B.TECH.

EAS-101

FIRST SEMESTER THEORY EXAMINATION 2010-11

ENGINEERING PHYSICS-I

Time: 2 Hours *Total Marks: 50*

SECTION A

1. Attempt all parts. All parts carry equal marks. (10 × 1 = 10)

(a) Two photons approach each other, their relative velocity is:

(i) Zero (ii) c

(iii) 2c (iv) c/2

Ans. (ii) c

(b) Which of the following is invariant under Galilean transformation?

(i) velocity (ii) acceleration

(iii) speed (iv) none of these

Ans. (ii) acceleration

(c) A path difference of 3λ/2 between the two waves corresponds to the phase difference:

(i) 3π/2 (ii) π/3

(iii) 3π (iv) 2π/3

Ans. Path difference $(\Delta) = \dfrac{3\lambda}{2}$

Phase difference $(\phi) = ?$

$$\phi = \frac{2\pi}{\lambda}(\Delta)$$

$$\phi = \frac{2\pi}{\lambda}\cdot\frac{3\lambda}{2}$$

$$\boxed{\phi = 3\pi}$$

Ans. (iii)

(d) In a biprism experiment 5 mm wide fringes are obtained on a screen 1.0 m away from the coherent sources by using light of wavelength 5000 Å. The separation between two coherent sources is:

(i) 1.0 mm (ii) 0.1 mm

(iii) 0.01 mm (iv) 0.05 mm

Ans. Fringe width $\beta = 5 \text{ mm} = 5 \times 10^{-3}$ meter

$D = 1$ meter

$\lambda = 5000 Å$

$\lambda = 5 \times 10^{-7}$ meter

Separation between $(d) = ?$

Sources

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

$$\therefore d = \frac{\lambda D}{\beta}$$

$$d = \frac{5 \times 10^{-7} \times 1}{5 \times 10^{-3}}$$

$d = 10^{-4}$ meter

$d = 0.1 \times 10^{-3}$ meter

$$\boxed{d = 0.1 \text{ mm}}$$

Ans. (ii)

(e) Which of the following does not change on the refraction of light?

(i) wavelength (ii) frequency

(iii) velocity (iv) intensity

Ans. (ii) Frequency

(f) If first secondary maximum of wavelength 4600 Å falls on the first minimum of some wavelength λ in single slit diffraction pattern, the wavelength λ is:

(i) 6900 Å (ii) 2300 Å

(iii) 4600 Å (iv) 4900 Å

Ans. Condition for minima due to single slit is

$a \sin\theta = n\lambda_1$ ...(1)

for first minimum $n = 1$

$$\sin\theta = \frac{\lambda_1}{a} \quad ...(2)$$

Condition for first secondary maximum

$$\alpha = \frac{3\pi}{2} \quad ...(3)$$

and $$\alpha = \frac{\pi}{\lambda_2}(a\sin\theta) \quad ...(4)$$

From equation (2), (3) and (4), we have get

$$\frac{3\cancel{\pi}}{2} = \frac{\cancel{\pi}}{\lambda_2}\lambda$$

$$\lambda = \frac{3\lambda_2}{2}$$

$$\lambda = \frac{3\times 4600}{2} = 3\times 2300$$

$$\boxed{\lambda = 6900\text{Å}}$$

Ans. (i)

(g) Wave that cannot be polarized is:

(i) electromagnetic wave

(ii) matter waves

(iii) longitudinal wave

(iv) transverse wave

Ans. (iii) Longitudinal wave

(h) If N_1 and N_2 are the number of atoms in ground state and excited state respectively, then in population inversion:

(i) $N_1 < N_2$ **(ii) $N_1 > N_2$**

(iii) $N_1 = N_2$ **(iv) None of these**

Ans. (i) $N_1 < N_2$

(i) Light gets attenuated in an optical fiber due to:

(i) scattering **(ii) micro bending**

(iii) absorption **(iv) all the above**

Ans. (iv) All the above

(j) If the hologram is broken into pieces, then:

(i) there is irreparable loss of information

(ii) entire image of the object is lost

(iii) each piece is capable of reconstructing the entire image

(iv) none of these

Ans. (iii) each piece is capable of reconstructing the entire image

SECTION B

2. Attempt any three parts. All parts carry equal marks. **(5 × 3 = 15)**

(a) Calculate the length and orientation of a rod of length 5 m in a frame of reference moving with a velocity of 0.6c in the direction making an angle 30° with the rod.

Ans. $L_0 = 5$ meter

$v = 0.6\,\text{C}$

$\theta = 30°$

The length of the rod along the direction of the moving frame of reference = $L_0 \cos 30°$.

The apparent length of the rod along the direction of motion

$$L_x = L_0\cos 30°\sqrt{1-\frac{v^2}{c^2}}$$

$$L_x = 5\times\frac{\sqrt{3}}{2}\sqrt{1-\frac{(0.6c)^2}{c^2}}$$

$$L_x = \frac{5\sqrt{3}}{2}\sqrt{1-(0.6)^2}$$

$$L_x = \frac{5\sqrt{3}}{2}\sqrt{1-0.36}$$

$$L_x = \frac{5\sqrt{3}}{2}\sqrt{0.64}$$

$$L_x = \frac{5\sqrt{3}}{2}\times 0.8$$

$$L_x = 5\sqrt{3}\times 0.4$$

$$L_x = 2\sqrt{3}$$

Apparent length in a direction perpendicular to the direction of motion.

$$L_y = L_0\sin 30°$$

$$L_y = 5 \times \frac{1}{2}$$

$$L_y = 2.5 \text{ meter}$$

The length of the rod in a moving frame in a direction making an angle of 30° with rod

$$L = \sqrt{L_x^2 + L_y^2}$$

$$L = \sqrt{\left(2\sqrt{3}\right)^2 + (2.5)^2}$$

$$L = \sqrt{12 + 6.25}$$

$$L = \sqrt{18.25}$$

$$\boxed{L = 4.24 \text{ meter}}$$

If the rod makes angle θ with x - axis in the moving frame, then

$$\tan\theta = \frac{L_y}{L_x}$$

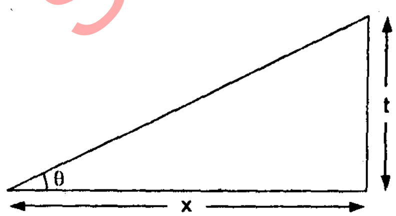
$$\tan\theta = \frac{2.5}{2\sqrt{3}} = \frac{2.5}{3.464} = 0.72$$

$$\theta = \tan^{-1}(0.72)$$

$$\boxed{\theta = 35.75°}$$

(b) Two plane glass surfaces in contact along one edge are separated at the opposite edge by a thin wire. If 20 interference fringes are observed between those edges, in sodium light of wavelength λ = 5890 Å of normal incidence, find the diameter of the wire.

Ans. The fringe width in air-wedge for normal incidence is given by



$$\beta = \frac{\lambda}{2\theta} \quad \text{... (1)}$$

Let t be the thickness of the wire and x be the length of the glass surface from the point of contact, then wedge angle

$$\theta = \frac{t}{x} \quad \text{... (2)}$$

from equation (1) and (2), we get

$$\beta = \frac{\lambda}{2\left(\frac{t}{x}\right)} = \frac{\lambda x}{2t} \quad \text{...(3)}$$

If n fringes are seen in the entre film, then

$$x = n\beta$$

$$\therefore \quad \beta = \frac{\lambda n\beta}{2t}$$

$$\therefore \quad t = \frac{n\lambda}{2}$$

Given $n = 20$

$$\lambda = 5890 \text{Å} = 5890 \times 10^{-10} \text{ meter}$$

$$\therefore \quad t = \frac{20 \times 5890 \times 10^{-10}}{2}$$

$$\boxed{t = 5.89 \times 10^{-6} \text{ meter}}$$

(c) Find the angular separation of 5048 Å and 5016 Å wavelengths in second order spectrum obtained by a plane diffraction grating having 15000 lines per inch.

Ans. We know grating equation for plane transmission grating or position of principle of maxima are

$$(a + b)\sin\theta = n\lambda \quad \text{... (1)}$$

Here $n = 2$

$$\lambda_1 = 5048 \text{ Å} = 5048 \times 10^{-8} \text{ cm}$$

$$\lambda_2 = 5016 \text{ Å} = 5016 \times 10^{-8} \text{ cm}$$

And $a + b = \dfrac{2.54}{15,000}$ cm

from equation (1) we get

$$(a + b)\sin\theta_1 = n\lambda_1$$

$$\sin\theta_1 = \frac{n\lambda_1}{a+b}$$

$$\sin\theta_1 = \frac{2 \times 5048 \times 10^{-8}}{\left(\frac{2.54}{15000}\right)}$$

$$\sin \theta_1 = \frac{2 \times 5048 \times 15000 \times 10^{-8}}{2.54}$$

$$\sin \theta_1 = \frac{2 \times 5.048 \times 1.5 \times 10^{-1}}{2.54}$$

$$\sin \theta_1 = \frac{2 \times 5.048 \times 1.5}{2.54 \times 10}$$

$$\sin \theta_1 = \frac{15.144}{25.4}$$

$$\theta_1 = \sin^{-1}(0.596)$$

$$\boxed{\theta_1 = 36.58°}$$

for $\lambda_2 = 5016$ Å

$$(a+b) \sin \theta_2 = n\lambda_2$$

$$\sin \theta_2 = \frac{n\lambda_2}{(a+b)}$$

$$\sin \theta_2 = \frac{2 \times 5016 \times 10^{-8}}{\left(\frac{2.54}{15000}\right)}$$

$$\sin \theta_2 = \frac{2 \times 5.016 \times 10^{-5} \times 15000}{2.54}$$

$$\sin \theta_2 = \frac{2 \times 5.016 \times 1.5 \times 10^{-1}}{2.54}$$

$$\sin \theta_2 = \frac{2 \times 5.016 \times 1.5}{2.54 \times 10}$$

$$\sin \theta_2 = \frac{15.048}{25.4}$$

$$\sin \theta_2 = 0.592$$

$$\theta_2 = \sin^{-1}(0.592)$$

$$\theta_2 = 36.299°$$

$$\boxed{\theta_2 = 36.30°}$$

Hence angular separation is given by

Angular sep. $= \theta_1 - \theta_2$

$$= 36.58° - 36.30° = 0.28°$$

(d) Find the thickness of a quarter wave plate for the wavelength of light of 5890 Å. The refractive indices for ordinary and extraordinary rays are 1.55 and 1.54 respectively.

Ans. The thickness of a quarter wave plate for negative crystal is

$$t = \frac{\lambda}{4(\mu_0 - \mu_e)}$$

$$t = ?$$

Here $\lambda = 5890°$ Å

$$\lambda = 5890 \times 10^{-10} \text{ meter}$$

$$\mu_0 = 1.55$$

$$\mu_0 = 1.54$$

$$\therefore \quad t = \frac{5890 \times 10^{-10}}{4(1.55 - 1.54)}$$

$$t = \frac{589 \times 10^{-9}}{4 \times 0.01}$$

$$t = 147.25 \times 10^{-7} \text{ meter}$$

$$\boxed{t = 1.4725 \times 10 - 5 \text{ meter}}$$

(e) A step index fiber has core and cladding refractive indices 1.466 and 1.460 respectively. If the wavelength of light 0.85 μm is propagated through the fiber of core diameter 50 μm, find the normalized frequency and the number of mode supported by the fiber.

Ans. We know that normalized frequency or cut-off parameter or V-meter is

$$V = \frac{2\pi a}{\lambda}\sqrt{n_1^2 - n_2^2}$$

Where a is the radius of core, n_1 is refractive index of the core, n_2 is refractive index of the cladding and λ operating wavelength

Here $\quad a = \frac{50}{2}$ μm

$$a = 25 \ \mu m$$

$$\lambda = 0.85 \ \mu m$$

$$n_1 = 1.466$$

$$n_2 = 1.460$$

$$V = \frac{2 \times 3.14 \times 25}{0.85}\sqrt{(1.466)^2 - (1.460)^2}$$

$$V = 184.70\sqrt{2.149 - 2.132}$$

$$V = 184.70\sqrt{0.017}$$
$$V = 184.7 \times 0.130$$
$$\boxed{V = 24.08}$$

$$\text{Number of modes } (N) = \frac{V^2}{2}$$

$$N = \frac{24.08 \times 24.08}{2}$$

$$N = 289.9$$

$$\boxed{N = 300}$$

SECTION C

Note: Attempt all questions of this section. All questions carry equal marks.

3. Attempt any one parts of the following:

(1 × 5 = 5)

(a) Show that no signal can travel faster than the velocity of light.

Ans. If $u' = c$ i.e moving particle be a photon moving with the velocity of light in the positive direction of X-axis, then its velocity observed by an observer in frame S is given by

$$u = \frac{c+v}{1+\frac{cv}{c^2}} = \frac{c\,(c+v)}{c+v} = c$$

Thus observer in frame S' and S recorded the same value for the velocity of photon.

If we put $u' = c$ and $v = c$

$$u = \frac{c+c}{1+\frac{c^2}{c^2}} = c$$

Hence we conclude that the addition of any velocity of the velocity of light simply reproduces the velocity of light. It means that the velocity of light in vacuum is the maximum attainable velocity in nature and **no signal** can travel faster than light in vacuum.

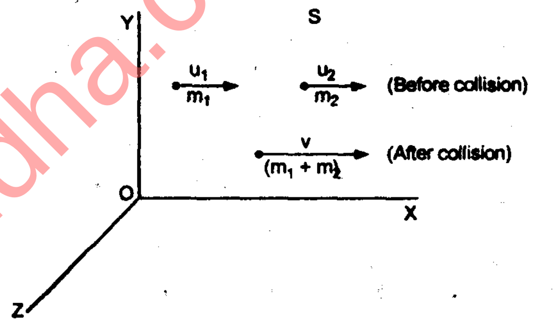
(b) Show that the relativistic invariance of the law of conservation of momentum leads to the concept of variation of mass with velocity.

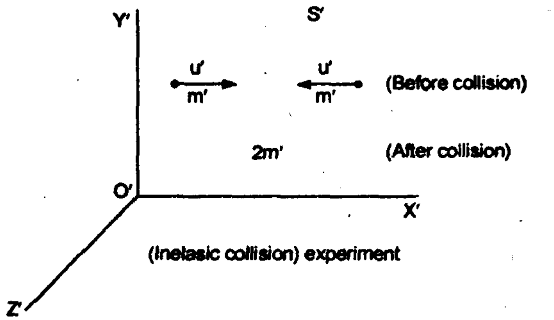
Ans. Relativity of Mass

Relativistic variation of Mass with velocity: According to Newtonian mechanics the mass of a moving body is constant and independent of velocity. But according to theory of relativity mass varies with velocity.

To determine the velocity dependence of mass. Consider a **Collision experiment** of two identical **perfectly elastic smooth balls.**

Suppose a frame S' is moving along $+x$-direction with a uniform velocity v relative to the frame S. In this inertial frame S' two bodies of equal masses m' travelling u' and $-u'$ parallel to x-axis collide and after collision they form into one body.





(Inelasic collision) experiment

Hence by the principle of conservation of momentum in frame S'.

Momentum before collision = momentum after collision

$$m'u' - m'u' = 2m'v'$$

$$\therefore \quad \boxed{v' = 0}$$

Thus the velocity of coalesceed body is frame S' will be zero i.e coalesced body is at rest in frame S'.

Let us now consider how this collision experiment appear to an observer in frame S. The velocity of the two bodies will not appear to be equal for an observer in frame S as it is moving with a velocity $-v$ relative to the frame S'.

If the velocity of the two bodies are observed as u_1 and u_2 before collision in frame S, then by relativistic law of addition of velocities.

$$u_1 = \frac{u'+v}{1+\frac{u'v}{c^2}} \quad \text{...(1)}$$

$$u_2 = \frac{-u'+v}{1-\frac{u'v}{c^2}} \quad \text{...(2)}$$

If we assume that mass of bodies is variable, then the mass of the bodies in frame S will appear to be different as their velocities are different.

Let m_1 be the mass of the body travelling with a velocity u_1 and m_2 be the mass of the body travelling with a velocity u_2.

After collision as the coaleseed body is at rest with respect to frame S', it will appear to be moving with a velocity v in frame S and its mass will be $(m_1 + m_2)$.

Thus, Momentum before collision = momentum after collision.

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

$$m_1\left(\frac{u'+v}{1+\frac{u'v}{c^2}}\right) + m_2\left(\frac{-u'+v}{1-\frac{u'v}{c^2}}\right) = (m_1 + m_2)v$$

$$m_1\left(\frac{u'+v}{1+\frac{u'v}{c^2}} - v\right) = m_2\left(v - \frac{-u'+v}{1-\frac{u'v}{c^2}}\right)$$

$$m_1\left(\frac{u' + \cancel{v} - \cancel{v} - \frac{u'v^2}{c^2}}{1+\frac{u'v}{c^2}}\right) = m_2\left(\frac{\cancel{v} - \frac{u'v^2}{c^2} + u' - \cancel{v}}{1-\frac{u'v}{c^2}}\right)$$

$$\frac{m_1u'\left(1-\cancel{\frac{v^2}{c^2}}\right)}{1+\frac{u'v}{c^2}} = \frac{m_2u'\left(1-\cancel{\frac{v^2}{c^2}}\right)}{1-\frac{u'v}{c^2}}$$

$$\frac{m_1}{m_2} = \frac{1+\frac{u'v}{c^2}}{1-\frac{u'v}{c^2}} \quad \text{...(3)}$$

But from eq^n (1)

$$1-\frac{u^2}{c^2} = 1-\frac{(u'+v)^2}{c^2\left(1+\frac{u'v}{c^2}\right)^2} = 1-\frac{c^2(u'+v)^2}{\left(c^2+u'v\right)^2}$$

$$= \frac{1+\frac{u'^2v^2}{c^4} + \cancel{\frac{2u'v}{c^2}} - \frac{u'^2}{c^2} - \frac{v^2}{c^2} - \cancel{\frac{2u'v}{c^2}}}{\left(1+\frac{u'v}{c^2}\right)^2}$$

$$= \frac{\left(1-\frac{v^2}{c^2}\right) - \frac{u'^2}{c^2}\left(1-\frac{v^2}{c^2}\right)}{\left(1+\frac{u'v}{c^2}\right)^2}$$

$$= \frac{\left(1-\frac{v^2}{c^2}\right)\left(1-\frac{u'^2}{c^2}\right)}{\left(1+\frac{u'v}{c^2}\right)^2} \quad \text{...(4)}$$

From eq^n (2)

$$1-\frac{u_2^2}{c^2} = \frac{\left(1-\frac{u'^2}{c^2}\right)\left(1-\frac{v^2}{c^2}\right)}{\left(1-\frac{u'v}{c^2}\right)^2} \quad \text{...(5)}$$

Hence (5)/(4):

$$\frac{\left(1-\frac{u_2^2}{c^2}\right)}{\left(1-\frac{u_1^2}{c^2}\right)} = \frac{\left(1+\frac{u'v}{c^2}\right)^2}{\left(1-\frac{u'v}{c^2}\right)^2}$$

$$\frac{\sqrt{\left(1-\frac{u_2^2}{c^2}\right)}}{\sqrt{\left(1-\frac{u_1^2}{c^2}\right)}} = \frac{\left(1+\frac{u'v}{c^2}\right)}{\left(1-\frac{u'v}{c^2}\right)} \qquad \text{... (6)}$$

From (6) and (3):

$$\frac{m_1}{m_2} = \frac{\sqrt{1-\frac{u_2^2}{c^2}}}{\sqrt{1-\frac{u_1^2}{c^2}}}$$

$$m_1\sqrt{1-\frac{u_1^2}{c^2}} = m_2\sqrt{1-\frac{u_2^2}{c^2}} \qquad \text{... (7)}$$

$$m\left(1-\frac{u^2}{c^2}\right)^{1/2} = \text{Constant} \qquad \text{... (8)}$$

For a particle at rest i.e $v = 0$, if mass is m_0 then

$$\Rightarrow \quad m\left(1-\frac{v^2}{c^2}\right)^{1/2} = m_0(1-0)^{1/2} = m$$

$$\Rightarrow \cancel{m}_0(\cancel{1}-\cancel{0})^{\cancel{1/2}}$$

$$\Rightarrow \cancel{m}_{\cancel{0}}$$

$$\boxed{m = \frac{m_0}{\left(1-\frac{v^2}{c^2}\right)^{1/2}}} \qquad \text{... (9)}$$

is the effective mass of the particle of rest mass now moving with a velocity v_0.

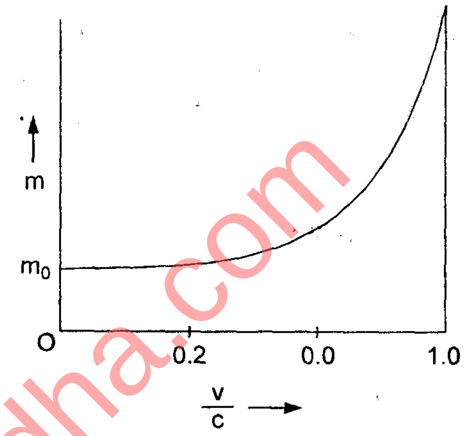
It is evident from equation (9), that for small values of v i.e

$$v << c$$

$$\frac{v^2}{c^2} << 1$$

So $\quad m = m_0$

But as the velocity of the particle increases the effective mass of the particle increases in comparison of its rest mass. Also as v approaches the speed of light c, the observed mass approaches infinity.



4. Attempt any one part of the following:(1 × 5 = 5)

(a) What are coherent sources? State the essential conditions for observing the phenomenon of interference of light.

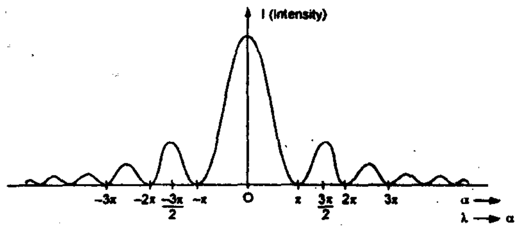
Ans. Coherent Sources: Two sources of light are said to be coherent if they emit light which has always a constant phase difference between them.

Essential conditions for observing the phenomenon of interference of light:

1. The two interfering sources must be coherent.
2. The light source must be monochromatic.
3. The amplitudes or intensities of the interfering waves must be equal.
4. The two interference waves must be propagated along the same direction.
5. If the interfering waves are polarised they must be polarised in the same state of polarisation.

(b) Explain briefly how the Fraunhofer diffraction pattern is modified when single slit is replaced by a double slit arrangement. (Derivation is not required)

Ans. Fraunhofer's Diffraction pattern due to single slit:



$$\boxed{I = R^2 = A^2\left(\frac{\sin\lambda \to \alpha}{\lambda \to \alpha}\right)^2}$$

Fraunhofer diffraction pattern due to double slit:

$$I = 4A^2\left(\frac{\sin^2\lambda \to \alpha}{\lambda^2 \to \alpha}\right)^2 \cos^2\beta$$

Where, $\dfrac{\sin^2\lambda \to \alpha}{\lambda^2 \to \alpha} \to$ gives diffraction pattern due to each single slit

$\cos^2\beta \to$ gives the interference pattern due to two waves of same amplitude.

Hence, the resultant intensity, due to double slit of equal width, at any point on the screen is given by the product of $\dfrac{\sin^2\lambda \to \alpha}{\lambda^2 \to \alpha}$ and $\cos\beta$.

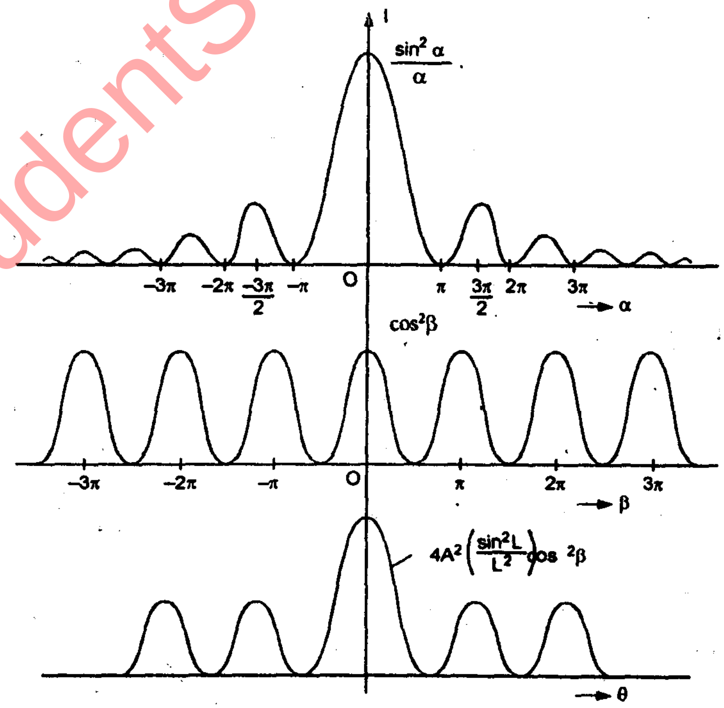


Fig. Intensity distribution due to double slit (Diffraction pattern)

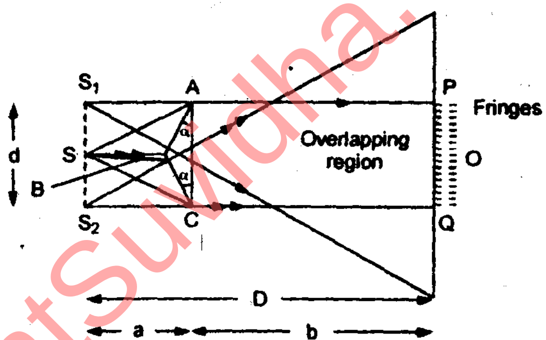
5. **Attempt any one part of the following:** **(1 × 5 = 5)**

(a) Explain the formation of interference fringes by means of a Fresnel's biprism and derive the expressions for the wavelength.

Ans. Fresnel's Biprism: It is a device for producing coherent sources by division of wave front. Fresnel produces the interference fringes by deriving two coherent sources S_1 and S_2 from a single monochromatic sources S.

Fresnel used a birprism to show interference pattern. He used a prism which was actually a simple prism, the base angles of which are extremely small $\left(=\frac{1}{2}^{\circ}\right)$.

In order to obtain interference fringes a vertical narrow slit S is illuminated with monochromatic light produced by **Sodium Lamp.** Biprism is placed infront of the slit S in such a way that the middle edge of the biprism remains parallel to slit. The slit is perpendicular to paper.



When a wavefront emitted from a sources S in incident on the refracting surfaces AB and BC, half of the wave front is refracted by AB and rest half of the wave front is refracted by BC. The refracted rays appear coming from S_1 and S_2. In this way two virtual images S_1 and S_2 of source S are formed. In overlapping region interference fringes are produced. These fringes can be seen with the help of eye piece.

The position of n^{th} bright fringe and n^{th} dark fringe from centre O of the central fringe may be obtained by relation

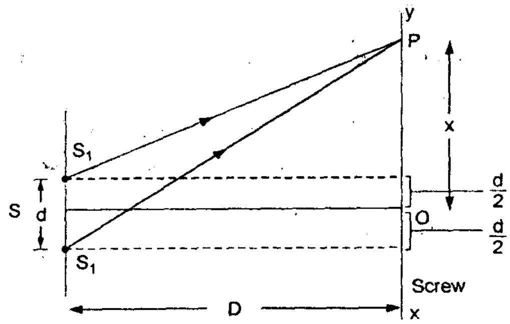
For **Bright Fringe** $x_n = \dfrac{n\lambda D}{d}$ $(n = 0, 1, 2, 3, ...)$

For **Dark Fringe** $x'_n = (2n+1)\dfrac{\lambda D}{2d}$ $(n = 0, 1, 2, 3...)$

Fringe width $\boxed{\beta = \dfrac{\lambda D}{d}}$

Expression for Wavelength:

Let S be a narrow slit illuminated by monochromatic light of wavelength λ, and S_1, and S_2 be the two narrov slits separated by a distance d.



The path difference between the waves reaching at P from S_1, and S_2 is given by

$$\Delta = S_2P - S_1P \qquad ...(1)$$

But $$S_2P = \left[D^2 + \left(x + \frac{d}{2}\right)^2\right]^{\frac{1}{2}}$$

$$S_2P = D\left[1 + \frac{1}{D^2}\left(x + \frac{d}{2}\right)^2\right]^{\frac{1}{2}}$$

$$S_2P = D\left[1 + \frac{1}{2D^2}\left(x + \frac{d}{2}\right)^2\right]$$

$$S_2P = D + \frac{1}{2D}\left(x + \frac{d}{2}\right)^2 \qquad ...(2)$$

Similarly $$S_1P = D + \frac{1}{2D}\left(x - \frac{d}{2}\right)^2 \qquad ...(3)$$

$$S_2P - S_1P = \frac{1}{2D}\left[\cancel{x^2} + \cancel{\frac{d^2}{4}} + xd - \cancel{x^2} - \cancel{\frac{d^2}{4}} + xd\right]$$

$$S_2P - S_1P = \frac{xd}{D} \qquad ...(4)$$

(i) Condition of bright fringes:

$S_2P - S_1P = n\lambda$

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

If n^{th} bright fringe is formed at point P, then

i.e. $\quad x = x_n$

$$\frac{x_n d}{D} = n\lambda$$

$$x_n = \frac{n\lambda D}{d}$$

If $(n + 1)^{nth}$ bright fringe is formed at position at x_{n+1}, then

$$x = x_{n+1}$$

$$\therefore \quad x_{n+1} = \frac{(n+1)\lambda D}{d} \qquad ...(6)$$

Distance between two bright fringe is

$$x_{n+1} - x_n = \frac{\lambda D}{d} \qquad ...(7)$$

The distance between two bright fringes is known as fringe width β then

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

or $$\boxed{\lambda = \frac{\beta d}{D}}$$

Similarly for dark fringe $\beta = \dfrac{\beta d}{D}$

$$\boxed{\lambda = \frac{\beta d}{D}}$$

(b) What do you understand by dispersive power of grating? show that the dispersive power of grating can be expressed as $\dfrac{1}{\sqrt{\left(\frac{e+d}{n}\right)^2 - \lambda^2}}$ where all terms have their usual meaning.

Ans. Dispersive Power of Diffraction Grating: The dispersive power of a grating is defined as the rate of change of the angle of diffraction with the change in the wavelength of light used.

Thus, if the wavelength changes from λ to $\lambda + d\lambda$ and corresponding angle of diffraction changes θ and $\theta + d\theta$, then the ratio $\dfrac{d\theta}{d\lambda}$ is called the dispersive power of the grating

We know that grating equation or condition for principal maxima is

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

Where a + b $\rightarrow$ grating element, $\theta \rightarrow$ angle of diffraction, $n \rightarrow$ order.
Differentiating equation (1) w.r.t λ,

$$(a+b)\cos\theta \frac{d\theta}{d\lambda} = n$$

$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\cos\theta}$$

$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\sqrt{1-\sin^2\theta}}$$

$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\sqrt{1-\left(\frac{n\lambda}{a+b}\right)^2}} \qquad \left(A \sin\theta = \frac{n\lambda}{a+b}\right)$$

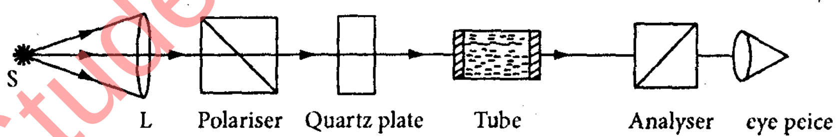
$$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\left(\frac{n}{a+b}\right)\sqrt{\left(\frac{a+b}{n}\right)^2 - \lambda^2}}$$

$$\boxed{\frac{d\theta}{d\lambda} = \frac{1}{\sqrt{\left(\frac{a+b}{n}\right)^2 - \lambda^2}}}$$

6. Attempt any one part of the following: **(1 × 5 = 5)**

(a) Describe the construction and working of a biquartz polarimeter.

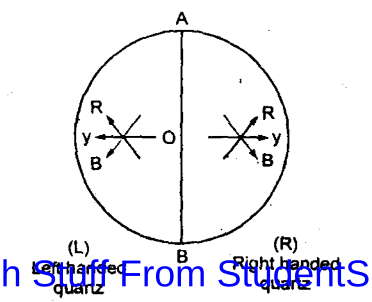
Ans. Biquartz Polarimeter: The experimental polarimeter is same as shown in figure (4), but (i) **white light** source is used in it, and (ii) Half shade plate is replaced by a biquartz plate.



Biquartz Plate: For this device two semicircular plates of same radius are cut from **right-handed** and **left handed** quartz in such way that the optic axis ⊥ and to their faces.

The thickness of each of the plate is about **3.75 mm**. Each plate having this thickness will rotate the **plane of vibrations** of yellow light (of λ = 5900Å) through ± 90°Å.

These semicircular plates are cemented together along the diameter so as to form complete circular plate.



Working

This biquartz plate is placed in between the polarizer P and tube T. Plane of vibration of plane polarized light (PPL) coming from polarizer P is incident normally on the biquartz plate and along the diameter AOB. It is transmitted through the semicircular plates parallel to optic axis.

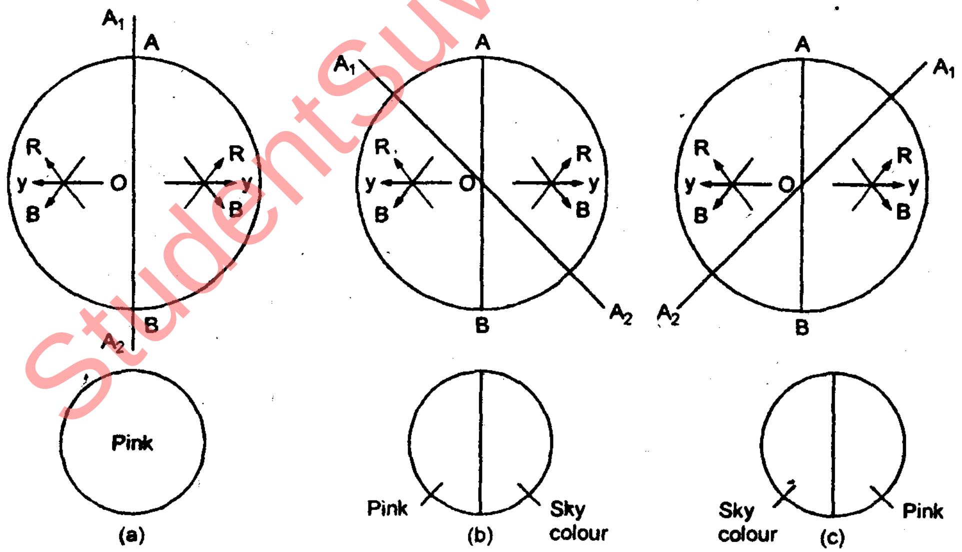
These plates rotate the plane of vibrations of light of different wavelengths through different angles due to **rotatory dispersion.**

The angle of rotation of the violet colour is greater than that of red colour. Thickness of biquartz plate is taken such that it rotates the yellow light component of white light through 90°.

Now vibrations of polarised light of different colour transmitted from the quartz plate are seen through the analyse A. If the principal section, A, A_2 of the analyser is || to the dividing diameter AOB. Fig 8(a), then vibrations of yellow colour from the two semicircular plates are incident in crossed position of the analyser A. As a result the vibrations of yellow colour get eliminated completely from the light emerging from both semicircular plates and the resultant colour of the light is seen a violet (mixture of pink and sky colour).

This position is called the position of **tint of passage.** In this case colour of the light emerging from both semicircular plates appears same in the field of view.

If the principal section of the analyser A_1OA_2 is rotated slightly in anti-clockwise direction according to figure 8(b), then the analyser A will transmit vibrations parallel to A_1OA_2 and stops the normal vibrations i.e it will make left half of the field of view as pink and the right half as sky colour.



Now if the principal section of the analyser A_1OA_2 is rotated slightly in the clockwise direction according to fig 8(c), then it will make left half of the field of view as sky colour and right half as pink.

To determine Specific rotation of solution:

(i) First of all, the polarimeter tube is filled with water and using white light source S, the position of **sensitive tint** is obtained by rotating analyser A and the position of analyser is noted down.

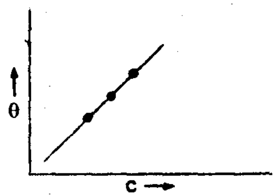
(ii) Now polarimeter tube, containing the optically active solution is introduced and similarly the position of **'sensitive tint'** is obtained by rotating analyser and position of analyser is noted down.

(iii) The difference between two positions of analyser gives the optical rotation θ by the optically active solution.

(iv) The values θ is determined for different concentrations of the solution using step (ii) + (iii).

(v) Now we find the specific rotation using formula

$$S = \frac{\theta}{l \times C}$$



(a) If we plot a curve between θ ans c which comes out to be a straight line.

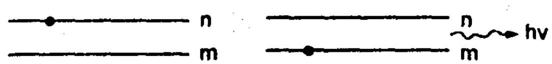
(b) Using formula $S = \dfrac{\theta}{l \times C}$, find values of S for every values of 'θ'. Corresponding concentrations, then average value of 'S' gives the accurate value of S.

(b) Explain the spontaneous and stimulated emission of radiation. Why is spontaneous radiation incoherent?

Ans. Spontaneous emission: The atom has a small life time (mean life time ~ 10^{-8} sec) in the excited state. After that it spontaneously emits a photon and falls to the lower state. This process is called **spontaneous emission.**

The energy of emitted photon in this process is equal to the energy difference $(E_n - E_m)$ of both energy levels n and m and the frequency is

$$\nu = \frac{E_n - E_m}{n}$$



Before transition After transition

Spontaneous Emission: The probability of spontaneous emission will depends only on the two energy levels between which the atom makes a transition but it will be independent of the presence of any photon incident on the system.

Thus according to Einstein the rate of transitional probability is spontaneous emission is always constant.

Hence Rate of transitional probability

$$(P_{nm})_s \propto Nm$$

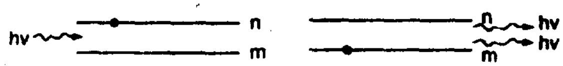
$$(P_{nm})_s = A_{nm} N_m$$

Where A_{nm} is constant and is called Einstein coefficient for spontaneous emission.

$Nn \rightarrow$ no. of atoms in state Nn.

$$(R_{nm})_s = \underset{\substack{\downarrow \\ \text{Einsteincoff}}}{A_{nm}} N_n \qquad \ldots(2)$$

Induced or stimulated Emission: While discussing the interaction with matter Einstein proposed that emission process was also influenced that if a photon of proper frequency intracts with as atomic system, it is not essential that it may always be absorbed, it may also interact with an atom in the excited state and induce it to emit a new photon such a process of emission can be termed as induced or stimulated emission.



Before transition After transition

The **Phase, direction** and **Polarisation** fo this induced photon is same as that of the incident photon.

In other words, both incident and induced photons are completely coherent with each other.

The rate of transitional probability of induced emission will be perpendicular to intensity of incident radiation and two energy levels involved in this process.

$$(P_{nm})_i \propto I(\nu)$$

$$(P_{nm})_i \propto u(\nu)$$

and $$(P_{nm})_i \propto Nn$$

Rate of value $(P_{nm})_i \propto u(\nu) N_n$

$$(R_{nm})_i = (P_{nm})_i = B_{nm}\, u(\nu)\, N_n \qquad \ldots(3)$$

7. Attempt any one part of the following: **(1 × 5 = 5)**

(a) What do you understand by attenuation in optical fiber? Discuss the important factors responsible for the loss of power in optical fiber.

Ans. Attenuation in optical Fibers: The reductions in amplitude or power and intensity of a signal as it is guided through an optical fibre is called attenuation.

The loss of optical power and decrease in signal strength along a fibre are due to the absorption of light due to impurities and imperfection present in fibre materials.

Important factors responsible for the loss of power in optical fibre:

1. **Absorption losses:** The absorption of light by the core and cladding materials of a fibre during wave propagation is the main source of attenuation.
   There are three main source for the absorption of light by the glass core and cladding of the fibre. The light is absorbed by the material itself impurities and imperfection, and the atomic defects present in the glass fibre.
2. **Rayleigh Scattering Losses:** Rayleigh Scattering is a major cause of the attenuation of radiation in the optical fibre. Rayleigh scattering is the process in which light is scattered by microscopic inhomogeneities, microscopic fluctuations in density of the silica material contents, small spherical volumes of variant refractive index, such as particle, bubble etc.
   Attenuation in the light signal due to this scattering effect vary inversely with the fourth power of the wavelength i.e λ^{-4} and thus rapidly decrease with increasing wavelength.
3. **Bending Losses:** These losses occur due to imperfection and deformation present in the fibre structure.

There are two types of bending losses:

(i) Microbending losses

(ii) Macrobending losses

(i) Microbending losses: Microbending losses occur when the core surfaces has small variations in shape.

(ii) Macrobending losses: Macrobending loss may occur when wrapping the fibre on a spool or pulling the fibre cable around a corner.

The attenuation coefficient of the fibre in dB/km

$$\alpha = \frac{10}{L}\log_{10}\left(\frac{P_{out}}{P_{in}}\right) \text{ dB/kw}$$

To indicate loss we are introducing negative sign in the expression as

$$\alpha = \boxed{\frac{10}{L}\log_{10}\left(\frac{P_{out}}{P_{in}}\right)}$$

(b) Explain the principle of holography using construction and reconstruc... f images.

Ans. Holography

Holo → (Means) → Complete

Graphy → recording

Holography: Complete recording (i.e intensity & phase). In conventional photography a lens system (camera) focuses that light reflected from a illuminated three-dimensional object and a negative is made first and using it a positive print is produced later.

The positive print is only a 2 - D record of a 3 - D object. In 1947 **Dennis Gabor** developed new technique of photography using interferometric technique. He called this technique **Wavefront recording.**

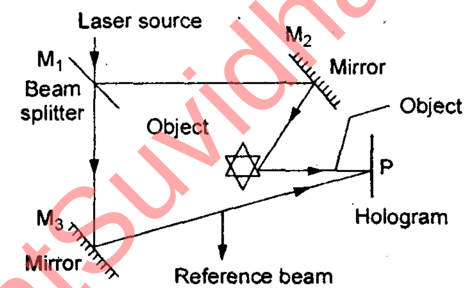
According to this technique both **intensity** and **phase** variation of light wave, coming from different part of the 3 - D object are recorded on a transparent photographic plate and when viewed the photography shows a 3 - D image of the object. This technique is named **holography**. The recorded transparent photographic plate is called **hologram**.

Holography is two step process [Recording reconstruction]

First stage: Hologram is recorded in the form of **interference** pattern and it is called recording of **holograms.**

Second Stage: Hologram acts as a diffraction grating for the reconstruction beam and the image of the object is reconstructed from the hologram. This process is called reconstruction of image.

Recording of Hologram: In the construction of hologram the light waves scattered from an object is superimposed on a reference wave obtained from the same source of light and the interference pattern so formed is recorded on a transparent photographic plate. This interference pattern contains all the information about the **intensity** and **phase** of the scattered waves.



Laser beam is made to fall on an optically plane transparent plate M_1, called **beam splitter.**

It splits the laser beam into two beams of proper intensity.

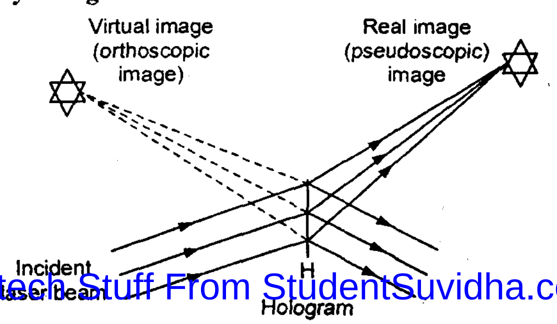
One laser beam called **object beam**, after reflection from mirror M_2, falls on the object and the scattered waves from the object are also made to fall on a transparent photographic plate P.

Another laser beam emerging from a bean. splitter M_1, is made to fall on a mirror M_3 and the reflected beam is then made to fall directly on a photographic plate P. This beam is called **reference beam.**

Both of these laser beams form an interference pattern after superposition on a photographic plate P. This recorded **interference patter** (complicated interference pattern) called hologram.

In this pattern the variation of **intensity** as well as **phase** of the light waves are recorded.

Reconstruction of an image by Hologram.:



In reconstruction of image the hologram is illuminated by the same laser light coming in the same direction as that of reference beam at the time of production of image. Two images are formed by the diffracted wave emerging from the hologram.

One of the beam produces a **real image** which can be photographed directly by placing a photographic plate at the position of real image.

Another diffracted beam seems to come from the point where the original object was placed form a virtual image.

Special Feature of Hologram

1. The destruction of any portion of an ordinary photographic image causes a permanent removal of information corresponding to that part of the object. Unlike this, in holographic, the damage of a part of the hologram does not disappear any information.
2. If hologram is broken into different fragments, each separate fragment can reproduce the entire image of the object.