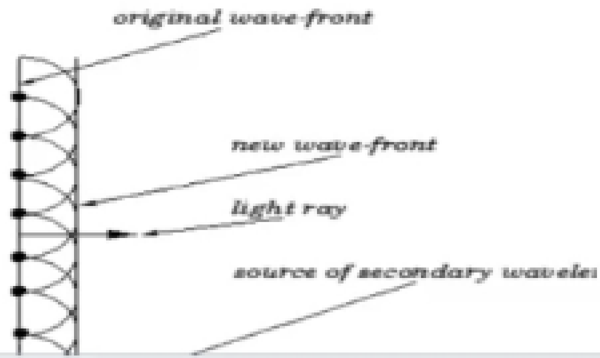
Huygens' principle

The first person to explain how wave theory can also account for the laws of geometric optics was **Christian Huygens** in **1670**. At the time, of course, nobody took the slightest notice of him. His work was later rediscovered after the eventual triumph of wave theory.

'Every point on a wave-front may be considered a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wave-front is the tangential surface to all of these secondary wavelets'.

According to Huygens' principle, a plane light wave propagates though free space at the speed of light. The light rays associated with this wave-front propagate in straight-lines, as shown in **Fig. a.** It is also fairly straightforward to account for the laws of reflection and refraction using Huygen's principle.



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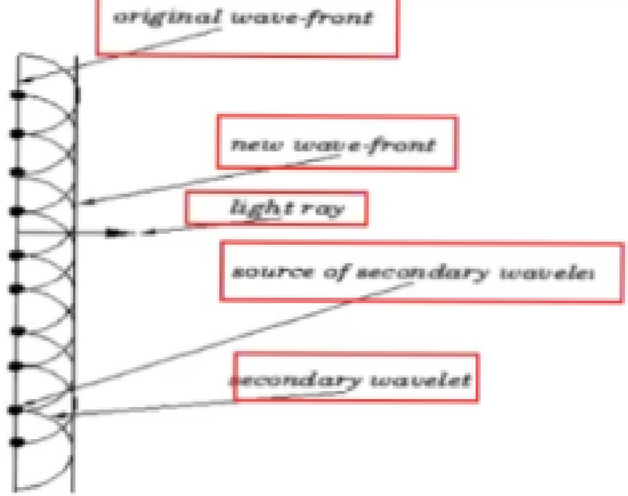

Fig. a.

Reflection of a plane wave using Huygens Principle

Fermat's Principle and the Laws of Reflection and Refraction

Fermat's principle states that "**light travels between two points along the path that requires the least time, as compared to other nearby paths.**" From Fermat's principle, one can derive (a) the law of reflection [the angle of incidence is equal to the angle of reflection] and (b) the law of refraction [Snell's law]. The derivations are given below.

(a) Derivation of the laws of reflection

Consider the light ray shown in the figure. A ray of light starting at point A reflects off the surface at point P before arriving at point B, a horizontal distance l from point A. We

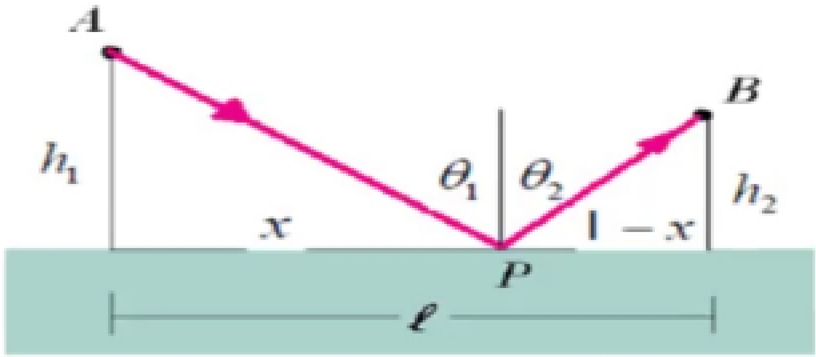

fig.a

From the fig.a

$$t = \frac{\sqrt{x^2 + h_1^2}}{c} + \frac{\sqrt{(l - x)^2 + h_2^2}}{c}$$

To minimize the time we set the derivative of the time with respect to x equal to zero. We also use the definition of the sine as opposite side over hypotenuse to relate the lengths to the angles of incidence and reflection.

$dt \qquad x \qquad -(l - x)$

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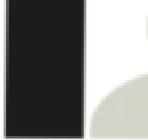
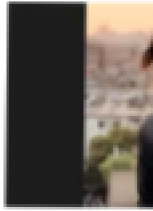
$$0 = \frac{dt}{dx} = \frac{x}{c\sqrt{x^2 + h_1^2}} + \frac{-(l - x)}{c\sqrt{(l - x)^2 + h_2^2}} \rightarrow$$

$$\frac{x}{\sqrt{x^2 + h_1^2}} = \frac{(l - x)}{\sqrt{(l - x)^2 + h_2^2}} \rightarrow \sin\theta_1 = \sin\theta_2 \rightarrow \boxed{\theta_1 = \theta_2}$$





(b)Derivation of the laws of refraction

Now we consider a light ray traveling from point A to point B in media with different indices

(b) Derivation of the laws of refraction

Now we consider a light ray traveling from point A to point B in media with different indices of refraction, as shown in the figure. The time to travel between the two points is the distance in each medium divided by the speed of light in that medium.

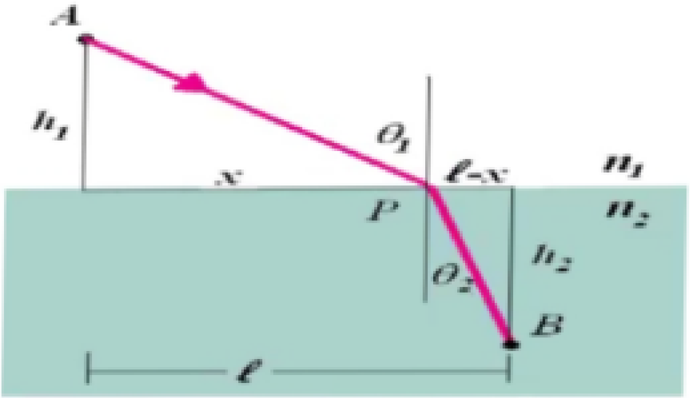
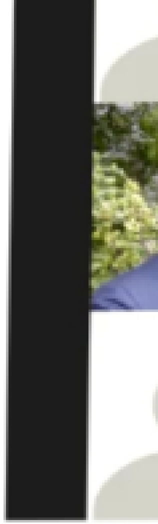


Fig: b

From the fig.b

$$t = \frac{\sqrt{x^2 + h_1^2}}{c/n_1} + \frac{\sqrt{(l - x)^2 + h_2^2}}{c/n_2}$$



the sphere. Then, AE = $v_2 r$, and CE would represent the refracted wavefront. If we now consider the triangles ABC and AEC, we readily obtain.

$$\sin i = BC / AC = v_1 r / AC$$

$$\sin r = AE / AC = v_2 r / AC$$

Where' i ' and ' r ' are the angles of incidence and refraction, respectively. Substituting the values of v_1 and v_2 in terms of we get the Snell's Law,

$$n_1 \sin i = n_2 \sin r$$

Interference:

Due to superposition of two light waves emitted from coherent sources intensity of light increase at some point and decreases at other point. As a result alternate bright and dark state is produced on a plane. The alternate variation of intensity of light from point on a plane is called interference of light.

Condition of Interference:

1. The light sources should be coherent.
2. The amplitude of the two waves producing interference should be equal or almost equal.
3. The sources should be very narrow.
4. The sources should be very close to each other.

Young's Double Slit Experiment:

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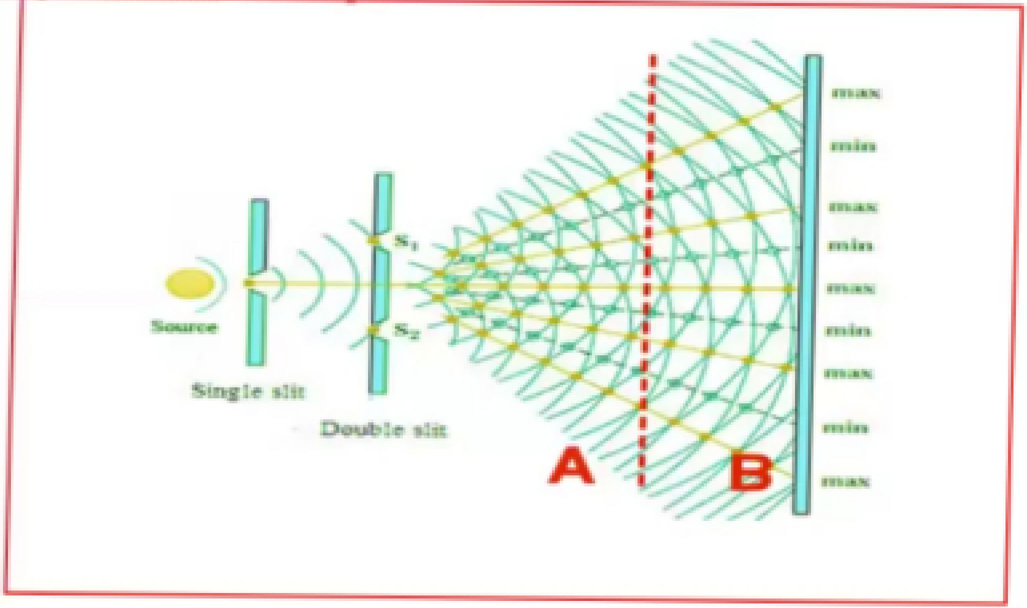
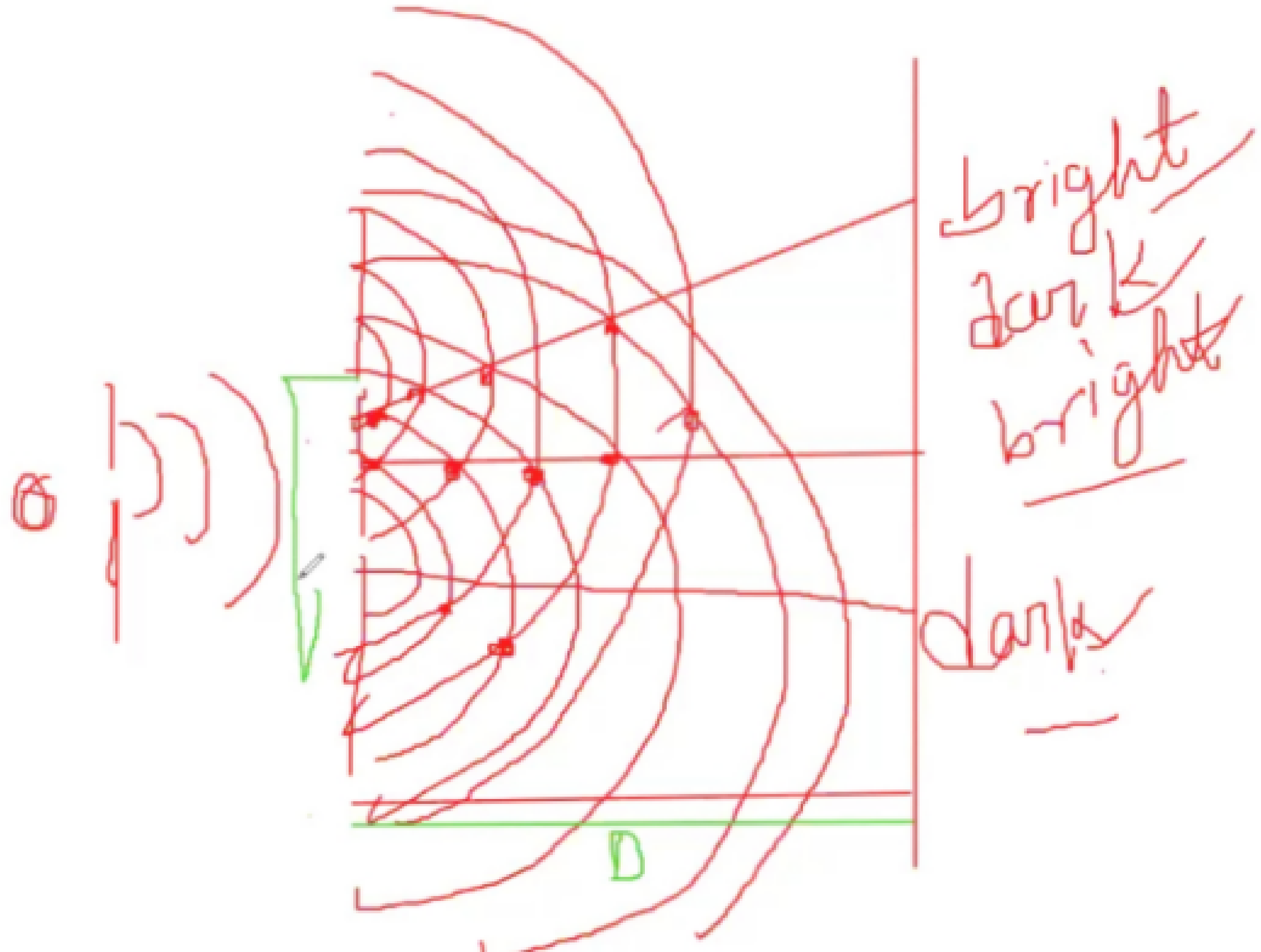



bright
dark
bright
dark
D

$$X = x_{n+1} - x_n$$

$$\therefore \quad X = \frac{D}{d}(n+1)\lambda - \frac{D}{d}n\lambda$$

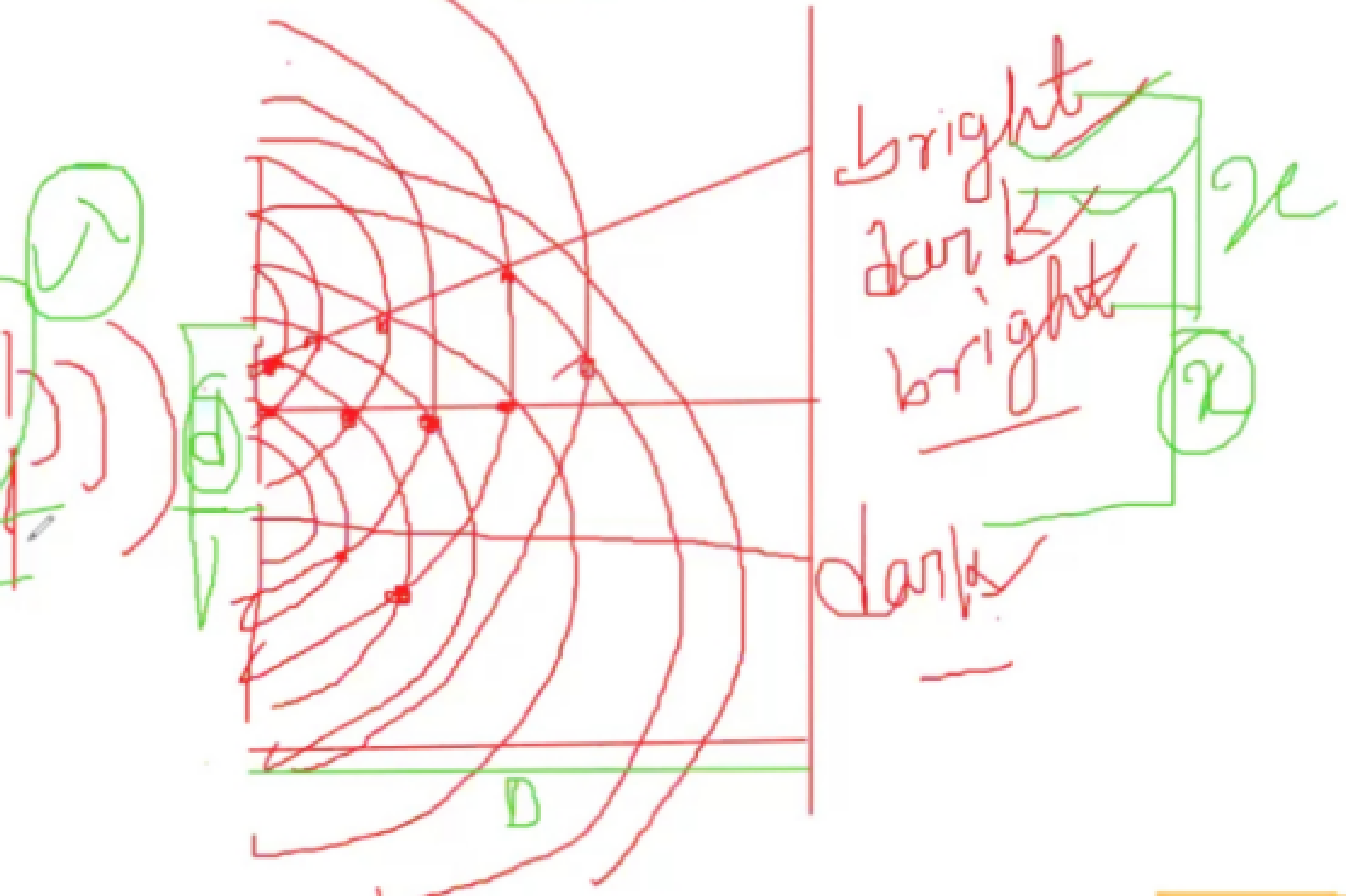
$$\therefore \quad X = \frac{D}{d}(n+1-n)\lambda$$

$\therefore$ Distance between consecutive bright band

$$\therefore \quad X = \frac{\lambda D}{d} \quad \text{.............} (5)$$

$$x = \frac{\lambda D}{d}$$

$$x = \frac{\lambda D}{2d}$$



$$\frac{r^2}{4} = n\lambda R$$

$$D_n = 2\sqrt{n\lambda R}$$

if D_{n+m} be the diameter of $(n + m)$th dark ring

$$D_{n+m} = \sqrt{4(n + m)\lambda R}$$

$$\boxed{\lambda = \frac{D^2{}_{n+m} - D^2{}_{n}}{4(m + n) - 4n}R}$$

<u>Mathematical Problem:</u>

1. Suppose you pass light from a He-Ne laser through two slits separated by 0.0100 mm and find that the third bright line on a screen is formed at an angle of 10.95° relative to the incident beam. What is the wavelength of the light?

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$+4n-4n$

$= 4m$

$n+m$

m

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$D^2_{n+m} - D^2_n$

$4m$

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2. Young double slit experiment the distance between two slits is 2mm. the separation between two consecutive fringes at a distances 1m from the slits is found to be 0.295mm. Find the wavelength of light.

Solution,

Where,

Width of the slit **d** = 2mm = 2 x 10^{-3}m

Distance of the screen from the slit **D** = 1m

Fringe seoeraton **x** = 0.295mm = 0.295 x 10^{-3}m

Wavelength λ = ?

$$\lambda = \frac{xd}{D}$$

$$= \frac{0.295 \times 10^{-3} \times 2 \times 10^{-3}}{1}$$

$$= 5.9 \times 10^{-7}\ \text{m}$$

3. In a Newton's rings experiment the diameter of the 15th ring was found to be 0.59 cm and that of the 5th ring is 0.336 cm. If the radius of curvature of the lens is 100 cm, find the wave length of the light.

Solution,

$= \frac{\quad}{1}$

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D^2_{n+m}

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D^2_n

$R = 1m$

Solution,

λ

Where,

Diameter of Newton's 15th ring (D15) = 0.59 cm = 0.59×10–2 m

Diameter of Newton's 5th ring (D5) = 0.336 cm = 0.336 × 10–2 m

$n+m=15$

$\Rightarrow 5+m=15$

$\cdot 10$

Diffraction

Definition: The bending of light into geometrical shadow area when light passes along the edge of a sharp obstacle or going through a narrow slit is called the diffraction of light.

Types of diffraction:

Diffraction phenomena can conveniently be divided into two groups. They are,

1. Fresnel Diffraction: In the Fresnel class of diffraction, the source or the screen or the both are at finite distance from the aperture or obstacle causing diffraction.
2. Fraunhofer Diffraction: In the Fraunhoffer class of diffraction, the source or the screen or the both are at infinite distance from the aperture or obstacle causing diffraction.

Diffraction of Single Slit Experiment

secondary wavelets which spread in all directions on the other side of the grating.

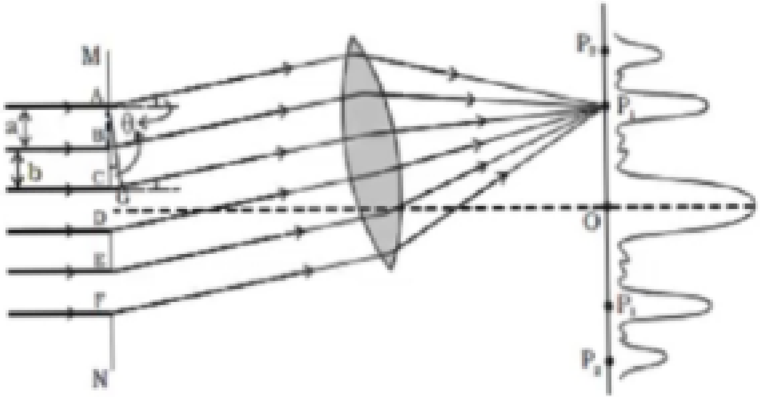
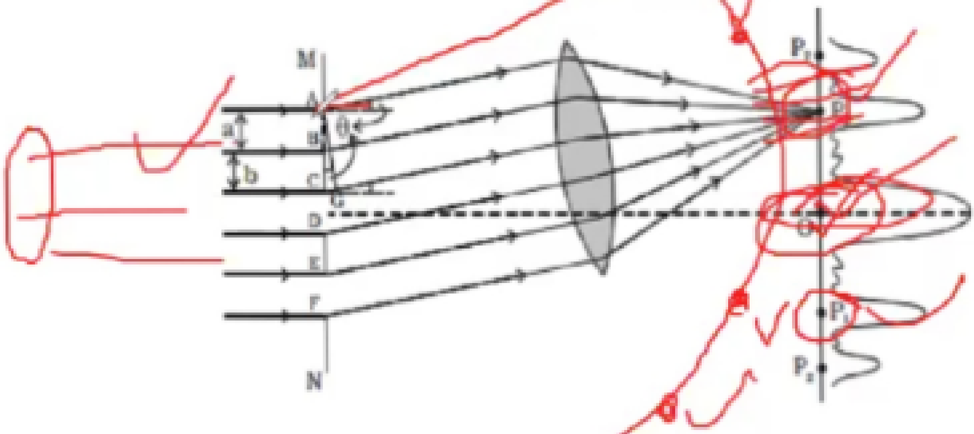


Fig: Diffraction grating.

Let us consider the secondary diffracted wavelets, which make an angle θ with the normal to the grating.

The path difference between the wavelets from one pair of corresponding points A and C is CG = (a + b) sin θ. It will be seen that the path difference between waves from any pair of corresponding points is also (a + b) sin θ = d sin θ secondary wavelets which spread in all directions on the other side of the grating.



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	Interference	Diffraction
1.	It is due to the superposition of secondary wavelets from two different wavefronts produced by two coherent sources.	It is due to the superposition of secondary wavelets emitted from various points of the same wave front.
2.	Fringes are equally spaced.	Fringes are unequally spaced.
3.	Bright fringes are of same intensity	Intensity falls rapidly
4.	Comparing with diffraction, it has large number of fringes	It has less number of fringes.

<u>Polarization</u>

Definition:

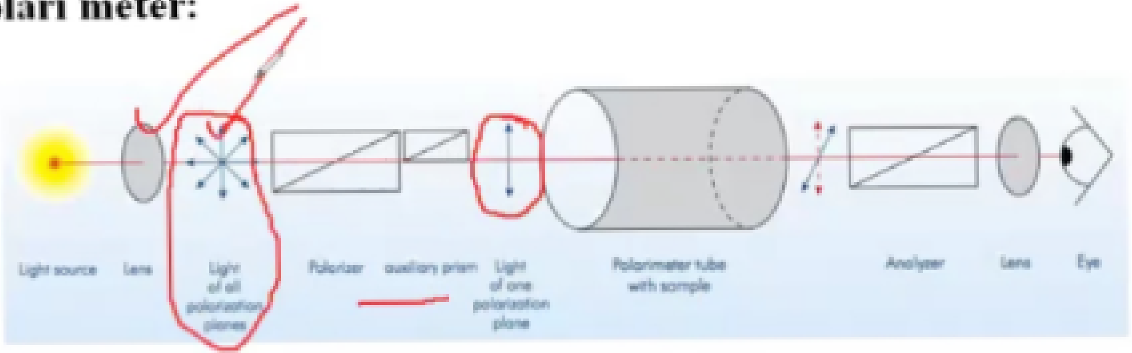
If such condition can be imposed on the vibration of a wave so that its vibration is confined along a particular direction or in a particular plane then it is call polarization.

Please move this

polarization parallel to the surface.

the Iceland Spar crystal are polarized with perpendicular orientations.

Polari meter:



Brewster's Law:

The tangent of the angle of polarization is numerically equal to the refractive index of the medium. Moreover, the reflected and refracted rays are perpendicular to each other.