Diffraction of light.

Diffraction is the phenomenon of bending of light around the corner of obstacles (or slit) are spreading into geometrical shadow region.

The necessary condition is that the size of the slit or Obstacle must be comparable with the wavelength of the wave. That is why diffraction of sound is more common than that in light.

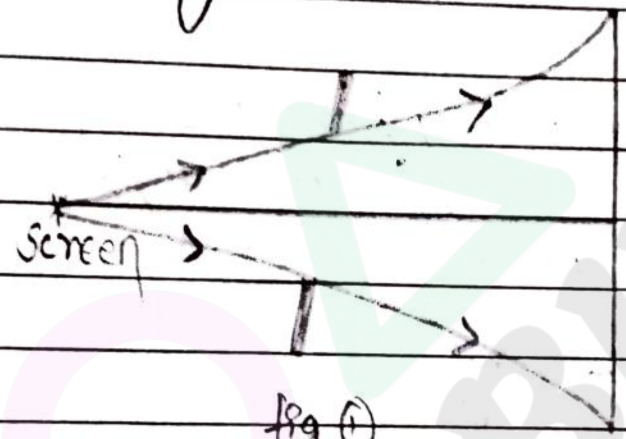


fig ①

Diffraction at a single slit

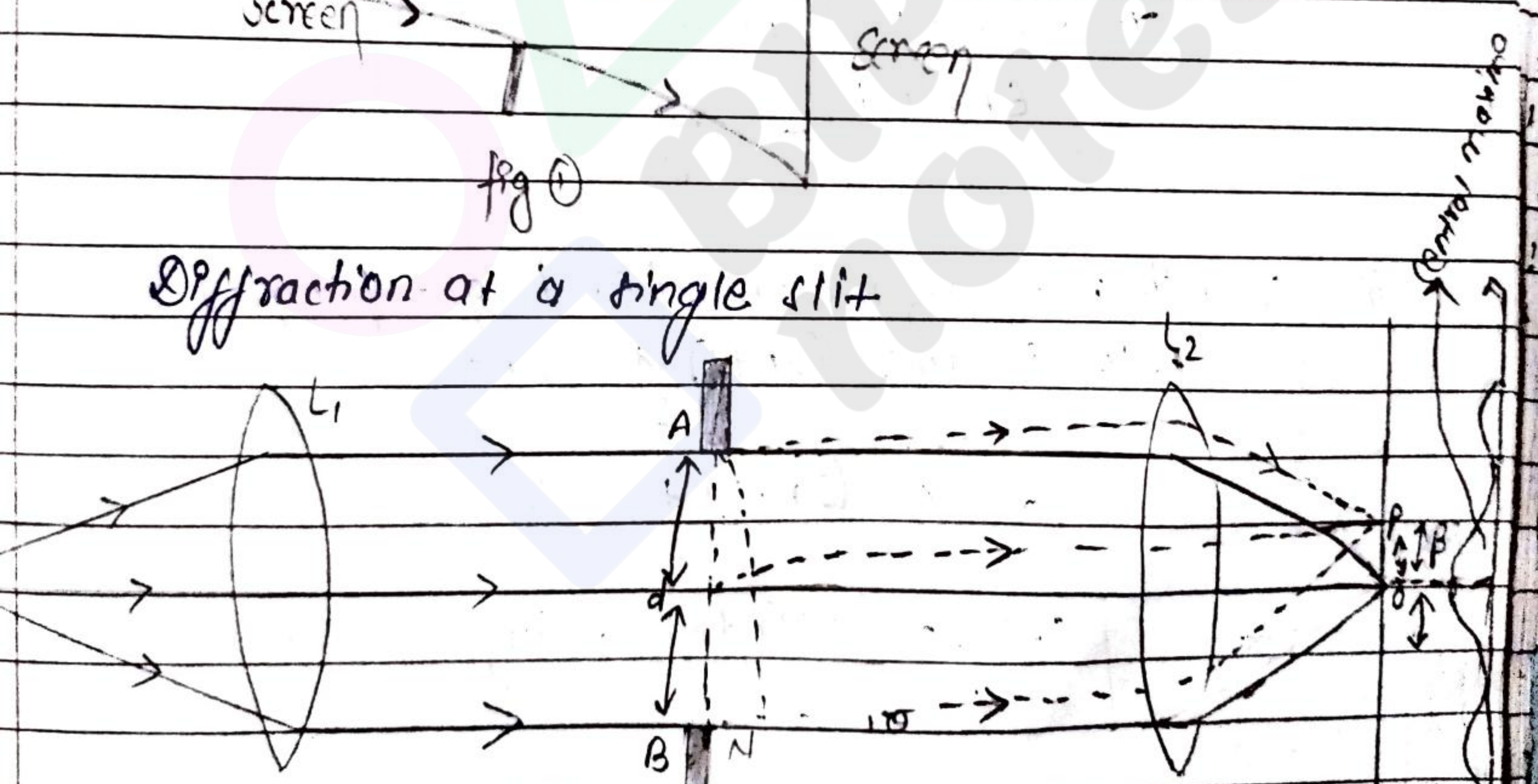


fig (2) diffraction of light at a single unit.

In fig (a) parallel beam of light is incident normally at AB of width d. After diffraction the beam is focused on screen with lens L_2.

A central followed by minima and maxima of decreasing intensity are observed on screen as shown in fig 3.

At centre 'O' of screen path difference between light coming from A and B is same, hence 'O' corresponds central (or principal) maxima.

At point P on screen the path difference between light coming from B and A is

$$(BP - AP) = BN = d\sin\theta$$

$$\therefore d\sin\theta = BN \quad \text{--- i)}$$

For n^{th} secondary minima (i.e dark fringe)

path difference $= n\lambda$; $n = 1, 2, 3 \ldots$

$$\therefore d\sin\theta = n\lambda$$

$$\sin\theta = \frac{n\lambda}{d} \approx \theta \quad \left[\because \sin\theta = \theta \text{ for small angle}\right]$$

Thus for n^{th} minima

$$\boxed{\theta_n = \frac{n\lambda}{d}} \quad \text{--- ii)}$$

For n^{th} secondary maxima (i.e. bright fringe)

path difference $= (2n+1)\frac{\lambda}{2}$; $n = 1, 2, 3 \ldots$

$$d\sin\theta = (2n+1)\frac{\lambda}{2} \approx d\theta$$

$$\boxed{\therefore \theta_n = \frac{(2n+1)\lambda}{2d}} \quad \text{--- iii)}$$

iii) width of central maxima (B_0)

It is defined as the distance between two first minima on either side of central maxima.

Thus, $B_0 = 2B$.

or, $B_0 = \frac{2\lambda D}{d}$ where,

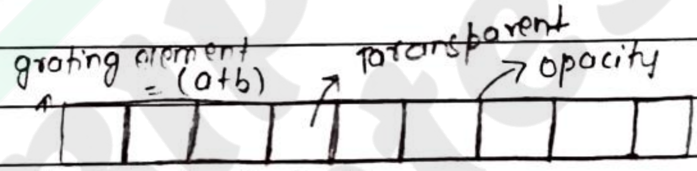
B = distance of first minima from centre $= \frac{\lambda D}{d}$ $\left(\therefore \theta_1 = \frac{\lambda}{d} = \frac{B}{D} \right)$

[Arc PO = D·θ
B = D·θ
θ = $\frac{B}{D}$]

iv) Angular width of central maxima.

$$= \frac{2\left[\frac{\lambda D}{d}\right]}{D}$$

$$= \frac{2\lambda}{d} \text{ radian.}$$



* Diffraction grating

An optical device to study the spectra of a source of light and to determine the wavelength of light, is called diffraction grating. There are two types of diffraction grating.

1500 inch per in cm

1 cm = 6000 turns

i. Transmission grating:- In transmission grating the lines are ruled on glass. The light incident of line is scattered and lines behaves as opaque obstacle while the space between two lines transmit and act a slit.

ii. Reflection grating:- In reflection grating lines are ruled on metal which scatter light but the unrule parts reflect light regularly.

Theory of diffraction grating:-

A diffraction grating consists of a large number of fine, equidistant, closely spaced parallel lines of equal width ruled on glass or polished metal by a diamond point.

If a is the width of each transparency and b is width of each opacity then grating element is given by grating element $= (a+b) = \frac{1}{N}$ inch $= \frac{1}{N} \times 2.54$ cm where, N = Number of lines on grating per inch.

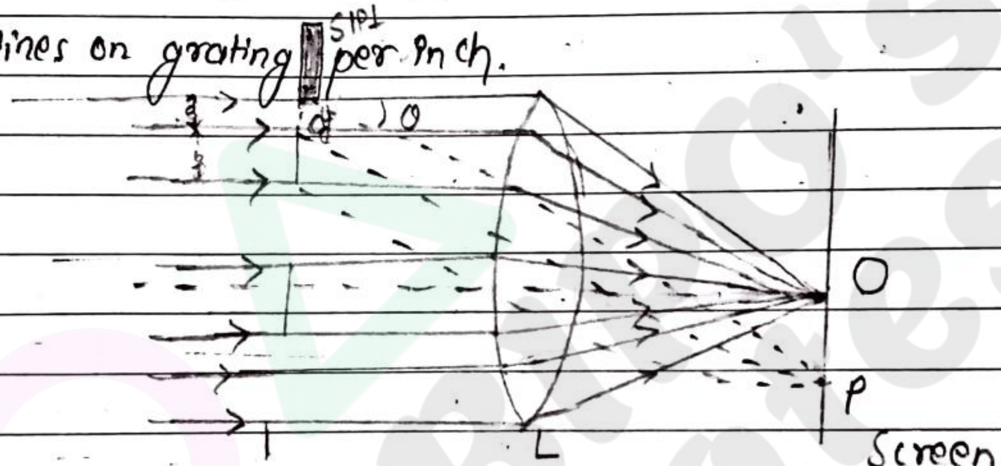


fig (3)

The diffracted light through N slits is focused by lens L on screen placed in the focal plane of the lens. The pattern obtained on screen is called fraunhofer diffraction pattern due to N slits which consists of

i) a central maximum at centre O of the screen. Secondary maxima are formed above and below O.

ii) A large number of faint subsidiary maxima and minima are formed in between secondary maxima.

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For nth order maxima

$\boxed{(a+b)\sin\theta_n = n\lambda}$; $n = 1, 2, 3 \ldots$

For $n=0$, central maxima is formed

Resolving power of optical instrument

For diffraction grating

$\boxed{\text{resolving power} = \frac{\lambda}{d\lambda} = nN}$ where n = order of diffraction
N = number of lines per unit length

$\boxed{\text{Dispersive power} = \frac{\text{Resolving power}}{\cos\theta}}$ $d\lambda = (\lambda_2 - \lambda_1)$

$\lambda = \frac{\lambda_1 + \lambda_2}{2}$

Numericals:

1. How wide is the central diffraction pattern on a screen 3.5 m behind 0.01 mm slit illuminated by 500 nm light.

Soln →

width of central maxima $(\beta_0) = \frac{2\lambda D}{d}$

$$\beta_0 = \frac{2 \times 500 \times 10^{-9} \times 3.5}{0.01 \times 10^{-3}} = 0.35 \text{ m}.$$

2) A parallel beam of monochromatic light is allowed to be incident normally on a plane transmission grating having 5000 lines cm^{-1} & second order spectrum is found to be diffracted through 30°. calculate the wavelength of light. Calculate the wavelength of light.

Given,

For grating

$$(a+b) = \frac{1}{N} = \frac{1}{5000 cm^{-1}} = \frac{cm}{5000} = \frac{10^{-2} m}{5000} = 0.2 \times 10^{-5} m$$

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$\theta_2 = 30^\circ$

$n = 2$ (second order)

$d = ?$

$(a+b)\sin\theta_n = n d.$

or, $0.2 \times 10^{-5} \times \sin 30^\circ = 2d$

or, $d = \frac{0.2 \times 10^{-5}}{2} \times \frac{1}{2}$

or, $d = 0.5 \times 10^{-6} m$

or, $d = 5 \times 10^{-7} m$

or, $d = 5000 \times 10^{-10}$

or, $d = 5000 A^\circ$.

3) A plane transmission grating having 500 lines mm^{-1} is illuminated normally by a light of wavelength 600 nm. How many diffraction maxima will be observed on screen?

⇒ here,

$a+b = \frac{1}{500 mm^{-1}}$

$= \frac{1 mm}{500} = \frac{10^{-3} m}{500} = 0.2 \times 10^{-5} m.$

Soln

$(a+b)\sin\theta_n = n d.$

For n max ; $\sin\theta_n = 1.$

$\therefore (a+b) = n_{max} d.$

$n_{max} = \frac{a+b}{d}$

$= \frac{0.2 \times 10^{-5}}{600 \times 10^{-9}}$

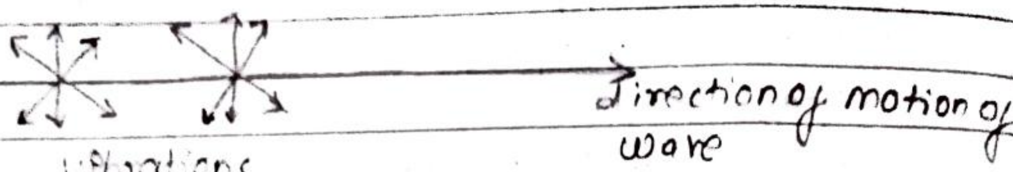
$= 3.33 \approx 3.$

XII (OPTICS)

CHAPTER-13: [Polarization of light]

Transverse nature of light:

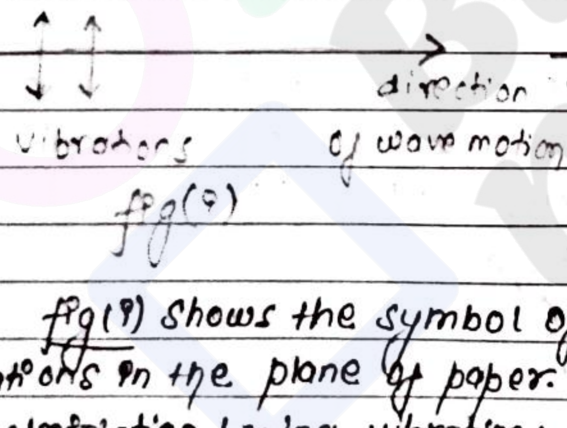
Ordinary light is transverse wave having vibration perpendicular to the direction of wave motion in all possible planes as shown in fig (1) below.



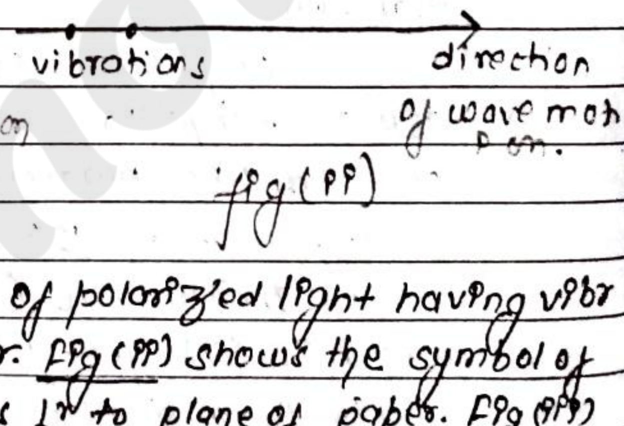
fig(1)

Polarization of light:-

When the vibrations of ordinary (or unpolarized) light are confined in a single plane, then the process is called polarization of light. The light having vibrations in a single plane is called polarized light.

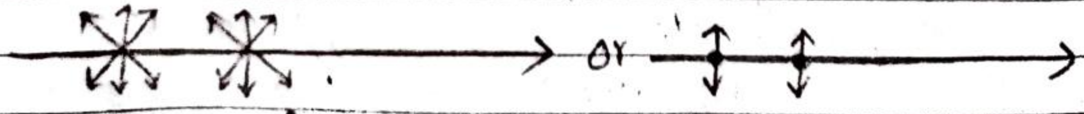


fig(i)



fig(ii)

fig(i) shows the symbol of polarized light having vibrations in the plane of paper. Fig (ii) shows the symbol of polarization having vibrations ⊥r to plane of paper. Fig (iii) shows the symbol of ordinary or unpolarized light.



fig(iii)

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Polarization by reflection and Brewster's law:-

When ordinary or unpolarized light is incident on a transparent medium like glass slab, then the reflected light is partially polarized. The degree of polarization of reflected light increases with the increase of angle of incidence.

When the angle of incidence becomes equal to certain angle i_p. Then the reflected ray is totally polarized as shown in fig (1). This angle i_p is called polarization angle.

According to Brewster's law when ordinary light is incident on transparent medium at polarizing angle then the reflected and refracted rays are perpendicular to each other.

Thus in fig. (1)

$\angle BOC = 90°$.

$\therefore \angle AON = \angle BON = i_p$. (law of reflection of light)

$\therefore \angle NOB + \angle r = 90°$.

or $i_p + r = 90°$.

$\therefore r = (90° - i_p)$ —(1)

From Snell's law of reflection

$$\frac{\sin i_p}{\sin r} = \mu$$

$$\therefore \frac{\sin i_p}{\sin (90 - \mu)} = \mu \quad [\because r = 90 - i_p)$$

or $\boxed{\mu = \tan i_p}$

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Numericals:-

(1) The critical angle of light in a glass is 41.8°. What is polarizing angle?

Soln→

$$\sin c = \frac{1}{\mu} \Rightarrow \mu = \frac{1}{\sin c} = \frac{1}{\sin 41.8} = 1.5$$

From Brewster's law,

$$\mu = \tan i_p$$

$$\therefore i_p = \tan^{-1}(\mu) = \tan^{-1}(1.5) = 56.3°$$

(2) Calculate the angle of incidence on glass (of refractive index 1.55) such that the reflected light is totally polarized if the glass is immersed in (a) air, (b) in water (refractive index 1.33)

Soln→

(a) When the glass is in air, then

$$\mu = {}^{a}\mu_g = 1.55$$

$$\therefore \mu = \tan i_p \Rightarrow i_p = \tan^{-1}(\mu) = \tan^{-1}(1.55) = 57.2°$$

(b) when the glass is immersed in water than.

$$\mu = {}^{w}\mu_g = \frac{\mu_g}{\mu_w} = \frac{1.55}{1.33} = 1.165$$

$$\therefore \mu = \tan i_p \Rightarrow i_p = \tan^{-1}(\mu) = \tan^{-1}(1.165) = 49.4°$$

(3) The velocity of light in a given medium is 2×10^8 ms^{-1}. Calculate the angle of polarization and angle of refraction.

Soln→

$$\text{Refractive index of medium} = \mu = \frac{c}{v} = \frac{3\times10^8}{2\times10^8} = 1.5$$

$$\therefore \mu = \tan i_p \Rightarrow i_p = \tan^{-1}(\mu)$$
$$= \tan^{-1}(1.5) = 56.3°$$

Now→

$$i_p + r = 90°$$

$$\therefore r = 90° - 57.2° = 33.7°$$

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Polaroid:- A device used to produce polarized light from unpolarized light is called polarizer. A circular plane she et acting as polarizer is called polaroid.

Applications of polaroid:- Polaroids are used :-

i) In sun glasses to block the harmful radiations from sun light.

(ii) To determine the size and shape of viruses that are not properly seen due to glare of light in microscopes.

(iii) In photography as a filter to record and reduce three - dimensional moving pictures.

MCQs.

1) The ratio of intensity $\frac{I_2}{I_1}$ for two waves $y_1 = 20 \sin \pi \theta$ and $y_2 = 40 \sin 100 \pi \theta$ will be

a) 1:4 b) 4:1 (c) 3:1 d) None of these

Hint →

$$\frac{I_2}{I_1} = \frac{A_2^2}{A_1^2} = \frac{1600}{400} = \frac{4}{1}$$

2) The phase differences between two waves $y_1 = a \sin \omega t$ and $y_2 = b \cos \omega t$ will be

(a) π (b) $\pi/2$ (c) $\pi/3$ (d) $\pi/4$

Hints

$$y_2 = b \cos \omega t = b \sin \left(\frac{\pi}{2} - \omega t\right)$$

$$\therefore \text{phase diff} = \pi/2.$$

3) Sky appears blue due to:-

a) more scattering of light of larger wavelength.

(b) more scattering of light of lesser wavelength.

(c) the lens of eye is blue.

d) all of above. [Hint: Scattering $\propto \frac{1}{\lambda^2}$]

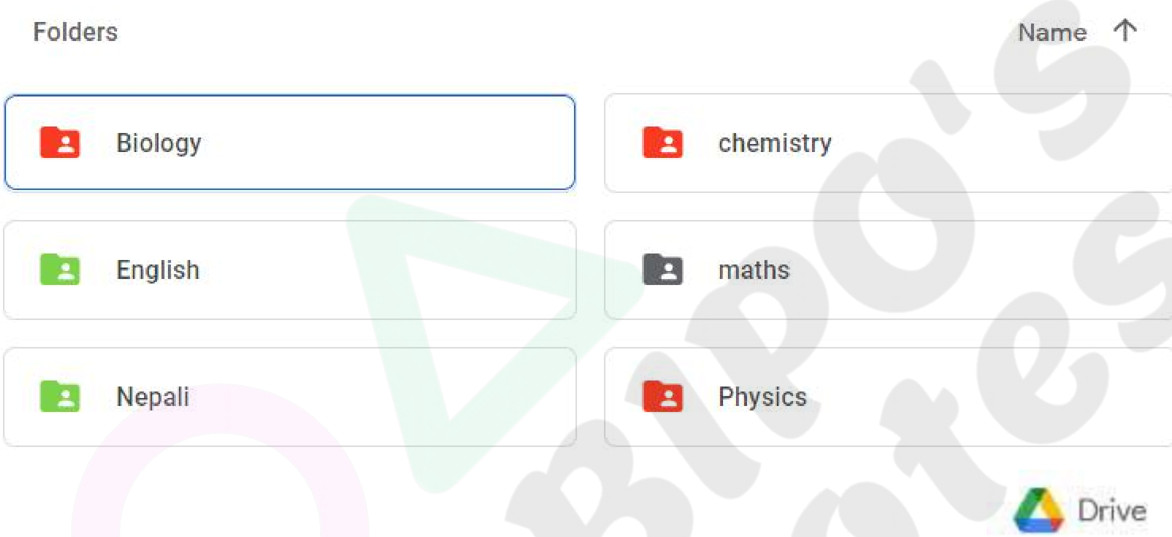
Teacher's Signature..........

Ultra White A4

Bipin Khatri

(Bipo)

Class 12 complete notes and paper collection.



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