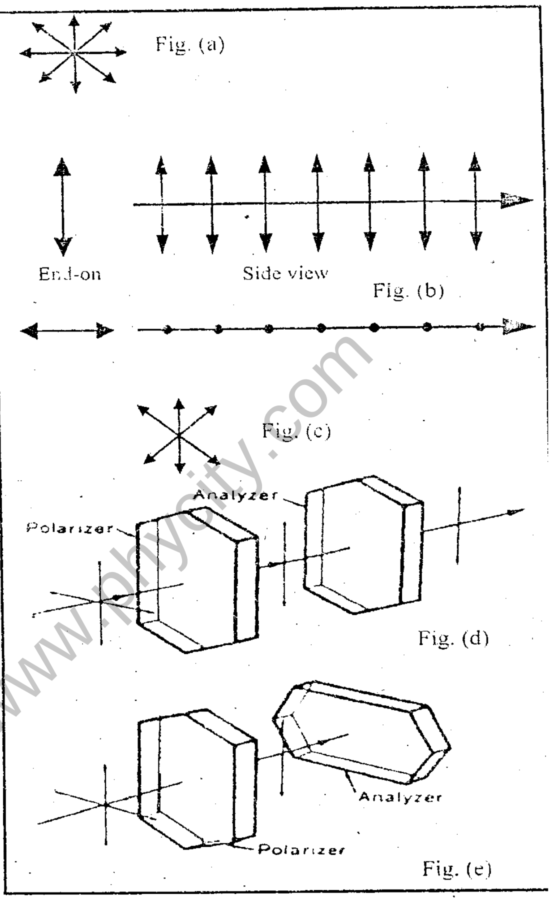
The bean of light is said to be polarized if unpolarized beam passes through a polarizing sheet known as Polaroid. In this case electric or magnetic fields vibrates only in one plane. Fig.(b) and (c)

Effects of polarization on light:

Polarization depends upon parallel arrangement of crystals which has two effects on light.

(i) It resolves the direction of vibration of the light wave into only two directions mutually at right angles.

(ii) It absorbs only the one component and transmit the other. Fig. (d) and (e)



PROOF OF TRANSVERSE NATURE OF LIGHT:
(By Selective absorption)

Plane polarized light can be obtained by passing unpolarized light through a tourmaline crystal. The crystal transmit only that component of light which is vibrating parallel to the axis of crystal while absorbs the other component. When two such crystal are placed parallel to each other. The light transmitted through first also transmitted through second when second crystal is rotated through 90° no light gets through. The observed effect is due to selective absorption. The first crystal is called polarizer and second is called Analyzer. This reveals that light waves are 'Transverse Waves'.

Now a days plastic sheets in which special types of crystals are embedded, are used to get polarized light.

The method of polarizing the light discussed above is called POLARIZATION BY SELECTIVE ABSORPTION. However light can be polarized by other methods like reflection, double refraction & scattering of light.

APPLICATION OF THE PHENOMENON OF POLARIZATION:

1. The determination of the concentration of the optically active substances such as sugar solution.
2. In photography it is often desirable to enhance the effect of sky & clouds. Since light from the blue sky is partially polarized by scattering a suitable oriented polarizing disc infront of the camera lens will serve as a sky filter.