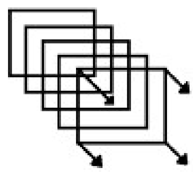
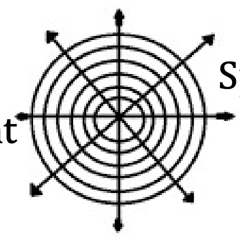
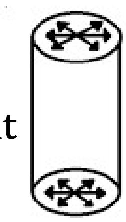
CH10 - WAVE OPTICS

✤ **WAVE FRONT :-** When light travel in a medium then particle of the medium vibrate continuously in same phase this continuous locus of particle is called **wave front.**

§ Nature of wave front depend upon the shape and size of source of light.

Ex ->  Plane Wavefront  Spherical Wavefront  Cylindrical Wavefront

Ex.

1. Light diverging from a Point source → spherical.
2. Light emerging out from a conventions → Plane wavefront
3. Light coming from a distant star → Plane w.f.

✤ **HUYGEN'S Principle:** It is based on wave theory of light.

(i) Every Particle in a wave front act as a new source of light for next Particle.

(ii) Tangent is drawn in forward direction of vibrating particles act as SWF and in backward direction act as PWF. R.

The amplitude of wavelet is max in forward direction and zero in backward direction.

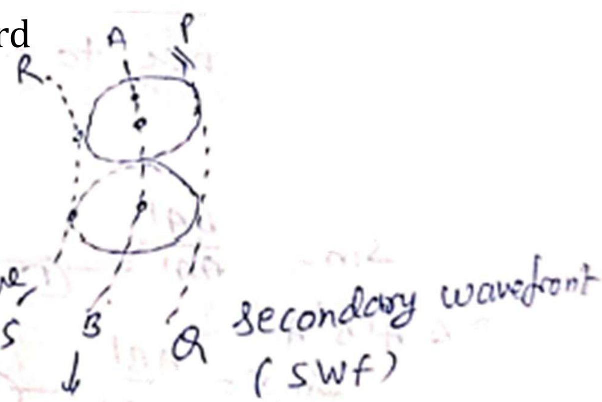
Amplitude wavelet = 1+cos θ

forward θ = 0°

backward θ = 180°

1+cos 180°/2

1+ (-1) = 20



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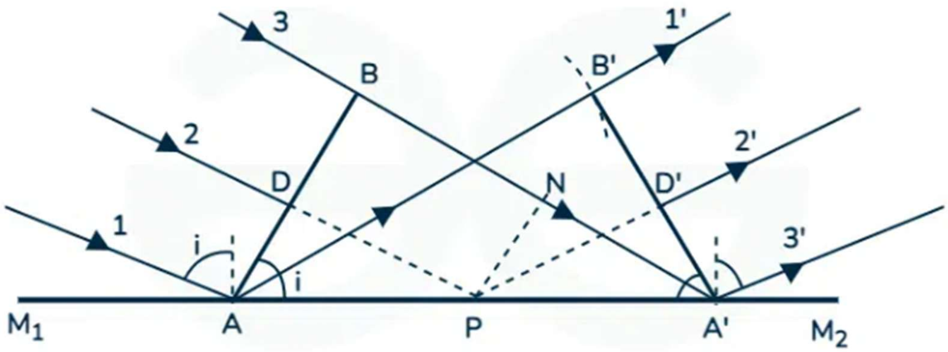
Afflication of huygon's.

1. <u>Proof of law & reflection.</u>



Let AB is on incident wavefront consist 3 rays (1,2,3) let speed of light = C,

So CA' = C X t

Make an arc A'B' = c x t, i.e. A'B' is Reflected waves front.

Now in ABA' and A'B'A

BA' = AB' (Cxt)

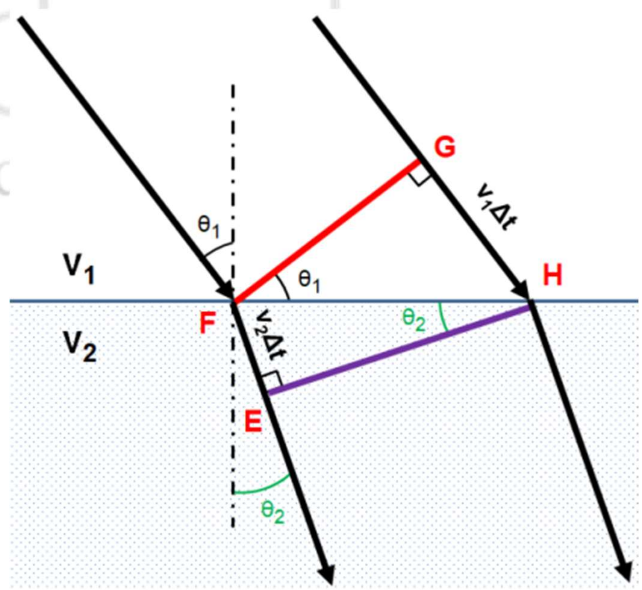
AA' = Common

:. By RHS, ABA' and A'B'A are congruent

By CPCT $I = r$

2. <u>Proof of law of Refraction:</u>

(from rarer to denser)



In ABA' sin I = BA' / AA'

In A'B'A sin r= AB' / AA'

Sin i / Sin r = BA' / AB'

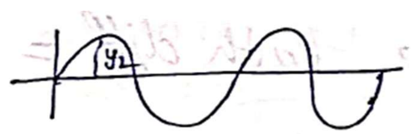
= c1 X t1/ c2 X t2

Sin I / Sin r = c_1 / c_2

Sind' = M

which is the law of refraction.

✤ <u>Principle of superposition:</u>

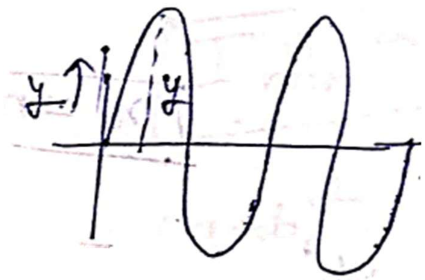


Let y_1 and y_2

are two waves then after superimpose of y_1 & y_2

New wave is formed

$y = y_1 + y_2$



✤ <u>INTERFERENCE</u>: It is defined as the phenomena of redistribution of light energy.

INTERFERENCE

CONSTRUCTIVE	DESTRUCTIVE
Intensity of light is maximum	Intensity of light is minimum dark

✤ <u>Conditions for constructive interference:</u>

we know Amplitude of resultant wave

$R = \sqrt{a^2 + b^2 + 2ab\cos\varphi}$

Here a and b are amplitude of interferencing wave.

φ = Phase difference b/w two waves.

for constructive → Intensity is maximum for which R should be maximum.

i.e $\cos\varphi = \max$

$\cos\varphi = 1$

$\Rightarrow \varphi = 2n\pi$

we know path diff $= \lambda/2\pi \times \varphi$

$x = \lambda/2\pi \times 2n\pi$

$x = n\lambda$

Resultant amplitude $R_{max} = a + b$

and Intensity $I_{max} \propto R^2_{max}$

$\Rightarrow I_{max} \propto (a+b)^2$

✤ <u>Conditions for destructive</u> => for destructive Intensity of light should be minimum (zero) for which R should be minimum for which $\cos\varphi = \text{minimum}$

$\cos\varphi = -1$

$\Rightarrow \varphi = (2n-1)\pi$

we know path diff $x = \lambda/2\pi \times \varphi$

$x = \lambda/2\pi\,(2n-1)\pi$

$x = (2n-1)\,\lambda/2$

Resultant amplitude

$R_{min} = a-b$

and intensity minimum

$I_{min} \propto R^2_{min}$

$I_{min} \propto (a-b)^2$

Note:

1) $I_{max} / I_{min} = (a+b)^2 / (a-b)^2$
2) $I_1 / I_2 = a^2 / b^2$ Here a, b are amplitude.
3) $I_1 / I_2 = w_1 / w_2$ w_1, w_2 are width.

✤ <u>Types of source of light:</u>

Coherent

If two source of light. emit the light of Same freq. (or wavelength) with zero or Constant phase difference are Known as coherent

Incohorent

If two sources do not emit the light of same frequency and do not have zero phase difference then they are called Incohorent

Note: 1. two source should obtained from single source
2. two source emit the light of monochromatre.

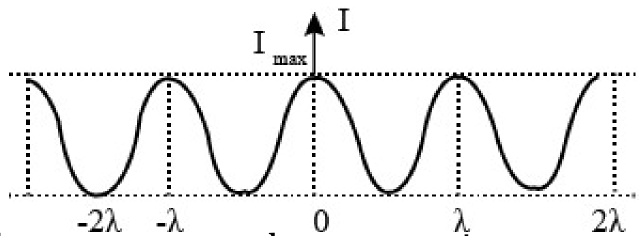
Note: two independent source can't be coherent.

❈ <u>Sustained interference</u>: In this interference Position of manimum and minima of intensity on the screen do not change with time.

Conditions:- 1. The sources (two) should continuously emit wave of same frequency or wave length.
2. Two source should be coherent.

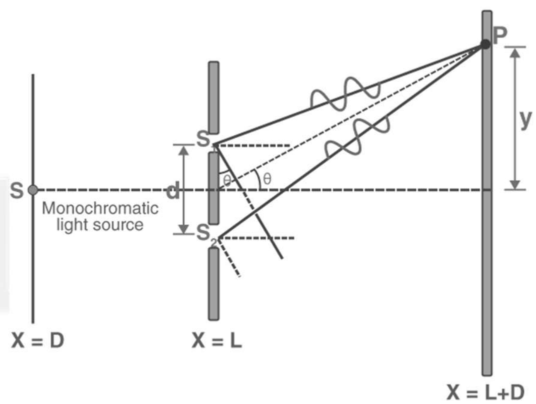
3. for better contrast, amplitude of two wave should be equal.
4. Interferencing wave should be in the same state of polarisation.

✤ Intensity distribution curve



Note: in interference energy always remain conserved.

❋ Young's double slit experiment (Y.D.SE): → It is the practical explanation of interference.



Let two wave interference at P point. distance of P from centre is x and width of slit = d.

then the Position of bright fringe $x = n\lambda D / d$

Note: When A&Bare ∞ close i e disv small the position of fringe (x) uv large-hence a single fringe may occupy the whole screen: no interference pattern detected.

When A&B are far away (ov will be vsmall the interference pattern cannot be detected.

❋ Width of fringe: It is the difference b/w two successive dark or two successive bright fringes distance from the centre.

$$\therefore \quad ß = X_n - X_{n-1}$$

$$\beta = \lambda D / d$$

Note: width of dark and bright fringes always equal.

1. angular width $\theta = \lambda/a$
2. If refractive index of medium is μ then width $\beta' = \beta/\mu$
3. Angular Position of n^{th} bright fringe.

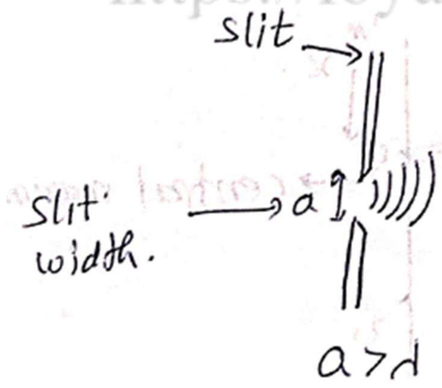
$$\theta_n = x_n/D$$

$$\theta = n\lambda/d$$

✤ <u>Some Imp Questions</u>

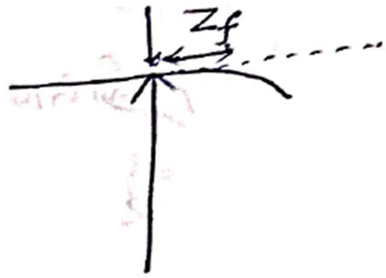
1. Why are coherent sources necessary to obtain a sustain interference.
2. What happen to interference if the phase difference b/w two sources varies continuously.
3. When a thin transparent film is placed just in front of one of its slit in YDSE using white light, what change results in the fringe system.
4. What changes in the interference pattern in YDSE will observed when
   1) light of smaller frequency is used.
   2) apparatus is immersed in water.
5. One of the two slit in YDSE is so painted that it transmit half Intensity, what is the effect on interference.

✤ <u>Diffraction of light</u> : It is the phenomenon by which light bends in the shadow of a sharp object like blade.



<u>Note</u>: diffraction pattern depend upon the comparison b/w amplitude or wavelength and slit width (a).

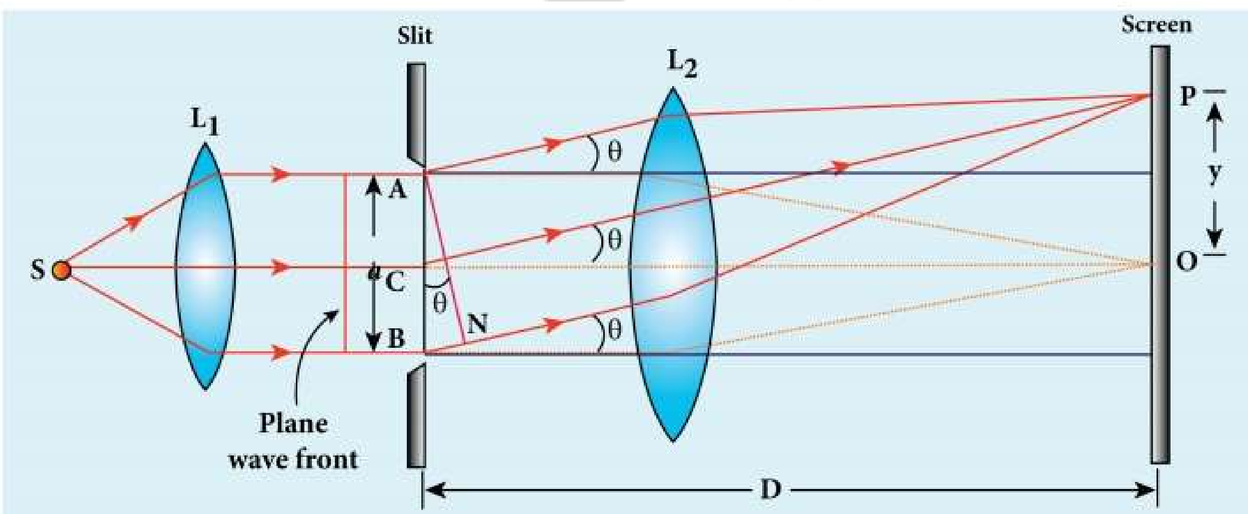
❈ **Fresnel distance:** It is the maximum distance travel by the light before bending in the shadow of sharp object.



$Zf = a^2/\lambda$

Note: Ray optics is valid upto a distance of 4000cm or 40m from the aperture.

✤ Diffraction by single slit:



AB = width of the slit = a

Let initally diffraction does not take place, o is the position of central maxima.

Let angle of diffraction is o and P is the Position of interference.

$$\text{Path dif (BM)} = a.\sin\theta$$

$$\text{for constructive Poth diff} = (2n+1)\,\lambda/2$$

$$a\sin\theta = (2n+1)\,\lambda/2$$

for small angle $\quad Qn = (2n+1)\,\lambda / 2a$

for destructive interference:

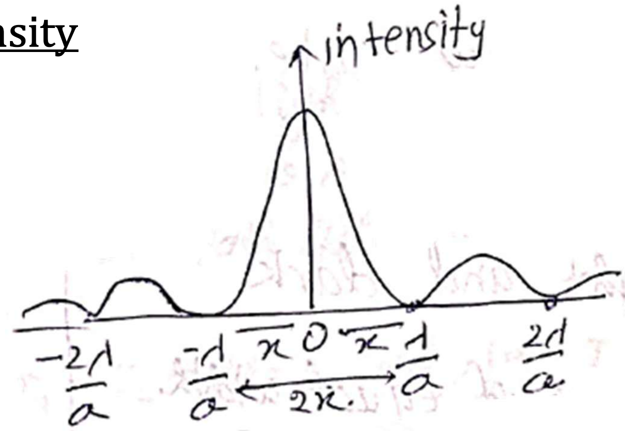
$$\text{Path diff} = n\,\lambda$$

$$\Rightarrow a\sin\theta = n\lambda$$

for small angle

$$\theta = n\,\lambda / d$$

✤ <u>Variation of intensity</u>



Note: 1. '0' is called central maxima (maximum bright)

2. Position of nth secondary maxima

$$a \sin\theta_n = (2n+1)\lambda/2,\ n=1,2,3\ldots$$

3. Direction of secondary maxima

$$\theta n = (2n+1)\lambda/2a;$$

4. minima position:

$$Qn = \pm\, \lambda \times n/a,\ n \neq 0$$

5. distance of nth secondary maxima from centre.

$$Xn = (2n+1)\lambda D/2a$$

[[[[*the intensity of 2 maxima are with the n. With the increase in n (order of spectrum) then wavelets from lesser and lesser parts of the slit produce constructive interference to form 2nd maxima*]]]]]

6. with of central maximum

$$= 2\beta \qquad\qquad = 2\,\lambda\, D\,/d$$

❇ difference b/w interference and diffraction:

Interference	Diffraction
1. bright and dark fringes are of equal width	1. They are difference in width.
2. All bright fringes are of equal intensity	2. Intensity decreases with the distance from centre.
3. There is a perfect contrast b/w bright and dark fringes.	3. There is no proper contrast b/w them.

✤ Resolving Power of microscope:

$$R.P = 2\mu\sin\theta / \lambda$$

μ = Refractive index of medium
λ= wave length of light used

✤ Resolving Power of telescope

$$R.P. = D / 1.22\lambda$$

D = diameter of objective lens
λ = wave length of light used.

✤ Some Imp. Questions

Q. In YDSE, the intensity of light at a point on the screen where path difference is λ is k units. find the intensity at a point where path difference is (i) $\lambda/4$ (ii) $\lambda/3$

Ans: we know $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\,\text{Cos}\varphi$, let $I_1 = I_2 = I_0$

$$I = I_0 + I_0 + 2I_0I_0\,\text{Cos}\pi/2$$

$$I = 2I_0 \qquad I_0 = I/2$$

$$I_0 = K/2$$

(ii) your self.

Q. Two coherent sources of light of intensity ratio β.
Prove that $I_{max} - I_{min} / I_{max} + I_{min} = 2\sqrt{\beta}/ 1+\beta$

Q. Why is no interference pattern observed when two coherent sources are (i) infinite close each other.
(ii) far from each other.

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Q. What changes in the interference Pattern in YDSE will be observed when
1) light of smaller frequency is used
2) the apparatus is immersed in water.

Q. What change will occur in diffraction Pattern If
1) light of smaller wave length is used.
2) slit is made narrower
3) frequency is changed.

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