MODULE 2

INTERFERENCE

Optics is the scientific study of light. Optics is divided in toRay optics and Wave optics. In ray optics, we consider the propagation of light on the basis of Newton's corpuscular theory of light. Then came the wave theory of light, proposed by Huygens.

NEWTON'S CORPUSCULAR THEORY OF LIGHT

Light consists of stream of particles called corpuscles. They travel in a straight line with large velocities. The corpuscular theory was successful in explaining reflection, refraction of light and rectilinear propagations of light.

WAVE THEORY OF LIGHT

Light propagated through a medium in the form of transverse waves.The Wave theory of light could explain almost all phenomena like reflection, refraction ,interference, diffraction and polarisation

PERIOD(T)

The time taken by the particle to make one complete vibration is called period

FREQUENCY(υ)

The number of vibrations made by the particle in one second is called frequency

Frequency $\upsilon = \dfrac{1}{T}$

WAVELENGTH(λ)

The distance between two successive crests or two successive trough is called wavelength

RELATION BETWEEN VELOCITY, WAVELENGTH AND FREQUENCY

$V = \upsilon\lambda$

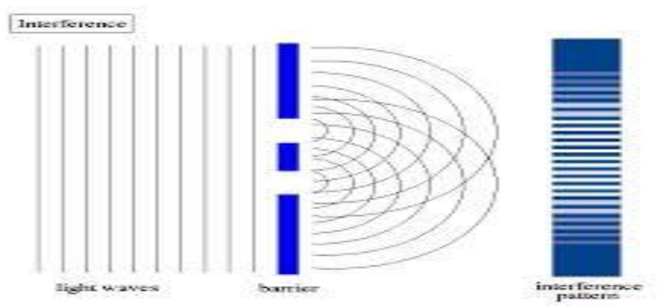
INTERFERENCE

When light from a single source travels through a region, there will be more or less uniform intensity of illumination. But when light from two or more sources travel through the same region, there will be modification in the distribution of intensity due to superposition. This modification is called interference.

The remodification of light energy due to the superposition of two light wave of the same amplitude, same frequency and of constant phase difference is called interference

INTERFERENCE PATTERN

The intensity distribution received on a screen is called interference pattern. Such pattern consists of intensity maxima and minima.



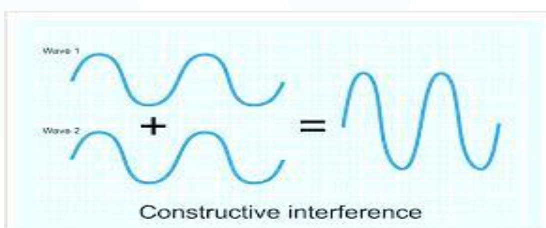
PRINCIPLE OF SUPERPOSITION

According to this principle ,the resultant displacement of a particle of the medium acted on by two waves simultaneously, is equal to the algebraic sum of the displacement due to each wave

$$Y=y1 +y2$$

CONSTRUCTIVE INTERFERENCE

At the points in the region where the two light waves arrive in the same phase, the resultant intensity is maximum and the interference is said to be constructive



Constructive interference

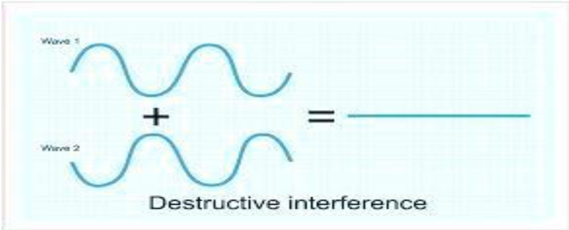
For Constructive Interference

The waves must arrive to the point of study in phase. So their path difference must be integral multiples of the wavelength: p.d =0, 1λ ,2 λ,3 λ.....

p.d=n λ n=0,1,2,3,………

DESTRUCTIVEINTERFERENCE

At points where the two light waves arrive in phase opposition, the resultant intensity is minimum and the interference is said to be destructive



For destructive interference

The waves must arrive to the point of study out of phase. So the path difference must be an odd multiple of λ/2:

p.d=1 λ/2,3 λ/2,5 λ/2,...

p.d=(2n+1) λ/2 n=0,1,2,...

COHERENT SOURCES

Two sources of light are said to be coherent if the waves emitted from them have the same frequency ,same amplitude and zero or constant phase difference.

Two independent sources of light cannot produce interference fringes. This is because, even if the two sources produce light waves of same frequency and amplitude, they may undergo random changes in their phases. The two coherent sources are to be derived from the same parent source.

EXAMPLES

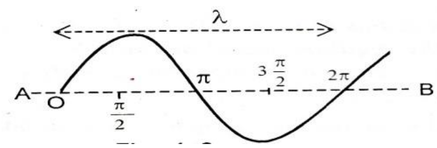
Two slits illuminated by a monochromatic source of light, A source of light and its reflected image

CONDITIONS FOR INTERFERENCE

- **There should be two coherent source of light emitting light waves of same frequency and same amplitude with a constants phase difference**
- **The light waves from the coherent sources should superimpose, at the same time and at the same place**
- **The two coherent sources of light should be very close to each other**
- **The two sources must be very narrow**
- **The two sources should be of equal intensities**

PHASE DIFFERENCE AND PATH DIFFERENCE

Phase difference =2π/λ x path difference



OPTICAL PATH

Optical path is the distance that light would travel in air or vacuum equivalent to the distance d it travells in a medium of refractive index μ

OPTICAL PATH =μd

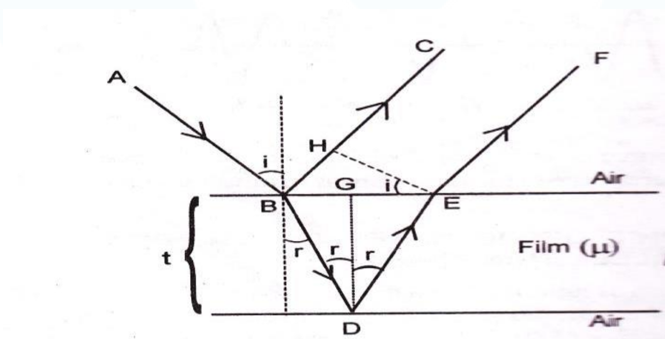
Path difference due to dissimilar reflection

If a ray is reflected at a surface backed by a denser medium then there will be a additional path difference of λ/2

INTERFERENCE OF LIGHT REFLECTED FROM PLANE PARALLEL THIN FILMS

When a beam of light falls on a thin film, apart of light is reflected from the top surface of the film and a part is reflected from the lower surface of the film. These two reflected rays interfere. If the incident light is white, the film is beautifully coloured.

Consider a thin transparent film of thickness t and refractive indexμ. A ray of light AB is incident on the upper surface of the film. A part of the ray is reflected along BC. The remaining part is transmitted along BD.



Since the film is very thin the rays BC and EF are very close to each other hence they interfere and produce brightness or darkness according to the path difference between them. Draw EH perpendicular to BC. Then beyond EH, the two reflected rays travel the same distance.

The optical path difference =(BD +DE) in film – BH in air

o.p.d=(BD+DE) μ- BH

Δ BDG and Δ EDG ARE congruent

BD=DE and BG=GE

o.p.d=2 BD μ - BH ………(1)

From Δ BEH

sin i = BH/BE

BH=BE sini

BE=BG+GE and BG=GE

BH=2 BGsini

Substitute in eqn (1)

o.p.d =2 BD μ - 2 BGsini………(2)

From Δ BDG

cos r=DG/BD=t/BD

BD=$\frac{t}{cos\, r}$………………(3)

tan r=BG/t

BG=t tan r ……………(4)

Substitute in eqn (3) and (4) in eqn (2)

Opd=$\frac{2\mu t}{\cos r} - 2t\, tan r . \sin i$

=$\frac{2\mu t}{\cos r} - 2t\frac{\sin r}{\cos r}\mu \sin r$

=$\frac{2\mu t}{\cos r}(1 - sin^2 r)$

= 2μt cos r

The reflection at B is at the surface of a denser medium. Hence reflected ray BC undergoes a phase change of π or the ray travels an additional distance of λ/2

Correct path difference = 2μt Cos r - λ/2

CONDITION FOR CONSTRUCTIVE INTERFERENCE

Path difference = nλ
2 μ t Cos r - λ/2 = nλ
2 μ t Cos r = (2n+1) λ/2
The film appears bright

CONDITION FOR DESTRUCTIVE INTERFERENCE

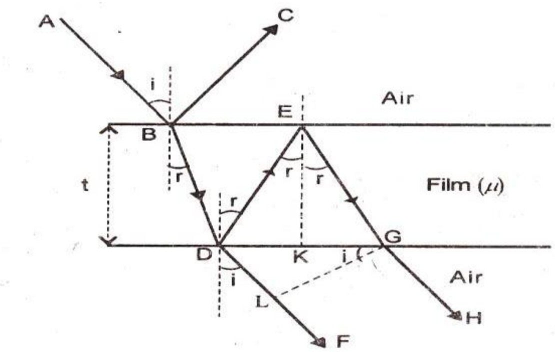
Path difference $= (2n+1)\lambda/2$

$2\mu t \cos r - \lambda/2 = (2n+1)\lambda/2$

$2\mu t \cos r = n\lambda$

The film appears dark

INTERFERENCE IN THIN FILMS DUE TO TRANSMITTED LIGHT



Correct path difference = $2\mu t \cos r$

CONDITION FOR CONSTRUCTIVE INTERFERENCE

$2\mu t \cos r = n\lambda$

The film appears bright

CONDITION FOR DESTRUCTIVE INTERFERENCE

$2\mu t \cos r = (2n+1)\lambda/2$

The film appears dark

COLOURS OF THIN FILMS

A thin transparent film observed in white light appears coloured

Condition for darkness is $2\mu t \cos r = n\lambda$

Depends on

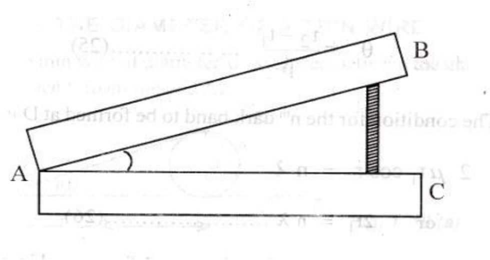
Wavelength, Angle of refraction, Thickness

At any region of film ,ifμ ,t and cos r satisfies this condition for particular wavelength λ, that colour will be absent in that reflected light.Hence that part of the film will appears to have the colours of remaining light.

It depends on angle of refraction r hence on angle of incidence i. So when we observe the same film from different positions the colour of the film will be varying. If the thickness is different, colour of the film will be varying. When t is very small, path difference between reflected rays $\lambda/2$.ie , darkness condition. Hence the film appears as dark. When t is large, almost all colours undergo constructive interference. So the film appears to be white.Soa thick film does not show colours. A thin film alone will show different colours.

Eg: The brilliant colours of peacock feather, pigeon's neck etc

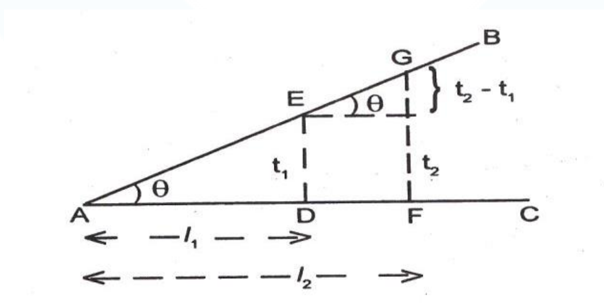
INTERFERENCE IN A WEDGE SHAPED FILM



Two plane glass plates are placed such that they are in contact at one end and separated by a small distance at the other end. A wedge shaped air film is formed between them.

A beam of monochromatic light is incident normally on the glass plate. A part of the light is reflected from the top surface of the thin film another part of light is reflected from the top surface of the lower glass plate. These two reflected beams interfere. A system of equidistant, parallel, dark and bright bands are observed.

Since thickness of air film is same along a line parallel to the line of contactof the glass plate,the interference pattern are parallel and straight to the line of contact.Each fringe is the locus of all points where the thickness of air flim has a constant value. The angle between the glass plates is called ANGLE OF WEDGE (θ in radian).



Let nth dark band is formed at D where thickness of airfilm is t_1 and (n+1)th dark band be formed at F where thickness of film is t_2. Let AD=l_1 and AF=l_2

$$\tan \theta = t_1 / l_1 = t_2 / l_2$$

$$\tan \theta = (t_2 - t_1)/(l_2 - l_1)$$

Since θ is very small, $\tan\theta = \theta$

$\Theta = (t_2 - t_1)/(l_2 - l_1)$

But $l_2 - l_1 = \beta$, the band width, the distance between two successive dark bands.

$$\Theta = \frac{t_2 - t_1}{\beta}$$

Condition for the nth dark band to de formed at D

$2\mu t_1 \cos r = n\lambda$

$\mu = 1$ & $\cos r = 1$

$2t_1 = n\lambda$ …….(1)

For (n+1)th dark band at F

$2t_2 = (n+1)\lambda$ …..(2)

Equation (2) -(1)

$2(t_2 - t_1) = \lambda$

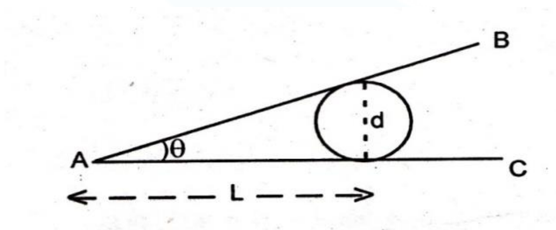
$(t_2 - t_1) = \lambda/2$

Then $\Theta = \frac{\lambda}{2\beta}$

If the medium between the glass plate has refractive index μ,

$$\Theta = \frac{\lambda}{2\mu\beta}$$

DIAMETER OF THE THIN WIRE



Let a thin wire of diameter d be placed between the glass plates at a distance L from the end A

$\Theta = d/L$ and $\Theta = \lambda/2\beta$

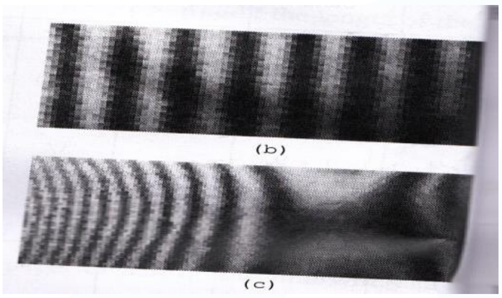
$d/L = \lambda/2\beta$

$$d = \frac{\lambda L}{2\beta}$$

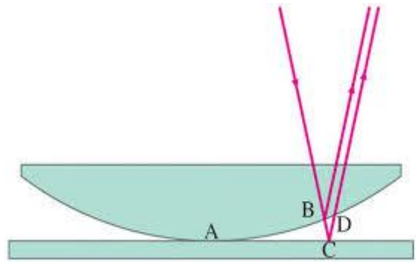
OPTICAL PLANENESS OF SURFACES

The planeness of a surface can be tested by observing the nature of fringes obtained using air wedge method.Each fringe is the locus of all points where the thickness of air film has a constant value. Since thickness of air film is same along a line parallel to the line of contactof the glass plate, the interference pattern are parallel and straight to the line of contact .

If the fringes are straight and of equal thickness, the surfaces are optically plane. If the fringes are irregular (not straight) and not of equal thickness, the surfaces are not optically plane



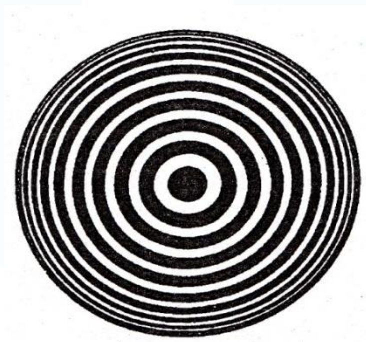
NEWTON'S RINGS



The arrangement consists of a plano convex lens of large radius of curvature placed on an optically plane glass plate. A thin film of air of varying thickness is formed between the lens and the glass plate . The thickness of thin film is zero at the point of contact and gradually increases towards the edge of the lens.

A beam of monochromatic light is incident normally on the lens.A part of the light is reflected from the top surface of the thin film and another part of light is reflected from the top surface of the glass plate. These two reflected beams interfere destructively or constructively and produce darkor bright band.

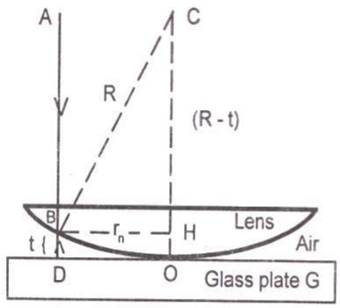
If a point appears dark, all the points along a circle through this point are dark since the thickness of air film is same along a circle. So we get a dark ring. If the point appears bright, we get a bright ring. Thus alternate dark and bright rings of increasing radii are observed.As the radii increase, the rings become thinner and closer. These are called newton's rings.



DARK CENTRAL SPOT IN NEWTON'S RINGS

At the point of contact between the lens and the glass plate, the thickness of air film t=0. Hence the path difference $2\mu t=0$. But at the time of reflection, the reflected wave from the glass plate undergoes a phase change of π(path difference of $\frac{\lambda}{2}$). So the waves at the centre are interfering destructively and hence a dark spot is obtained at the centre of newton's ring.

RADIUS OF THEn^{th} DARK RING



Let C be the centre of curvature of the curved surface of the lens and R be its radius of curvature. Let nth dark ring be formed through B where the thickness of the air film is 't'. Let r_n be the radius of dark ring ,ie BH=r_n

The condition for the formation of the n^{th} dark ring at D is,

$2\mu t \cos r = n\lambda$ ....(1)

where n = 0, 1, 2, 3 ....

Since the light is incident normally, r = o or Cos r = 1.

Also $\mu = 1$ for air.

$\therefore 2t = n\lambda$ ....(2)

From the right angled triangle CBH,

$CB^2 = CH^2 + BH^2$

ie, $R^2 = (R - t)^2 + r_n^2$

$= R^2 + t^2 - 2Rt + r_n^2$.

Since t is v ery small t^2 is negligible.

$\therefore R^2 = R^2 - 2Rt + r_n^2$

or $r_n^2 = 2Rt$ ....(3)

$2t = n\lambda$ from (2).

$\therefore r_n^2 = Rn\lambda$ ....(4)

or $r_n = \sqrt{Rn\lambda}$ ....(5)

Radius of the ring , r α $\sqrt{n}$

As n increases, the distance between the rings decreases. That is ,the rings come closer as we move away from the centre.

RADIUS OF THE n^{th} BRIGHT RING

If the n^{th} bright ring is formed at B where the thickness of the air film is t, the condition for brightness is

$$2\mu t\cos r + \frac{\lambda}{2} = n\lambda \quad \ldots\ldots\ldots\ldots\ldots(6)$$

$$2\mu t + \frac{\lambda}{2} = n\lambda.$$

$\mu = 1$ for air, $\cos r = 1$ for normal incidence.

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

$$\therefore 2t = (2n-1)\frac{\lambda}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

From equation (3), $r_n^2 = 2Rt$.

$$\therefore 2t = \frac{r_n^2}{R}$$

Substituting, $r_n^2 = R(2n-1)\frac{\lambda}{2}$

$$\text{or} \quad r_n = \sqrt{R(2n-1)\frac{\lambda}{2}} \quad \ldots\ldots\ldots\ldots\ldots(8)$$

This is the radius of the n^{th} bright ring.

Here radius of the ring , r α $\sqrt{(2n-1)}$

WAVELENGTH OF LIGHT

The radius of the n^{th} dark ring is

$$r_n = \sqrt{R n \lambda}$$

ie $r_n^2 = R n \lambda$

If D_n is the diameter of the n^{th} dark ring,

$$r_n = \frac{D_n}{2}$$

$$\text{or} \quad r_n^2 = \frac{D_n^2}{4} = Rn\lambda$$

$$\text{or} \quad D_n^2 = 4Rn\lambda \quad \text{.............(9)}$$

If D_{n+k} is the diameter of the $(n+k)^{th}$ dark ring,

$$D_{n+k}^2 = 4R(n+k)\lambda \quad \text{.............(10)}$$

$$\text{Then} \quad D_{n+k}^2 - D_n^2 = 4Rk\lambda.$$

$$\text{or} \quad \lambda = \frac{D_{n+k}^2 - D_n^2}{4kR} \quad \text{.................(11)}$$

Thus, measuring D_{n+k}, D_n, and R, the wavelength λ can be calculated.

Similarly, the radius of the n^{th} bright ring, r_n, is given by

$$r_n^2 = R(2n-1)\frac{\lambda}{2}$$

$$\text{Then} \quad r_n = \frac{D_n}{2}$$

$$\text{or} \quad r_n^2 = \frac{D_n^2}{4} = R(2n-1)\frac{\lambda}{2}$$

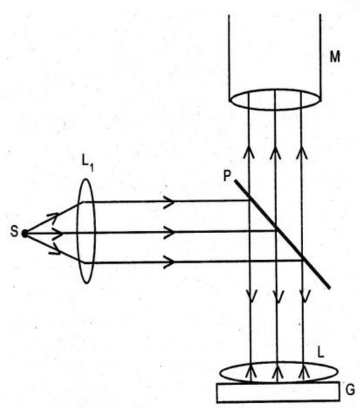
$$\text{or} \quad D_n^2 = 4R(2n-1)\frac{\lambda}{2} \quad \text{......................(12)}$$

$$D_{n+k}^2 = 4R[2(n+k)-1]\frac{\lambda}{2} \quad \text{................(13)}$$

$$D_{n+k}^2 - D_n^2 = 4Rk\lambda$$

$$\lambda = \frac{D_{n+k}^2 - D_n^2}{4kR}$$

MEASUREMENT OF WAVELENGTH OF LIGHT



S is a sodium vapour lamp. Light from lamp is rendered parallel by a convex lens L_1 fall on the glass plate P kept inclined at 45 degree , gets reflected, and then falls normally on the convex lens L placed over the glass plate G. A pattern of bright and dark circular rings are observed through a microscope arranged vertically above the glass plate P. The microscope is focused so that the rings are clearly seen .

The cross wire of the microscope is kept at the central dark spot. Then by working the tangential screw of the microscope,thecross wire is moved towards the left so that the crosswire is tangential to the 20th dark ring on the left side. The main scale and vernier scale readings of the microscope are taken. Then by working the tangential screw , the cross wire is kept tangential to the18th 16th,14th etc dark rings up to the second dark ring on the left and the corresponding readings are taken. Then the cross wire is made tangential to the second dark ring on the right side. Readings are taken corresponding to the 2nd,4th etc..... 20th dark rings on the right side as before. The difference between the readings on the left and right of each ring gives the diameter D of the respective ring. Then D^2 is found out .Hence ($D_{n+k}^2 - D_n^2$) is calculated (k=10).

The radius of curvature R of the lower surface of the lens is found by Boy's method.For this ,the convex lens Lis placed in front of an illuminated wire gauze, with the marked surface away from the wire-gauze. With a black paper held behind the lens the position of the lens is adjusted so that a clear image of the wire-gauze is formed side by side with it. The distance 'd' between the lens and the wire-gauze is measured. This is repeated 3 times and the mean value of'd' is found out.

Then the focal length 'f' of the convex lens L is determined by plane mirror method. For this,aplane mirror is held behind the lens and the position of the lens is adjusted so that a clear image of the wire is formed side by side with .The distance between the wire gauze and the convex lens is the focal length(f).Repeat the measurement three times and the average value of 'f' is found out .

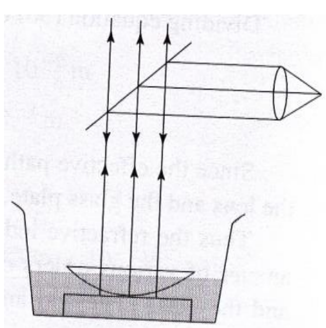
Then the radius of curvatureof the lens is found out using the formula

$$R = \frac{fd}{f-d}$$

The wave length of sodium light is hence calculated using the formula,

$$\lambda = \frac{D_{n+k}^2 - D_n^2}{4kR}$$

REFRACTIVE INDEX OF LIQUID



Let a liquid of refractive index μ be introduced between the glass plate and the lens. The radius of the n^{th} dark ring is given by

$$r_n^2 = 2Rt$$

$$\text{or} \quad 2t = \frac{r_n^2}{R} \quad \text{..........................(17)}$$

where 't' is the thickness of the liquid film where the n^{th} dark ring is formed and R is the radius of curvature of the lens.

The condition for the formation of the n^{th} dark ring is

$$2\mu t \cos r = n\lambda$$

Since $\cos r = 1$ for normal incidence.

$$\text{Then} \quad 2t = \frac{n\lambda}{\mu} \quad \text{......................(18)}$$

$$\frac{r_n^2}{R} = \frac{n\lambda}{\mu}$$

$$\text{or} \quad r_n^2 = \frac{nR\lambda}{\mu} \quad \text{......................(19)}$$

If d_n is the diameter of the n^{th} dark ring,

$$r_n = \frac{d_n}{2}$$

$$\therefore \quad \frac{d_n^2}{4} = \frac{nR\lambda}{\mu}$$

$$\text{or} \quad d_n^2 = \frac{4nR\lambda}{\mu} \quad \text{......................(20)}$$

If d_{n+k} is the diameter of the $(n+k)^{th}$ dark ring,

$$d_{n+k}^2 = \frac{4(n+k)R\lambda}{\mu} \quad \text{.................(21)}$$

$$\therefore \quad d_{n+k}^2 - d_n^2 = \frac{4kR\lambda}{\mu} \quad \text{....................(22)}$$

With air between the lens and the glass plate, we have,

$$D_{n+k}^2 - D_n^2 = 4kR\lambda \quad \text{................(23)}$$

Dividing eqn (23) by eqn (22)

The refractive index of the liquid, $\mu = \frac{(Dn+k^2 - Dn^2)}{(dn+k^2 - dn^2)}$

$r_1 = \sqrt{Rn\lambda}$ $\qquad$ $r_2 = \sqrt{\dfrac{Rn\lambda}{\mu}}$

$$D^2 = 4Rn\lambda \qquad d^2 = \frac{4Rn\lambda}{\mu}$$

It can be shown that

$$\mu = \frac{r_1^2}{r_2^2} = \frac{D^2}{d^2}$$

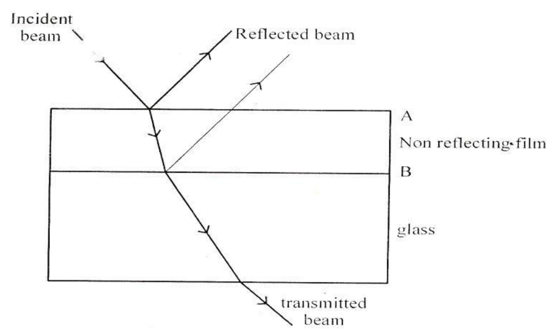
Where , r_1 = radius of nth dark ring with air ,r_2 = radius of the same nth dark ring with liquid as the medium , D = diameter of nth dark ring with air and d = diameter of the nth dark ring with liquid as the medium

Since $\mu>1$, $r_1>r_2$.

So the rings are contracting when a liquid is introduced.

ANTI REFLECTION COATING

This is an important application of thin film interference and it is used to reduce the loss of intensity of the incident beam of light by reflection . more and more intensity is lost if the number of reflection increases.



The loss of intensity due to reflection can be reduced by coating the reflecting surface with a suitable transparent dielectric material such as magnesium flouride. The refractive index of such material must be in between that of air and glass. Such a film is called non reflecting film.

When a narrow and parallel beam of white light is incident on this film , a part of it is reflected from the upper surface A and lower surface B of the film. Here reflections are taking place at the surface of a denser medium and hence the same phase change π occurs in both cases. Now the thickness of the film is so adjusted that the reflections from A and B are in opposite phase and they cancel each other by destructive interference. Thus the loss of intensity during reflection is reduced and the beam is transmitted with maximum intensity. The condition for destructive interference is $2\mu t=\lambda/2$

The thickness of film $t= \lambda/4\mu$

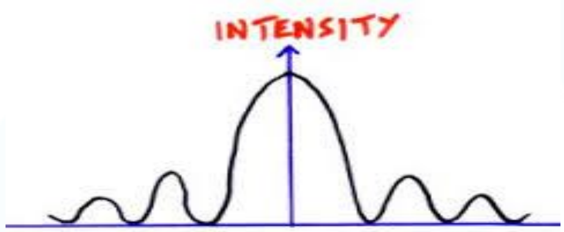
DIFFRACTION

Diffraction of light is the phenomenon of bending of light round the edges of an obstacle or encroachment of light in to the geometrical shadow of the obstacle.Diffraction of waves becomes noticeable only when the size of the obstacle is comparable to the wavelength of the light used.

Due to larger wavelength of sound, its diffraction can be easily detected in daily life around the windows, doors, building etc. The same is not the case with light, due to its shorter wavelength.

DIFFRACTION PATTERNS

The intensity distribution on the screen is known as diffraction pattern .



WAVEFRONT

A wavefront is an imaginary line that connects waves that are moving in phase

HUYGEN'S PRINCIPLE

Huygens principle states that each point on the wavefront will become a source of secondary waves spreading wavelets in all direction.

Diffraction is due to the mutual interference of the secondary wavelets originating from various points of the wavefront

COMPARISON BETWEEN INTERFERENCE AND DIFFRACTION

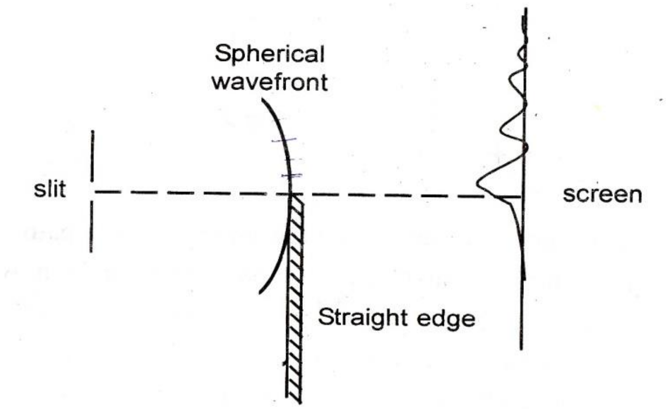
Interference	Diffraction
Interference bands are formed by superposition of waves from two coherent sources	Diffraction bands are formed by superposition of waves from different parts of the same wavefront
Bands are of equal width	Bands are of unequal width
Bands of minimum intensity are almost dark	Bands of minimum intensity are not dark
Intensity of bright bands is same	Intensity of bright bands is not the same

TYPES OF DIFFRACTION

There are two classes of diffraction, namely ,Fresnel Diffraction and Fraunhofer Diffraction

FRESNEL DIFFRACTION

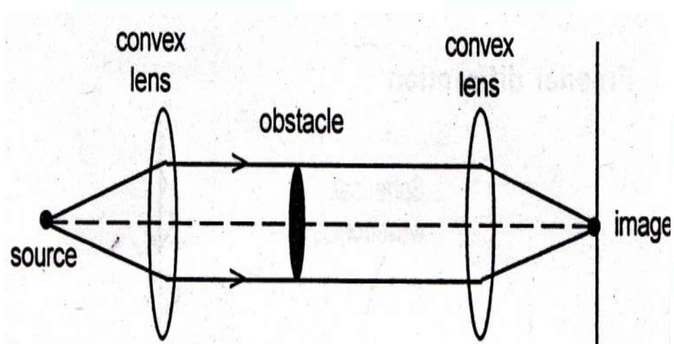
Either the source of light or the screen or both are at finite distance from the obstacle causing diffraction. Wavefront falling on the obstacle is spherical .Lenses are not used.



Example :Diffraction at a straight edge

FRAUENHOFER DIFFRACTION

The source of light and the screen are at infinite distance with respect to the obstacle causing diffraction. Wavefront falling on the obstacle is plane. Lenses are used



'ig. 2.4

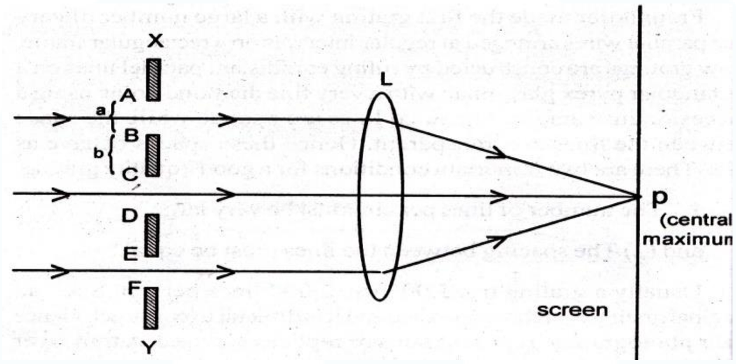
Example:Diffraction at a grating

PLANE TRANSMISSION GRATING

PLANE TRASMISSION GRATING is a plane glass plate containing a large number of equidistant parallel lines drawn using a fine diamond point . The space between the lines acts as narrow slits through which light is transmitted. The lines are opaque to light.

Grating is an arrangement of a large number of parallel slits of equal width separated by equal opaque spaces . Usually a grating has 5000 to 12000 lines per cm. There are two important conditions for a good quality grating.

1. The number of lines per cm must be very large.
2. The spacing between the lines must be equal.



Consider a plane transmission grating placed perpendicular to the plane of paper. AB represents a slit and BC represents a line. Let 'a' be the width of each slit and 'b' be the width of each line. The distant (a+b) is called grating element or grating constant.

A plane wavefront of monochromatic light of wavelength λ is falling normally on this slit. Each point of the wave front sends outsecondary waves in all direction. The straight and parallel waves from each point can be focussed on the screen using lens. These straight waves path difference will be zero. They will interfere constructively producing brightness at the centre. This central bright band is called central maximum.

The position of central maximum is same for all the wavelength.The central maxima will have the same colour as the incident light.

Consider two waves diffracted from two points A and C of slit. They travels along Am and CN. Draw CK perpendicular to AM. Then the path difference between the two waves is AK.

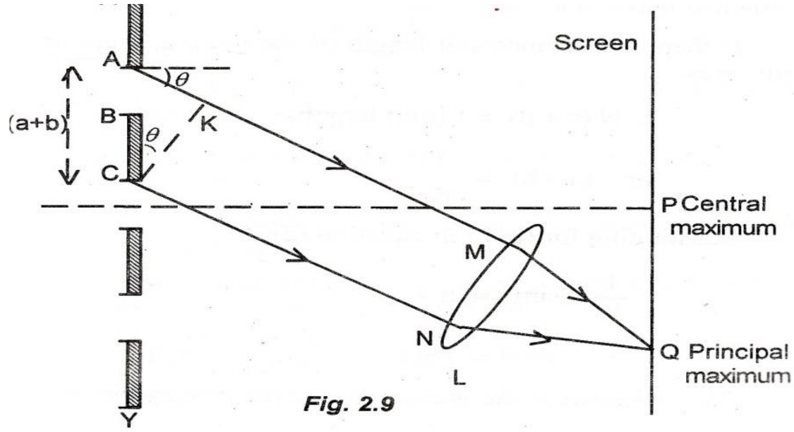


Fig. 2.9

From triangle ACK

$\sin\theta = AK/AC$

$AK = AC\sin\theta$

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

If $(a+b)\sin\theta = n\lambda$ …….(1)

where n=0,1,2,3….. two waves interfere constructively. This is called principle maximum. For different values of n , there are different values of θ.

If n=1, it is the first order principle maximum, if n=2, it is the second order principal maximum and so on. Thus on either side of central maximum ,a number of principal maxima are obtained.

If there are N lines/unit length of the grating , there are N slit also.

$N(a+b) = 1$ (unit length)

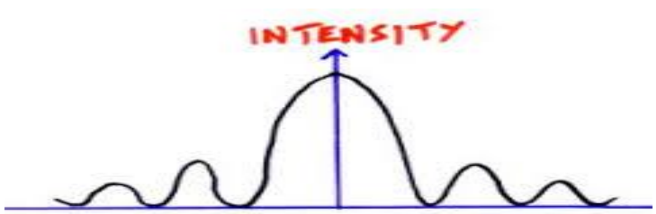
$(a+b) = 1/N$

Substitute in equation (1)

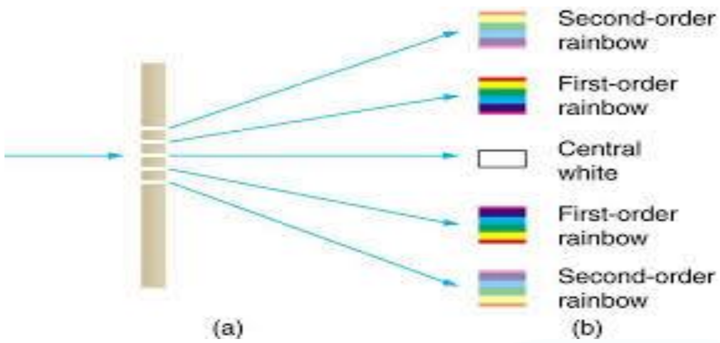
$1/N \sin\theta = n\lambda$

$\sin\theta = Nn\lambda$

This is known as grating law or grating equation.



For a grating θ is different for different colours (λ), for each value of n.If white light is used ,it get split up in to different colours.



MEASURMENT OF WAVELENGTH

A spectrometer is a device to measure wavelengths of light accurately using diffraction grating .

PRINCIPLE

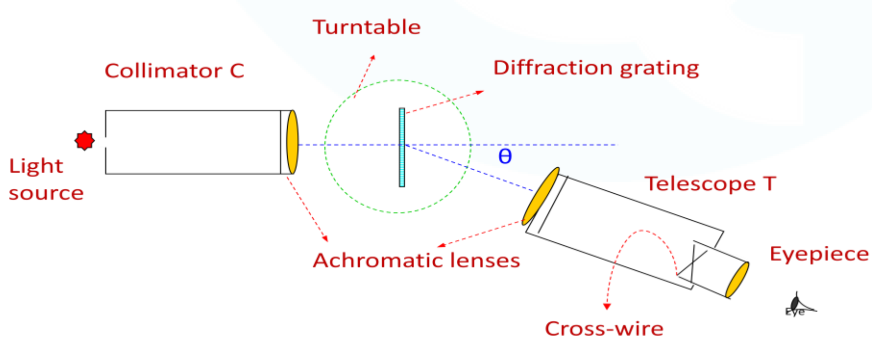
At normal incidence,

Sin θ=Nnλ

Where , θ = the angle of diffraction

N = the no. of lines per metre of the grating
n = the order of the spectrum
λ = the wavelength of light used

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



ARRANGEMENT OF THE GRATING FOR NORMAL INCIDENCE

The preliminary adjustments of the spectrometer are made. The slit is made narrow and it is illuminated with monochromatic light. The telescope is brought in line with the collimator. The slit is madeto coincide with the vertical cross wire.The telescope is then clamped. Unclamp the vernier table and zero of the vernier 1 is made to coincide with the zero of the main scale and clamp it. Now the telescope is rotated through 90° and clamped. The grating is mounted on the grating table with its ruled surface facing the collimator . The grating table alone is rotated until the reflected image of the slit is obtained at the cross wire of the telescope.The vernier table *is* unclamped and rotated through exactly 45 degree in the proper direction so that the surface of the grating becomes normal to the collimator. The vernier table is clamped. Now the grating is set for normal incidence.

WAVELENGTH OF LIGHT

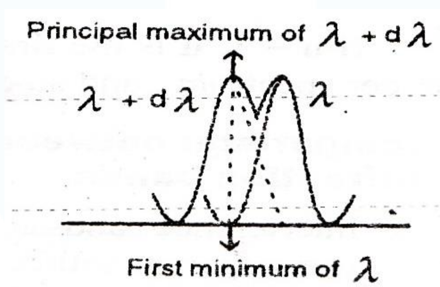
The telescope is unclamped. The direct image of the slit is obtained in the telescope. From this position, the telescope is rotated slowly to the left until the first order image of the slit is observed. The telescope is adjusted so that the vertical cross wire coincides with the line. Readings of both verniers are taken. The telescope is now moved to the right and the cross wire is made to coincide with the line of the first order on the right side. The vernier readings are again taken. The difference between the readings of the corresponding vernier on the left and right sides is determined. The mean value of this difference is 2θ .*The* angle of diffraction θ for the first order (m= 1) is thus determined. Knowing the value of N ,wavelength of sodium light is calculated from the formula

$$\lambda = \frac{\sin\Theta}{m\mathrm{N}}.$$

This is repeated for the second order (m=2) and then mean value of λ is calculated.

RAYLEIGH'S CRITERION FOR RESOLUTION OF SPECTRAL LINES

According to Rayleigh's criterion for resolution ,two neighbouring spectral lines will be just resolved when the principal maximum of one in any order falls on the first minimum of the other in the same order



Let λ and λ +d λ be the wavelengths corresponding to two neighbouring spectral lines of the same order. Then, the*two spectral lines are visible as separate* when the principal maximum of wavelength λ +d λ falls on the first minimum of wavelength λ of the same order.

RESOLVING POWER OF GRATING

It is the ability to show two neighboring spectral lines in a spectrum as separate.

The resolving power of a grating is defined as the ratio of wavelength of any spectral line to the difference in wavelength between two spectral line. If λ and λ +d λ are the wavelengths of two neighbouring spectral lines, the resolving power of the grating is defined

$\lambda / d\lambda = nN_1$ N_1-- total number of lines

The resolving power of the grating,

$$\frac{\lambda}{d\lambda} = nN_1$$

It is proportional to the order n and total number of lines N_1 on the Grating.

DISPERSIVE POWER OF A GRATING

The dispersive power of a grating is defined as the ratio of the change in the angle of diffraction to the corresponding change in wavelength.

Let two wavelengths λ and λ+dλ be diffracted through angles θ and θ+dθ respectively. Then the dispersive power of the grating is

Dispersive Power, $\frac{d\theta}{d\lambda} = \frac{Nn}{Cos\,\theta}$

For small values of θ, Cosθ= 1

$$\frac{d\theta}{d\lambda} = Nn$$

Dispersive power is proportional to the order n and the number of lines per unit length N.