Electromagnetic Waves and Wave Optics

SOLUTIONS

EXERCISE - O

1. **Ans. (C)**

Length of football field ≈ 100 m

$$C = f\lambda \Rightarrow f = \frac{3\times10^8}{100} = 3MHz$$

Radio waves: 3 kHz to 300 GHz

2. **Ans. (B)**

Food has many dipoles which tend to rotate in alternating electric field. This rotational energy sense to increases the temperature.

3. **Ans. (C)**

Magnetic field when electromagnetic wave propagates in +z direction

$$B = B_0 \sin(kz - \omega t)$$

where,

$$B_0 = \frac{60}{3\times10^8} = 2\times10^{-7}$$

$$k = \frac{2\pi}{\lambda} = 0.5\times10^3$$

$$\omega = 2\pi f = 1.5\times10^{11}$$

4. **Ans. (B)**

$\vec{E} = 10\hat{j}\cos(6x+8z) = 10\hat{j}\cos\left[(6\hat{i}+8\hat{k}).(x\hat{i}+z\hat{k})\right]$

$\therefore$ $\vec{k} = 6\hat{i}+8\hat{k}$: this is the direction of 'c'.

$\vec{c}\times\vec{E}$ is direction of $\vec{B}$: $(6\hat{i}+8\hat{k})\times\hat{j} = 6\hat{k}-8\hat{i}$

$\therefore$ $\vec{B} = \left(\frac{6\hat{k}-8\hat{i}}{c}\right)cos[6x+8z-10ct]$ as $B = \frac{E}{c}$

5. **Ans. (A)**

$f = 5\times10^8\ Hz$

EM wave is travelling towards $+\hat{j}$

$$\vec{B} = 8.0\times10^{-8}\hat{z}T$$

$$\vec{E} = \vec{B}\times\vec{C} = (8\times10^{-8})\times(3\times10^8)$$

$$= -24\ \hat{x}V/m$$

6. **Ans. (A)**

$$q = \frac{\phi_i-\phi_f}{t} = \frac{A}{t}(B_i-B_f) = \frac{3.5\times10^{-3}}{10}(0.4-0)= 14\ mC$$

7. **Ans. (D)**

$$\left(\frac{1}{2}\epsilon_0 E_0^2\right)C = I$$

8. **Ans. (D)**

$$v = \frac{1}{\sqrt{\mu_0 \in_r \in_0}}$$

$$\frac{3}{2} \times 10^8 = \frac{3\times10^8}{\sqrt{\in_r}}$$

$\in_r = 4$

9. **Ans. (A)**

Energy density = $\in_0 \, E_{RMS}^2$

10. **Ans. (B)**

White spot-on screen would be central maxima where

$\Delta x = 0$

$$y = \frac{d}{2} - \frac{d}{6} = \frac{d}{3}$$

11. **Ans. (A)**

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x \text{ and } \Delta x = \left(\frac{y}{D}\right) \times d$$

$$y_1 = \frac{3\lambda D_1}{d}$$

Now for y_2

$$I_{\max}\cos^2\frac{\Delta\phi}{2} = I_{max}\frac{3}{4}$$

$\Rightarrow \Delta\phi = \frac{\pi}{3} + 2n\pi$ and this can be $4\pi + \frac{\pi}{3}$ or $6\pi - \frac{\pi}{3}$

$$\Rightarrow \left(\frac{y_2}{D_2} \times d\right)\frac{2\pi}{\lambda} = \Delta\phi$$

$$\Rightarrow y_2 = \frac{17D_2\lambda}{6d}, \frac{13D_2\lambda}{6d}$$

$\because y_1 = y_2$

$$\Rightarrow \frac{13D_2}{6} = 3D_1$$

Finally, $D_2 = \frac{18}{13}D$

$$v = \frac{D_2 - D_1}{\Delta t} = \frac{5D}{13}$$

12. **Ans. (B)**

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

$\Rightarrow 2\mu t = \lambda n$

$$\Rightarrow y = \frac{(\mu-1)tD}{d} = (\mu t - t)\frac{D}{d}$$

$$\Rightarrow y = \left(\frac{\lambda}{2} - t\right)\frac{D}{d}$$

$$\Rightarrow 7.5 \times 10^{-3} = (250 - t)\frac{5}{10^{-4}}$$

$\Rightarrow 1.5 \times 10^{-7} = 250 \times 10^{-9} - t$

$\Rightarrow t = 100\ nm$

$$\Rightarrow \mu = \frac{500\times10^{-9}}{2\times100\times10^{-9}}$$

$= 2.5$

13. **Ans. (B)**

$2\mu t \cos r = (2n+1)\frac{\lambda}{2}$

or $\mu = \frac{(2n+1)}{2t\ \cos r}\ \frac{\lambda}{2} = \frac{(2n+1)\times 5320\times 10^{-10}}{2\times 5\times 10^{-5}\times 10^{-2}\times 1}$

$\Rightarrow \mu = 1.33$

14. **Ans. (B)**

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

$t = (2n-1)\ \frac{\lambda/2}{2\mu \cos r}$

$\cos r \to 1$

$\therefore\ \ t = (2n-1)\ \frac{\lambda}{4\mu}$

$n = 1$

$t = \frac{\lambda}{4\mu} = \frac{900}{4\times 1.5}nm$

$\therefore\ \ t = 150\ nm$

15. **Ans. (B)**

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

$t = \frac{n\lambda}{2\mu \cos r} = \frac{1\times 6\times 10^{-7}}{2\times 1.5\times \cos 60}$

$= \frac{6\times 10^{-7}}{1.5} = 4\times 10^{-7}m$

16. **Ans. (B)**

$2\mu t = \frac{\lambda}{2}$ condition for distructive interference

$t = \frac{5000\times 10^{-10}}{4\times 1.25} = 10^{-7}m$

17. **Ans. (C)**

Constructive interference occurs for

$OPD = 2nt = k\lambda + \frac{\lambda}{2}$

where t is the thickness of the film, k an integer. Hence for maximum reflection the wavelengths are

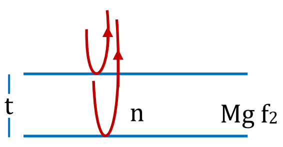
$\lambda = \frac{4nt}{2k+1} = \begin{cases} 6000Å f \text{ or } k = 2 \\ 4285Å f \text{ or } k = 3 \end{cases}$

18. **Ans. (A)**

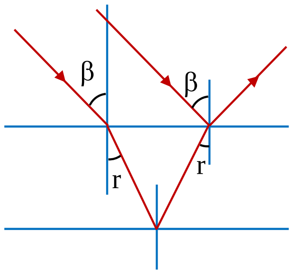
$2t = \left[\frac{2m+1}{2}\right]\frac{\lambda}{n}$

$\Rightarrow$ For t_{min} $m = 0$

$t_{min} = \frac{\lambda}{4n} = \frac{5.5\times 10^{-7}}{4\times 1.38} = 99.6\ nm$



19. **Ans. (C)**



$2\mu t \cos r = (2n + 1)\dfrac{\lambda}{2}$

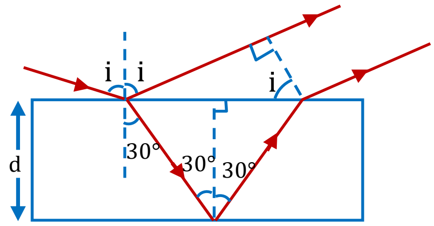
$t = \dfrac{(2n+1)\lambda}{4\mu\cos r}$ (putting $n = 0$) $= \dfrac{\lambda}{4\mu\cos r}$

$\cos r = \sqrt{1-\sin^2 r} = \dfrac{1}{\mu}\sqrt{\mu^2 - \sin^2\beta}$

Substituting all value $t = 1.01 \times 10^{-7} m$

Mass of soap $= \rho \times \ell \times h \times t = 6.06 \times 10^{-2}\, mg$.

20. **Ans. (C)**



For destructive interference

$\mu\,(2d \sec 30°) - 2d \tan 30° \sin i = n\lambda$

$n = 1, 2, 3$ ……

By Snell's law $1 \sin i = \dfrac{3}{2}\sin 30° = \dfrac{3}{4}$

$\therefore \quad d = \dfrac{2n\lambda}{3\sqrt{3}}$

$d_{min} = \dfrac{2\lambda}{3\sqrt{3}} \simeq 2263$ Å

Alter : $2\mu d \cos r = n\lambda$ for destructive interference.

21. **Ans. (D)**

Fringe width $b = \dfrac{D\lambda}{d}$

$l' = \dfrac{\lambda}{\mu}$

b decreases

22. **Ans. (D)**

$b = \dfrac{D\lambda}{d}$: only fringe width changes

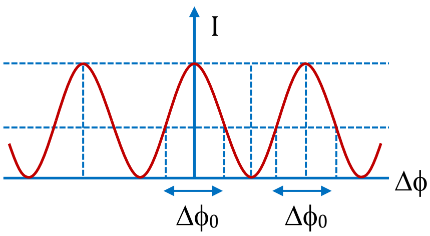
* CBF remains at the same position if liquid is filled.
* If path diff at O increases, then CBF will shift upward.

23. **Ans. (A)**

$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$; $I_1, I_2 = I_0$; I_{max}

$I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$; $I_1, I_2 = I_0$; I_{min}

24. **Ans. (C)**



$I = I_{max}\cos^2\left(\dfrac{\pi}{\lambda}\dfrac{dy}{D}\right)$

25. Ans. (C)

$I_0 = I_0 + I_0 + 2\sqrt{I_0}\sqrt{I_0}\, cos\,\theta$

$I_0 = 2I_0 + 2I_0\, cos\,\theta$

$1 = 2[1 + cos\,\phi]$

$\frac{1}{2} = 1 + cos\,\phi$

$cos\,\phi = \frac{-1}{2} \Rightarrow \phi = \frac{2\pi}{3}$

$\frac{2\pi}{3} = \frac{2\pi}{\lambda}(\Delta x) \Rightarrow \Delta x = \frac{\lambda}{3} \Rightarrow \frac{dy}{D} = \frac{\lambda}{3}$

$y = \frac{\lambda D}{3d}$

26. Ans. (C)

$I = I_0 \cos^2\left(\frac{\pi}{\lambda}\frac{dx}{D}\right)$

$= I_0 \cos^2\left(\frac{\pi}{6\times10^{-7}} \times \frac{25\times10^{-4}}{1} \times 4 \times 10^{-5}\right)$

$= I_0 \cos^2(p/6) = \frac{3I_0}{4}$

27. Ans. (A)

$\Delta\Phi = \frac{2\pi}{\lambda}(\Delta x_0)$

Optical path diff. $\Delta x_0 = \mu x$

28. Ans. (C)

$I = I_{max} \cos^2\left(\frac{\Delta\phi}{2}\right)$

$I = I_{max} \cos^2\left[\frac{\pi}{\lambda}(\mu - 1)t\right]$

29. Ans. (D)

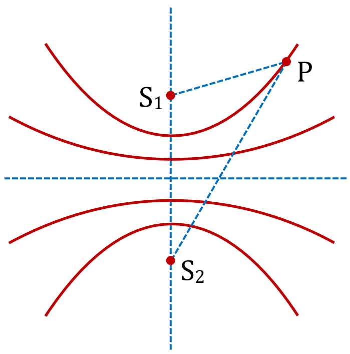
$\Delta x = (\mu_A - 1)t_A - (\mu_B - 1)t_B$

$\Delta x = t_B - t_A$

If $t_B > t_A$ then $\Delta x > 0$

CBF will shift towards *A*.

30. Ans. (B)



$S_2P - S_1P = n\lambda$

Represents family of hyperbolas.

31. Ans. (D)

$(2n_1-1)\frac{\lambda_1 D}{2d} \Rightarrow (2n_2-1)\frac{\lambda_2 D}{2d}$

$\frac{2n_1-1}{2n_2-1} \Rightarrow \frac{\lambda_2}{\lambda_1}, \frac{560}{400} \Rightarrow \frac{7k}{5k}, \quad k = 1, 2, 3..... \frac{7}{5}, \frac{14}{10}, \frac{21}{15}....$

Must be in integer

$\frac{2n_1-1}{2n_2-1} \Rightarrow \frac{7}{5} \qquad n_1 = 4, n_2 = 3$

$\frac{2n_1-1}{2n_2-1} \Rightarrow \frac{14}{10} \qquad n_1 = \frac{15}{2}$ (not possible)

$\frac{2n_1-1}{2n_2-1} \Rightarrow \frac{21}{15} \qquad n_1 = 11, n_2 = 8$

$$y_p = \frac{(2\times4-1)400\times10^{-9}\times1}{2\times10^{-3}} = 14mm$$

$$y_q = \frac{(2\times11-1)400\times10^{-9}\times1}{2\times10^{-3}} = 42mm$$

$$y_q - y_p = 42 - 14 = 28mm$$

32. Ans. (C)

As amplitudes are A and $2A$, so intensities would be in the ratio 1 : 4, let us say I and 4I.

$$I_{\max} = I_0 = I + 4I + 2\sqrt{4I^2} = 9I \Rightarrow I = \frac{I_0}{9}$$

Intensity at any point, $I' = I + 4I + 2\sqrt{4I^2}\cos\phi$; $I' = 5I + 4I\cos\phi = \frac{I_0}{9}(5+4\cos\phi)$

33. Ans. (C)

$\frac{yd}{D}+\frac{\lambda}{2}=n\lambda \Rightarrow \frac{x(2x)}{D}+\frac{\lambda}{2}=n\lambda$, where $n=1$

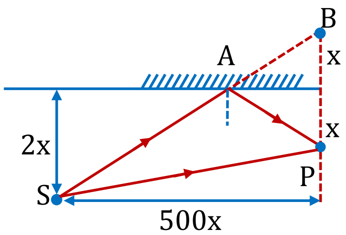
$\Delta x = (SA + AP) - SP$

$= (SA + AB) - SP$

$= SB - SP$

$= \sqrt{(500x)^2+(3x)^2} - \sqrt{(500x)^2+x^2}$

$= 500\times\left[\sqrt{1+\frac{9}{500^2}} - \sqrt{1+\frac{1}{500^2}}\right]$



$500\times\left[\left(1+\frac{9}{2\times500^2}\right)-\left(1+\frac{1}{2\times500^2}\right)\right]$

$= \frac{500x}{2\times500^2}[8] = \frac{\lambda}{2}, \frac{3\lambda}{2}....$

$x = 62.5\,\lambda$, $187.5\,\lambda$ ....

34. Ans. (A)

The waves arriving from slits S_2 will have increased optical path.

The path difference between arriving waves at O.

$\Rightarrow \Delta x = [S_2O+(\mu_{rel}-1)t]-S_1O$

$\Rightarrow \Delta x = (S_2O - S_1O)+(\mu_{rel} - 1)t$

From symmetry of figure,

$S_2O = S_1O$

$\Delta x = (\mu_{rel} - 1)t$

or, $Dx = \left|\left(\frac{\mu_2}{\mu_1} - 1\right)t\right|$

35. Ans. (C)

Let the power of light source be P, then intensity at any point on the screen is due to light rays directly received from source and that due to after reflection from the mirror.

$\Rightarrow I = \frac{P}{4\pi a^2} + \frac{P}{4\pi \times (3a)^2}$; $\left(\frac{P}{4\pi a^2}\right)\frac{10}{9}$ When mirror is taken away, $I_1 = \frac{P}{4\pi a^2} = \frac{9I}{10}$

36. Ans. (D)

Shift of central maxima = $n\lambda$ = $(\mu - 1)t$

We know that whenever we place my glass sheet (here plastic) in front of slits, the path difference occurs.

Δx (path difference) = $(\mu-1)t$

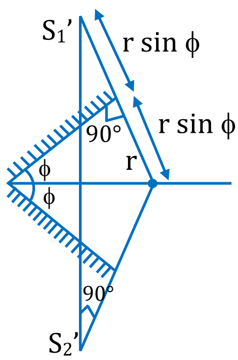
N = no. of friends shifted

t = thickness of plastic

Shift of central maxima = $N\lambda$ = $(\mu-1)t$

$\Rightarrow t = 24\ cm$

37. Ans. (A)



All light rays hitting the screen will be appearing to be coming from S_1' and S_2'

$\Rightarrow D = b + 2r\sin^2\phi$

$d = 4r\sin\phi\cos\phi$

fringe width = $\frac{\lambda D}{d}$

38. Ans. (A)

Phase difference between waves through S_1 and S_2 is $2 \times (\lambda/6) \times (2\pi/\lambda) = 2\pi/3$ and that through S_1 and S_3 is $2.\ 2\lambda/3.2\pi/\lambda = 8\pi/3$

$y = A\sin\theta + A\sin(\theta - 2\pi/3) + A\sin(\theta - 8\pi/3)$

$\therefore$ Resultant amplitude = $\sqrt{3}A$

As, Intensity $\propto$ (Amplitude)^2, new intensity = $3I$

39. Ans. (B)

Path difference at O : $(\mu_{rel} - 1)\, t = \left(\frac{n}{n_2} - 1\right) t$

$\therefore$ phase difference at O : $\left(\frac{n}{n_2} - 1\right) t\, \frac{2\pi}{\lambda_2}$ where $n_1\lambda_1 = n_2\lambda_2$

$= \frac{\pi}{2}$ after substitution of values.]

40. Ans. (D)

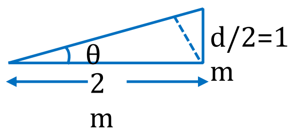
Path difference = $d \sin\phi + d \sin\theta$

and for maxima, $\Delta x = m\lambda$

$\Rightarrow \sin\phi + \sin\theta = \frac{m\lambda}{d}$]

41. Ans. (A)

$\Delta X = d \sin\theta = 2 \times 10^{-3} \times \frac{1\times10^{-3}}{2} = 10^{-6}\, m = 2\lambda$



42. Ans. (D)

$L = 2\, b\delta = 2\, b\, (\mu - 1)\alpha$

$$W = \frac{\lambda D}{d} = \frac{\lambda(a+g)}{2a\delta} = \frac{\lambda(a+b)}{2a(\mu-1)\alpha}$$

$$N = \frac{L}{W} = \frac{4ba(\mu-1)^2\alpha^2}{\lambda(a+b)}$$

43. Ans. (D)

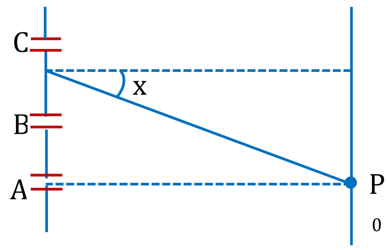
$\phi_{A/B}$ = Phase difference between A and B = $\frac{2\pi}{X}\times\frac{A}{3}=\frac{2\pi}{3}$

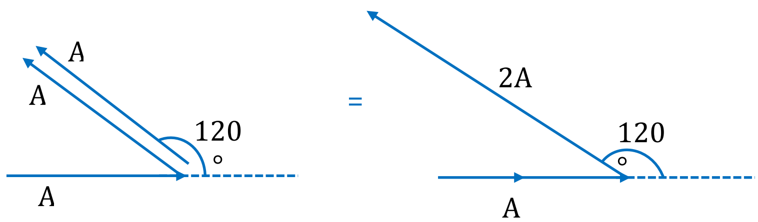
$\Delta x_{B/C} =$ path difference between B and C

$= d\sin\phi = d\tan\phi = \frac{3d^2}{D} = \lambda$

$\therefore \phi_{B/C} =$ phase difference between B and C $= 2\pi$

Phase diagram of waves arriving at P_0 in as shown





Resultant amplitude is given by

$$A' = \sqrt{A^2 + (2A)^2 + 2(A)(2A)120^\circ} = \sqrt{3}A$$

As $I \propto a^2 \quad \therefore \quad I' = 3I$

44. **Ans. (D)**

$\sqrt{x^2+16\lambda^2}-x=n\lambda$

For first maxima n = 3

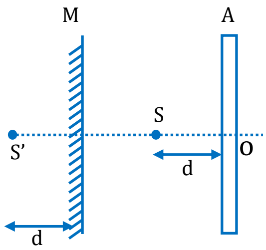
$\sqrt{x^2+16\lambda^2}-x=3\lambda$

$=x^2+16\lambda^2=x^2+9\lambda^2+6\lambda x$

$7\lambda^2=6\lambda x$

$x=\frac{7\lambda}{6}$

45. **Ans. (D)**



Initially at 'O' due to S $\Rightarrow I_1 = I_0 = \frac{P}{4\pi d^2}$

Intensity at 'O' due to S'

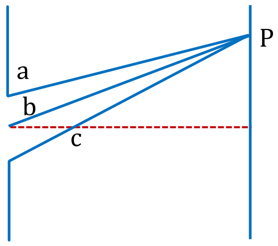
$\Rightarrow\quad I_2=\frac{P}{4\pi(3d)^2}=\frac{I_0}{9}$

sources are treated as incoherent.

$\Rightarrow$ resultant intensity

$I_{res} = I_1 + I_2 = \frac{10}{9}I_0$

46. **Ans. (B)**



For Ist minimum $\theta = \frac{\lambda}{a}$ and phase difference $\phi = \frac{2\pi}{\lambda}$

$\Rightarrow\ \Delta x = \frac{2\pi}{\lambda} a\sin\theta\ \phi = \frac{2\pi}{\lambda} a\theta = 2\pi$

New Solution

If 'P' is minima, than

$\phi_b - \phi_a = \pi$

$\phi_b - \phi_c = \pi$

$\therefore\ \phi_C - \phi_a = 2\pi$

47. **Ans. (A)**

$a\sin\theta = \lambda \Rightarrow \theta \simeq \frac{\lambda}{a} = \frac{0.5}{10} = \frac{1}{20} rad \simeq 3°$

$\therefore$ Angular pol » (30° – 3°) to (30° + 3°)

= 27° to 33°

48. **Ans. (D)**

$R = \frac{1.22\lambda D}{b}$

49. **Ans. (D)**

Resolving limits of microscope is $S = \frac{1.22\lambda}{2\sin i}$

i = Semi cone angle of light

$s = \frac{1.22\times5.5\times10^{-5}cm}{2\times\sin 30} = 6.7\times10^{-5}cm$

50. Ans. (C)

Resolving limit of eye = $1' = \left(\frac{1}{60}\right)^{o} = \frac{1}{60} \times \frac{\pi}{180}$

$Q = \frac{x}{D}$

$\Rightarrow \frac{1}{60} \times \frac{\pi}{180} = \frac{x}{11000} \Rightarrow x = 3.2\ m$

51. Ans. (D)

$R.P. = \frac{a}{1.22\lambda}$

$= \frac{6 \times 10^{-2}}{1.22 \times 540 \times 10^{-9}} = 9.1 \times 10^{4}$

52. Ans. (D)

$d = \frac{1.22\lambda}{2\mu \sin\alpha}$

$d = \frac{1.22 \times 9.6 \times 10^{-7}}{2 \times 0.06}$

$d = 97.6 \times 10^{-7}\ m = 9.76\ \mu m$

53. Ans. (B)

$R.P \propto \frac{1}{\lambda}$

$\frac{R.P_1}{R.P_2} \propto \frac{\lambda_2}{\lambda_1} = \frac{7200}{4200}$

$\frac{R.P_1}{R.P_2} = \frac{12}{7}$

54. Ans. (C)

Distance between Towers is 40 *km*. Height of the line joining the hills is *d*=50 *m*. Thus, the radial spread of the radio waves should not exceed 50 *m*. Since the hill is located halfway between the towers, Fresnel's distance can be obtained.

$Z_P = 20\ km$

Aperture is $a = d = 50\ m$

Fresnel's distance is given by the relation,

$Z_P = \frac{a^2}{\lambda} = 2 \times 10^4$

$\lambda = \frac{a^2}{Z_P} = 12.5\ cm$

55. Ans. (B)

More slit width more will be light intensity coming from it and width of central maxima decreases with slit width, so *A* will move towards *O*.

56. Ans. (B)

$A = A_0\left(\frac{\sin\beta}{\beta}\right)$

or $\frac{A}{A_0} = \frac{\sin\beta}{\beta}$

Now $\beta = \frac{\pi a \sin\theta}{\lambda} = \frac{\pi}{2}$

$\therefore \frac{A}{A_0} = \frac{\sin\left(\pi/2\right)}{\left(\pi/2\right)} = \frac{2}{\pi}$

57. **Ans. (C)**

The Braggs angle is half the angle through which the beam is deviated. Thus, in this case, the braggs angle.....

$\theta = 1/2 \times 60° = 30°$

by braggs equation, $2d \sin\theta = n\lambda$

Here, $d = 3 \times 10^{-10} m$, $\theta = 30°$; $n = 1$, $\lambda = ?$

$$\lambda = \frac{2d\sin\theta}{n} = \frac{2\times(3\times10^{-10})\sin 30°}{1} m$$

$$= 3\times10^{-10} m = 3Å$$

58. **Ans. (D)**

Intensity for first secondary maxima,

$$I = I_0\left(\frac{\sin\beta}{\beta}\right)^2$$

Here,

$$\beta = \frac{3\pi}{2}$$

$$\therefore \quad I = I_0\left(\frac{\sin\frac{3\pi}{2}}{\frac{3\pi}{2}}\right)^2 = \frac{4}{9\pi^2} I_0$$

I_0 = Intensity of principal maxima.

59. **Ans. (A)**

Only transverse waves can be polarised.

60. **Ans. (A)**

A plane which contains $\vec{E}$ and the propagation direction is called the plane of polarization.

61. **Ans. (B)**

$I = I_0 \cos^2\theta = I_0 \cos^2 45° = \frac{I_0}{2}$

62. **Ans. (D)**

$I = I_0 \cos^2\theta$

63. **Ans. (C)**

At polarizing angle, the reflected and refracted rays are mutually perpendicular to each other.

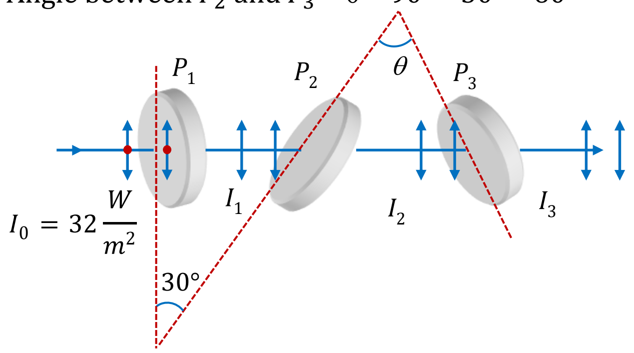
64. **Ans. (D)**

The amplitude will be $A \cos 60° = A/2$

65. **Ans. (B)**

Angle between P_1 and P_2 = 30° (Given)

Angle between P_2 and P_3 = θ = 90° – 30° = 60°



The intensity of light transmitted by P_1 is $I_1 = \frac{I_0}{2} = \frac{32}{2} = 16\frac{W}{m^2}$

According to Malus law the intensity of light transmitted by P_2 is

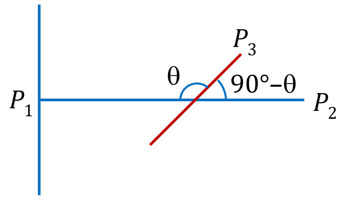
$$I_2 = I_1\cos^2 30° = 16\left(\frac{\sqrt{3}}{2}\right)^2 = 12\frac{W}{m^2}$$

Similarly, intensity of light transmitted by P_3 is

$$I_3 = I_2\cos^2\theta = 12\cos^2 60° = 12\left(\frac{1}{2}\right)^2 = 3\frac{W}{m^2}$$

66. Ans. (A)

No light is emitted from the second polaroid, so P_1 and P_2 are perpendicular to each other



Let the initial intensity of light is I_0.

So, Intensity of light after transmission from first polaroid = $\frac{I_0}{2}$.

Intensity of light emitted from P_3 $I_1 = \frac{I_0}{2}\cos^2\theta$

Intensity of light transmitted from last polaroid i.e. from

$$P_2 = I_1\cos^2(90^o - \theta) = \frac{I_0}{2}\cos^2\theta\,.\sin^2\theta$$

$$= \frac{I_0}{8}(2\sin\theta\cos\theta)^2 = \frac{I_0}{8}\sin^2 2\theta$$

67. Ans. (A)

According to Brewster's law, when a beam of ordinary light (i.e. unpolarised) is reflected from a transparent medium (like glass), the reflected light is completely plane polarised at certain angle of incidence called the angle of polarisation.

68. Ans. (C)

From Brewster's law $\mu = \tan i_p$

$$\Rightarrow \frac{c}{v} = \tan 60° = \sqrt{3}$$

$$\Rightarrow v = \frac{c}{\sqrt{3}} = \frac{3\times10^8}{\sqrt{3}} = \sqrt{3}\times10^8 m/\text{sec.}$$

69. Ans. (C)

From Brewster's law $\theta_p = \tan^{-1}\frac{\mu_2}{\mu_1}$

Here $\mu_1 = 1$, $\theta_p = 60°$, $\mu_2 = \mu$

$$\theta_p = \tan^{-1}\mu = 60°$$

$$\mu = \tan 60° = \sqrt{3}$$

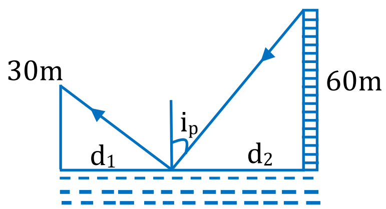
$$\Rightarrow v = \frac{c}{\mu} = \frac{c}{\sqrt{3}} = \frac{3\times10^8}{\sqrt{3}} = \sqrt{3}\times10^8 m/\sec$$

70. Ans. (A)

$$\tan i_p = \mu = \frac{4}{3}$$

$i_p = 53°$

$$\frac{30}{d_1} = \frac{3}{4} \Rightarrow d_1 = 40m$$



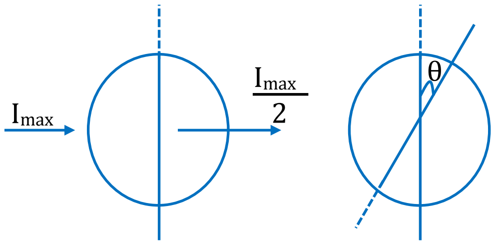
$$\frac{30}{d_2} = \frac{3}{4} \Rightarrow d_2 = 80m$$

Width = 120m (A)

71. Ans. (A)

By maulas law

$I = I_0\cos^2\theta$, $\qquad$ θ is the angle between two axis of polaroid.



$I = \frac{I_{max}}{2}\cos^2\theta$

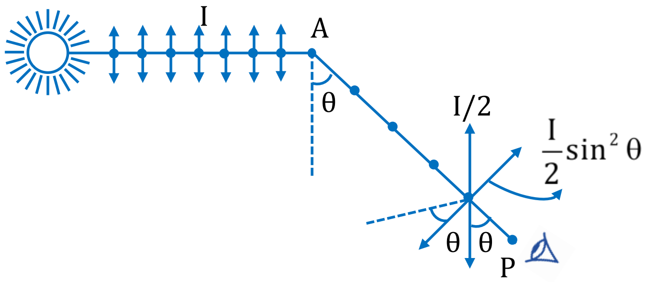
Third polaroids matches (90–θ) with IInd polaroids

$I = \frac{I_{max}}{2}\sin^2 2\theta \Rightarrow \frac{I_{max}}{16}[1-\cos 4\theta]$

$I = \frac{I_{max}}{16}[1-\cos 4\omega t]$

72. Ans. (C)

Eye receive all component of light which is along the line. AP



And perpendicular component is $\frac{I}{2}\sin^2\theta$

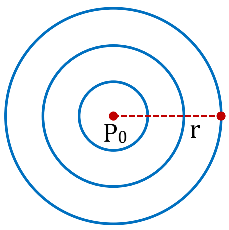
Net intensity received by light is

$\frac{I}{2} + \frac{I}{2}\sin^2\theta$

73. Ans. (ACD)

For spherical wave

$I = \frac{P_0}{4\pi r^2}$



$I \alpha \frac{1}{r^2}$

$I_{max} = 4\,I_0,\ I_{min} = 0$

74. Ans. (BD)

$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$

$I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$

For sustained interference, $I_1 = I_2 = I_0$

$A_1 = A_2 = A_0$

75. Ans. (BCD)

At central bright fringe the waves from slits are in phase and following bright fringes having a difference of $2\pi.4\pi = 2\times 2\pi \Rightarrow 2^{nd}$ order bright fringe.

76. Ans. (ABD)

From 2nd graph, when $\theta = \frac{\pi}{2}$, $\phi = 4\pi = 2\lambda$ = distance between S_1 & S_2

At $\theta = \frac{\pi}{6}$, $\phi = d\sin\theta = 2\lambda\frac{\ell}{2} = \lambda$.

$\therefore$ Intensity is maximum.

77. Ans. (AC)

$$\Delta x = \frac{\lambda}{2} + (2t)\mu_2$$

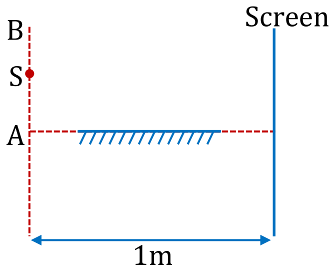
For constructive interference $\Delta x = n\lambda$

For destructive interference $\Delta x = \left(n + \frac{1}{2}\right)\lambda$

78. Ans. (BC)

Let $AS = h$ ...(i)

$\frac{1}{4} = \frac{\lambda(1)}{2h}$ ...(ii)



$$\frac{1}{6} = \frac{\lambda(1)}{2(h+0.6)}$$

$$\frac{\frac{1}{4}}{\frac{1}{6}} = \frac{h+0.6}{h}$$

$$\frac{3}{2} = \frac{h+0.6}{h}$$

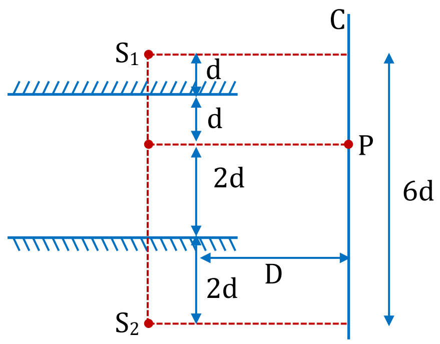
$h = 1.2\ mm$

$$\frac{1}{4}mm = \frac{\lambda(1m)}{2\times(1.2)mm}$$

$\lambda = 0.6 \times 10^{-6}\ m$

$\lambda = 6000$ Å

79. Ans. (CD)



For $P, y = d$

$$\Delta x = d.\frac{6d}{D} = \frac{6d^2}{D}$$

For constructive interference

$$\frac{6d^2}{D} = n\lambda$$

80. Ans. (A)

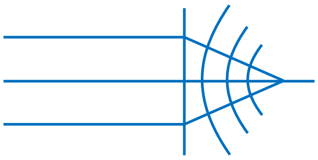
For a parallel beam wave fronts are plane wave fronts.

81. Ans. (B)

Intensity is maximum at the axis of the cylindrical beam. Hence μ is maximum at the axis due to the relation $\mu = \mu_0 + \mu_2 I$

82. Ans. (C)

v is minimum at the axis of beam. Hence beam will converge.



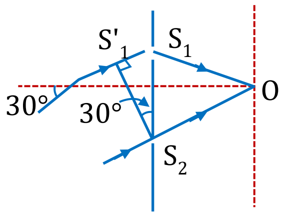
83. Ans. (A)

$\beta = \frac{D\lambda}{d} = \frac{1 \times 4000 \times 10^{-10}}{10 \times 10^{-3}} = 4 \times 10^{-5}\, m = 40\mu m$

84. Ans. (A)

Path difference at 'O'

$S_1'S_1O - S_2O = d \sin 30 = 10 \times \frac{1}{2} = 5\, mm$

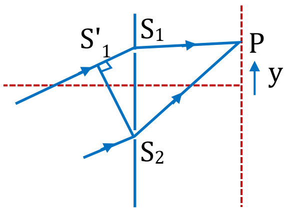


Phase difference at 'O'

$\phi = \frac{2\pi}{\lambda} \times \text{path difference} = \frac{2\pi \times 5 \times 10^{-3}}{4000 \times 10^{-10}} = \frac{\pi}{4} \times 10^5 = 25000\pi \equiv 0$

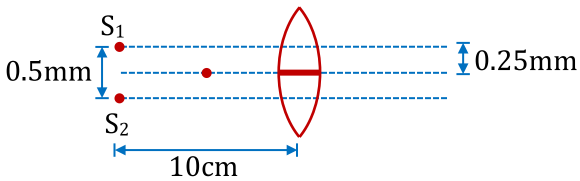
85. Ans. (A)

Path difference at 'P' = $S_2P - S_1'S_1P = S_2P - (S_1'S_1 + S_1P) = \frac{yd}{D} - d \sin 30 = 0$



For central maxima path difference = 0 $\Rightarrow Y = D \sin 30 \Rightarrow y = 50\, cm$

86. Ans. (A)



$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

$\Rightarrow \ v = -10\, cm$ and $m = \frac{-10}{-5} = 2$

$\Rightarrow \ d = 0.5\, mm$ (as shown in figure)

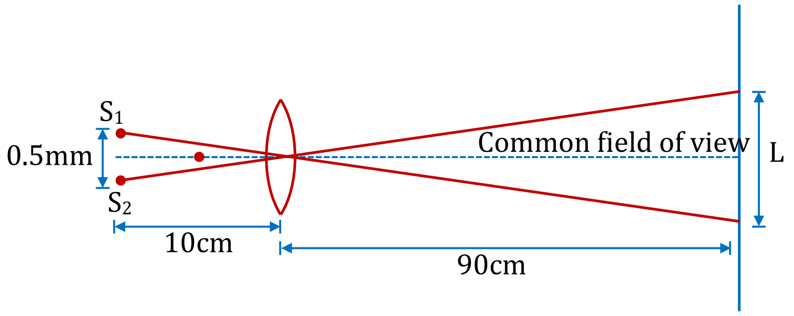
87. **Ans. (C)**

Now $d = \frac{1}{2}\,mm$

and $D = 1m$

so $\beta = \frac{\lambda D}{d} = \frac{5000\times10^{-10}}{\frac{1}{2}\times10^{-3}\times1} = 1\,mm$

88. **Ans. (A)**



$\frac{\frac{1}{2}}{10} = \frac{L}{90} \Rightarrow L = \frac{9}{2}\,mm$ and number of maxima $= \left[\frac{L}{\beta}\right] + 1$ (for central maxima) = 5

89. **Ans. (a-ii), (b-iv), (c-i), (d-iii)**

(a) Source of microwave frequency is magnetron.

(b) Source of infrared frequency is vibration of atoms and molecules.

(c) Source of Gamma rays is radioactive decay of nucleus.

(d) Source of X-rays inner shell electron transition.

EXERCISE – S

1. **Ans.** 2

Conduction current density = σE

Displacement current density :

$$\frac{\partial \vec{D}}{\partial t} = \varepsilon\varepsilon_0 \frac{\partial \vec{E}}{\partial t} = I\omega\varepsilon\varepsilon_0 \vec{E}$$

Ratio of magnitudes = $\sigma/\omega\varepsilon\varepsilon_0 = 2$

2. **Ans.** $\sqrt{\frac{\varepsilon_0}{\mu_0}}\frac{\vec{k}\times\vec{E}_m}{k}\cos ckt$

$$\vec{V}\times\vec{E} = -\frac{\partial \vec{B}}{\partial t} = -\mu_0\frac{\partial \vec{H}}{\partial t}$$

$$= \vec{V}\cos\left(\omega t - \vec{k}.\vec{r}\right)\times\vec{k}\times\vec{E}_m\sin\left(\omega t - \vec{k}.\vec{r}\right)$$

$\vec{r} = 0$

$$\frac{\partial \vec{H}}{\partial t} = -\frac{\vec{k}\times\vec{E}_m}{\mu_0}\sin\omega t$$

$$\vec{H} = \frac{\vec{k}\times\vec{E}_m}{\mu_0}\cos ckt \times \frac{1}{ck} = \sqrt{\frac{\varepsilon_0}{\mu_0}}\frac{\vec{k}\times\vec{E}_m}{k}\cos ckt$$

3. **Ans.** (a) $\vec{H}=\sqrt{\frac{\varepsilon_0}{\mu_0}}E_m\hat{e}_x\cos kx$, (b) $\vec{H}=\sqrt{\frac{\varepsilon_0}{\mu_0}}E_m\hat{e}_x\cos\left(kx-\omega t_0\right)$

Consider the case when E_m = 160 V/m, k = 0.51 m^{-1}, x= 7.7 m, and t_0 = 33 ns.

As in the previous problem

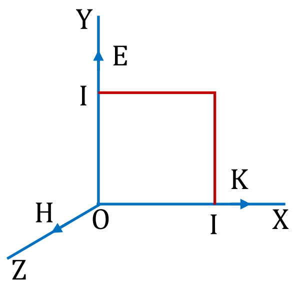
$$\vec{H}=\frac{\vec{k}\times\vec{E}_m}{\mu_0\omega}\cos\left(\omega t-\vec{k}.\vec{r}\right)=\frac{E_m}{\mu_0 c}\hat{e}_x\cos\left(kx-\omega t\right)$$

$$=\sqrt{\frac{\varepsilon_0}{\mu_0}}E_m\hat{e}_x\cos\left(kx-\omega t\right)$$

(a) at t=0 $\vec{H}=\sqrt{\frac{\varepsilon_0}{\mu_0}}E_m\hat{e}_x\cos kx$

(b) at $t=t_0$, $\vec{H}=\sqrt{\frac{\varepsilon_0}{\mu_0}}E_m\hat{e}_x\cos\left(kx-\omega t_0\right)$

4. **Ans.** $25\cos\left(\omega t-\frac{\pi}{3}\right)mV$



$$\varepsilon_{ind}=\oint\vec{E}.d\vec{l}=E_m l\left(\cos\omega t-\cos\left(\omega t-kl\right)\right)$$

$$=-2E_m l\sin\frac{\omega l}{2c}\sin\left(\omega t-\frac{\omega l}{2c}\right)$$

E_{m} = 50m V/m, $l=\frac{1}{2}$ metre

$$\frac{\omega l}{e}=\frac{2\pi vl}{c}=\frac{3\times10^8}{3\times10^8}=\frac{\pi}{3}$$

$$\varepsilon_{ind}=50mV\left(-\sin\frac{\pi}{6}\right)\sin\left(\omega t-\frac{\pi}{6}\right)$$

$$=-25\sin\left(\omega t+\frac{\pi}{6}-\frac{\pi}{2}\right)=25\cos\left(\omega t-\frac{\pi}{3}\right)mV$$

5. **Ans.** $\frac{2l}{e}\frac{\sqrt{\varepsilon_1}-\sqrt{\varepsilon_2}}{\ln\frac{\varepsilon_1}{\varepsilon_2}}$

Permitivity of the medium varies as

$$\varepsilon\left(x\right)=\varepsilon_1 e^{-1(x/l)in(\varepsilon_1/\varepsilon_2)}$$

Hence the local velocity of light

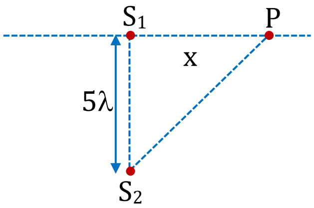
$$v(x)=c/\sqrt{\varepsilon}\left(x\right)=\left[c/\sqrt{\varepsilon_1}\right]e^{-(x/2l)\ln(\varepsilon1/\varepsilon2)}$$

Thus the required time,

$$t-\int_0^t\frac{dx}{v\left(x\right)}=\frac{\sqrt{\varepsilon_1}}{e}\int_0^t e^{-\frac{x}{2l}\ln\frac{e_1}{e_2}}$$

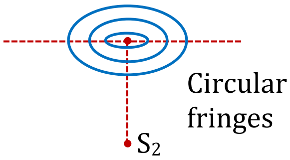
$$dx-\frac{\sqrt{\varepsilon_1}}{e}\frac{-e^{\frac{1}{2}\ln\frac{\varepsilon_1}{\varepsilon_2}}+1}{\frac{1}{2l}\ln\frac{\varepsilon_1}{\varepsilon_2}}=\frac{2l}{e}\frac{\sqrt{\varepsilon_1}-\sqrt{\varepsilon_2}}{\ln\frac{\varepsilon_1}{\varepsilon_2}}$$

6. **Ans.** 48, 21, $\frac{32}{3}$, $\frac{9}{2}$, 0 *m.m.* ; 



$S_2P - S_1P = n\lambda$

$\sqrt{(5\lambda)^2 + x^2} - x = n\lambda$



7. **Ans.** λ = 5850 $\AA$

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

D = 100 *cm*

$\frac{0.7cm}{d} = m = \frac{v}{u} = 7/3$

$\lambda = \frac{\beta d}{D} = \frac{0.0195\times0.3\times10^{-5}\times10^{-2}}{100\times10^{-2}}$

8. **Ans.** 35.35 *cm* approximate, 5

D = 1 *m*

$d = 3\times10^{-3}$ *m*

$\lambda = 10^{-3}m$

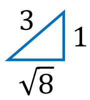
$d \sin\theta = n\lambda$

$d \sin\theta = \lambda$

$\Rightarrow \sin\theta = \frac{\lambda}{d} = \frac{10^{-3}}{3\times10^{-3}}$

$\sin\theta = \frac{1}{3}$

$\tan\theta = \frac{1}{\sqrt{8}} = \frac{x}{D}$



$\Rightarrow x = D\tan\theta$

$x = 1\times\frac{1}{\sqrt{8}} = \frac{1}{2\sqrt{2}}\times\frac{\sqrt{2}}{\sqrt{2}}$

$x = \frac{\sqrt{2}}{4}m = \frac{1.414}{4}$

$= 0.3535m$

$x = 35.35cm$

Total no. of maxima possible for value of n = 0,1,2

Total no. of maxima present is = 5

9. **Ans.** $\left(n-\frac{1}{48}\right)\lambda = x_1 - x_2$

$\phi_1 = \frac{2\pi x_1}{\lambda} - 2\pi f t + \frac{\pi}{6}$

$\phi_2 = \frac{2\pi x_2}{\lambda} - 2\pi f t + \frac{\pi}{8}$

$\phi_1 - \phi_2 = \Delta\phi$

$\frac{2\pi}{\lambda}(x_1 - x_2) + \left(\frac{\pi}{6} - \frac{\pi}{8}\right) = 2n\pi$ for constructive interference

$\frac{2\pi}{\lambda}(x_1 - x_2) = 2n\pi - \frac{\pi}{24}$

$(x_1 - x_2) = \left(2n\pi - \frac{\pi}{24}\right)\frac{\lambda}{2\pi}$

$(x_1 - x_2) = \left(n - \frac{1}{48}\right)\lambda$ where $n = 0,1,2,\ldots$

10. **Ans.** $1.99 \times 10^{-2}\ mm$

$I = I_{\max}\cos^2\frac{\Delta\phi}{2}$

$I = 0$ when $\Delta\phi = \pi$

$\frac{2\pi}{\lambda} d\sin\theta = \pi$

$d\sin\theta = \frac{\lambda}{2}$

$d \times 0.75 \times \frac{\pi}{180} = \frac{520 \times 10^{-9}}{2}$

11. **Ans.** $8\ \mu m$

$n\lambda \Rightarrow (\mu_1 - 1)t - (\mu_2 - 1)$

$n\lambda = (\mu_1 - \mu_2)t \quad \Rightarrow \quad t = \frac{5\times4800\times10^{-10}}{(1.7-1.4)}$

$t = 5 \times 16000 \times 10^{-10} \Rightarrow t = 8 \times 10^{-6}m$

$t = 8\mu m$

12. **Ans.** 1100

$d = x\theta$

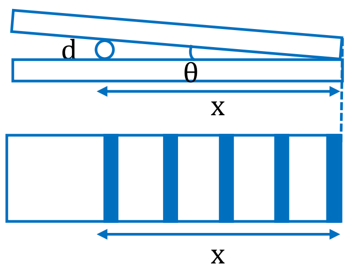
$x = \frac{n\lambda}{2\theta}$ = condition of dark fringe

$n = 0$, first dark fringe at join of plates

$n = 4$, fifth dark fringe at fiber

$d = x\theta = \frac{4\lambda}{2} = 2\lambda$

$d = 2 \times 550\ nm \Rightarrow 1100\ nm$



13. **Ans.** 3

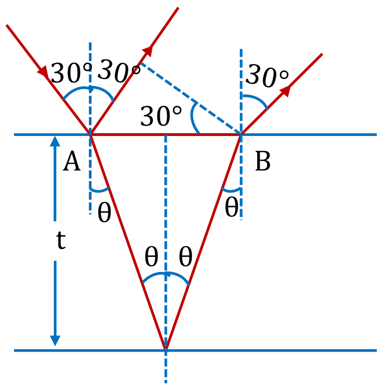
Given $d = 4\sqrt{3}\ cm$

$\sin 30° = \frac{17}{16}\sin\theta$

$\sin\theta = \frac{8}{17}$

$AB = d\sec 30° = 8\ cm$; $\tan\theta = \frac{4}{t} \Rightarrow \frac{4}{t}$

$\Rightarrow t = 7.5\ cm = 75\ mm$



14. **Ans.** (a) 5.4 μ*m* wide, (b) 0.99 *mm* high

(a) For width,

$$tan\theta = \frac{y}{L} = \frac{0.110}{4.5\times2} = 0.0122$$

$$a\ sin\ \theta = \lambda$$

$$a = \frac{660\times10^{-9}}{0.122} = 5.4\mu m$$

Now For height,

$$tan\ \theta = \frac{6}{2\times4.5} = 6.6\times10^{-4}$$

$$a = \frac{\lambda}{sin\ \theta} = \frac{660\times10^{-9}}{6.6\times10^{-4}} = 0.99mm$$

(b) vertical

15. **Ans.** $\left(\frac{25}{9}cm\right)$

$$M = \frac{2}{f_0} \Rightarrow 20 = \frac{16}{f_0}$$

$$\therefore\ f_0 = \frac{4}{5}cm$$

$\tan\beta = \frac{b/2}{v} = \frac{b}{2f_0}$ and $\mu \sin\beta = 0.9$

$\Rightarrow b \approx 2f_0 \sin\beta = 2 \times \frac{4}{5} \times \frac{0.9}{\mu}$

16. **Ans.** (a) 2.0 × is eyepiece, 4.0 × is objective (b) 37.5 *cm*

For a magnifying lens:

$$\Rightarrow m = \frac{0.25}{f}$$

$f = 0.25/2 = 0.125m$ (for $m = 2$)

$$m = \frac{0.25}{f}$$

$f = 0.25/4 = 0.0625m$ (for $m = 4$)

Objective lens should be 4.0 ×

Eyepiece lens should be 2.0 ×

$$m = \left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right)$$

$$12 = \left(\frac{L}{0.0625}\right)\left(\frac{0.25}{0.125}\right)$$

$$L = \frac{12\times0.125\times0.0625}{0.25}$$

$L = 0.375m$ or $37.5cm$

17. **Ans.** 0.6*mJ*

When the polarizer rotates with angular velocity *w* its instantaneous principal direction makes angle *wt* from a reference direction which we choose to be along the direction of vibration of the of plane-

polarized incident light. The transmitted flux at this instant is $\varphi_0 \cos^2 \omega t$ and the total energy passing through the polarizer per revolution is

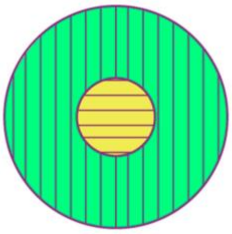
$$\int_0^T \phi_0 \cos^2 \omega t\ dt$$

$T = 2\pi/\omega$

$= \varphi_0\pi/\omega$

= 0.6 *mJ*

18. **Ans.** 30°



Let I_0 = intensity of the incident beam.

Then the intensity of the beam transmitted through the first Nicol prism is $I_1 = \frac{1}{2} I_0$

And through the 2nd prism is $I_2 = \frac{1}{2} I_0 \cos^2 \phi$

Through the N^{th} prism, it will be $I_N - I_{N-1} \cos^2 f$

$= \frac{1}{2} I_0 \cos^{2(N-1)} \phi$

Hence the N^{th} prism, it will be $I_N/I_0 = h = \frac{1}{2} \cos^{(2N-1)} \phi$

= 0.12 for $N = 6$

And $\phi = 30°$

EXERCISE - JEE (Main) PYQ

1. **Ans. (2)**

When polaroid is at Angle 30° with beam A, it makes 60° with beam B

By malus law

$I_A \cos^2 30° = I_B \cos^2 60°$

$\Rightarrow \frac{I_A}{I_B} = \frac{1}{3}$

2. **Ans. (4)**

$I_{av} = \frac{1}{2} \varepsilon_0 E^2 C = \frac{P}{4\pi r^2}$

$E = \sqrt{\frac{2P}{4\pi r^2 \varepsilon_0 c}}$

On putting value we get

= 2.45 V/m.

3. **Ans. (4)**

$\frac{d_0}{d_1} = \theta = \frac{1.22\lambda}{d}$

$d_0 = \frac{1.22 \times 500 \times 10^{-9}}{0.5 \times 10^{-2}} \times 25 \times 10^{-2}$

$d_0 = 1.22 \times 25 \times 10^{-6}$

$d_0 \simeq 30\ \mu m$

4. Ans. (4)

Spot size (diameter) $b = 2\left(\frac{\lambda L}{2a}\right) + 2a$

$a^2 + \lambda L - ab = 0$ ...(i)

For Real roots $b^2 - 4L\lambda \geq 0$

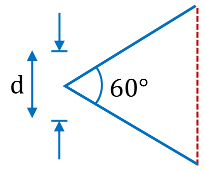
$b_{min} = \sqrt{4\lambda L}$

By equation (i)

$a = \sqrt{\lambda L}$

5. Ans. (4)

In diffraction



$d \sin 30° = \lambda$

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

Young's fringe width

[d' – separation between two slits]

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

$10^{-2} = \frac{d}{2} \times \frac{50\times10^{-2}}{d'}$

$10^{-2} = \frac{10^{-6}\times50\times10^{-2}}{2\times d'}$

$\boxed{d' = 25\mu m}$

6. Ans. (2)

Velocity of EM wave is given by $\frac{1}{\sqrt{\mu\epsilon}}$

Velocity in air $= \frac{\omega}{k} = c$

Velocity in medium $= \frac{c}{2}$

$\therefore \quad \frac{\frac{1}{\sqrt{\epsilon_{r_1}}}}{\frac{1}{\sqrt{\epsilon_{r_2}}}} = \frac{c}{\left(\frac{c}{2}\right)} = 2$

$\Rightarrow \quad \frac{\epsilon_{r_1}}{\epsilon_{r_2}} = \frac{1}{4}$

7. Ans. (4)

$E_0 = B_0 \times C = 100\times10^{-6} \times 3\times10^{8} = 3\times10^{4}\ N/C$

8. Ans. (4)

If we use that direction of light propagation will be along $\vec{E} \times \vec{B}$. Then (4) option is correct.

Detailed solution is as following.

Magnitude of $E = CB$

$E = 3 \times 10^8 \times 1.6 \times 10^{-6} \times \sqrt{5}$

$E = 4.8 \times 10^2\sqrt{5}$

$\vec{E}$ and $\vec{B}$ are perpendicular to each other

$\Rightarrow \quad \vec{E}.\vec{B} = 0$

$\Rightarrow$ either direction of $\vec{E}$ is $\hat{\imath} - 2\hat{\jmath}$ or $-\hat{\imath} + 2\hat{\jmath}$

From given option

Also wave propagation direction is parallel to $\vec{E} \times \vec{B}$ which is $-\hat{k}$

$\Rightarrow \quad \vec{E}$ is along $(-\hat{\imath} + 2\hat{\jmath})$

9. **Ans. (4)**

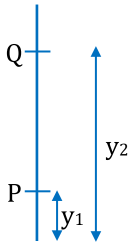
For diffraction

Location of 1st minima

$$y_1 = \frac{D\lambda}{a} = 0.2469D\lambda$$

Location of 2nd minima

$$y_2 = \frac{2D\lambda}{a} = 0.4938D\lambda$$



Now for interference

Path difference at P.

$$\frac{dy}{D} = 4.8\lambda$$

Path difference at Q

$$\frac{dy}{D} = 9.6\lambda$$

So, orders of maxima in between P and Q is

5, 6, 7, 8, 9

So, 5 bright fringes all present between P and Q.

10. **Ans. (2)**

$$P_{\text{refracted}} = \frac{96}{100}P_I$$

$$\Rightarrow \quad K_2A_t^2 = \frac{96}{100}K_1A_i^2$$

$$\Rightarrow \quad r_2A_t^2 = \frac{96}{100}r_1A_i^2$$

$$\Rightarrow \quad A_t^2 = \frac{96}{100} \times \frac{1}{\frac{3}{2}} \times (30)^2$$

$$A_t = \sqrt{\frac{64}{100} \times (30)^2} = 24\ V/m$$

11. **Ans. (1)**

$c < i_b$

Here i_b is "brewster angle"

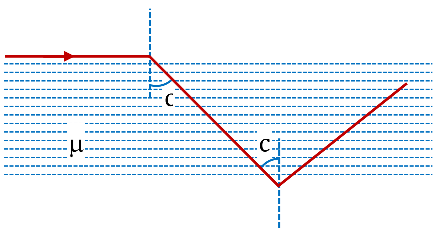
and c is critical angle

$\sin_c < \sin i_b$

Since $\tan i_b = \mu_{0_{rel}} = \frac{1.5}{\mu}$

$$\frac{1}{\mu} < \frac{1.5}{\sqrt{\mu^2 + (1.5)^2}}$$

$$\therefore \quad \sin i_b = \frac{1.5}{\sqrt{\mu^2 + (1.5)^2}}$$



$\mu^2 + (1.5)^2 < (\mu \times 1.5)^2$

$$\sqrt{\mu^2 \times (1.5)^2} < 1.5 \times \mu$$

$$\mu < \frac{3}{\sqrt{5}}$$

slab $\mu = 1.5$

12. Ans. (3)

$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

$\vec{E} = E_0\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right)\cos\pi$

$= -E_0\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

As $\vec{E} \times \vec{B} = \vec{c}$

$+E_0\left(\frac{\hat{i}+\hat{j}}{\sqrt{2}}\right) \times \vec{B} = c\hat{k}$

$\Rightarrow \vec{B} = -\left(\frac{\hat{i}-\hat{j}}{\sqrt{2}}\right)\frac{E_0}{c}$

$\vec{F} = q\left(-E_0\frac{(\hat{i}+\hat{j})}{\sqrt{2}} - \frac{v_0\hat{k}}{c} \times (\hat{i}-\hat{j})E_0\right)$

Since $\frac{v_0}{c} << 1$

$\Rightarrow$ F is antiparallel to $\frac{\hat{i}+\hat{j}}{\sqrt{2}}$

13. Ans. (1)

$\hat{E} = \hat{k}$

$\vec{B} = 2\hat{i} - 2\hat{j}$

$\Rightarrow \hat{B} = \frac{\vec{B}}{|B|} = \frac{2\hat{i}-2\hat{j}}{2\sqrt{2}}$

$\Rightarrow \hat{B} = \frac{1}{\sqrt{2}}(\hat{i}-\hat{j})$

Direction of wave propagation = $\hat{C} = \hat{E} \times \hat{B}$

$\hat{C} = \hat{k} \times \left[\frac{1}{\sqrt{2}}(\hat{i}-\hat{j})\right]$

$\hat{C} = \frac{1}{\sqrt{2}}(\hat{k} \times \hat{i} - \hat{k} \times \hat{j})$

$\hat{C} = \frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$

14. Ans. (3)

$\vec{F} = q(\vec{V} \times \vec{B})$

$\vec{F}_1 = 4\pi\left[0.5c\hat{i} \times B_0\left(\frac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\frac{\pi}{K} - 0\right)\right]$

$\vec{F}_2 = 2\pi\left[0.5c\hat{i} \times B_0\left(\frac{\hat{i}+\hat{j}}{2}\right)\cos\left(K.\frac{3\pi}{K} - 0\right)\right]$

$\cos\pi = -1, \quad \cos 3\pi = -1$

$\therefore \frac{F_1}{F_2} = 2$

15. Ans. (1)

Speed of wave = $\frac{2\times10^{10}}{200} = 10^8 m/s$

Refractive index = $\frac{3\times10^8}{10^8} = 3$

Now refractive index = $\sqrt{\varepsilon_r\mu_r}$

$\Rightarrow 3 = \sqrt{\varepsilon_r(1)}$

$\Rightarrow \varepsilon_r = 9$

16. Ans. (1)

$E_y = 540 \sin \pi \times 10^4(x - ct)\ Vm^{-1}$

$E_0 = 540\ Vm^{-1}$

$B_0 = \frac{E_0}{C} = \frac{540}{3\times10^8} = 18 \times 10^{-7} T$

17. Ans. (4)

$< u_E > = < u_B > = \frac{1}{2} < u_{\text{total}} >$

So $\frac{\langle u_E \rangle}{\langle u_{\text{total}} \rangle} = \frac{1}{2}$

18. Ans. (462)

$d = 2.5\ mm$, $D = 150\ cm$

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

Let n[th] bright tringle of λ_1 match with m^{th} bright triangle of λ_2

$\Rightarrow n\beta_1 = m\beta_2$

$\Rightarrow n\lambda_1 = m\lambda_2 \Rightarrow \frac{n}{m} = \frac{\lambda_2}{\lambda_1} = \frac{5500}{7000}$

$\Rightarrow \frac{n}{m} = \frac{11}{14}$

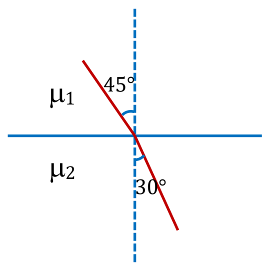
Distance where bright fringe will match

$= n\beta_1 = \frac{11 \times 7000A^0 \times 150cm}{0.25cm}$

$= 462 \times 10^{-5}$

19. Ans. (2)

Snell's law $\mu_1 \sin 45° = \mu_2 \sin 30°$



$\frac{\mu_1}{\mu_2} = \frac{1}{\sqrt{2}}$

$\Rightarrow \frac{\mu_1}{\mu_2} = \frac{\lambda_2}{\lambda_1} = \frac{1}{\sqrt{2}}$

$\Rightarrow \lambda_2 = \frac{\lambda_1}{\sqrt{2}}$

Frequency doesn't change on change in medium.

20. Ans. (3)

Fringe width $(\beta) = \frac{D\lambda}{d}$

$\Rightarrow \frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1}$

$\Rightarrow \frac{\beta_2}{2mm} = \frac{600nm}{400nm} = \frac{3}{2}$

$\Rightarrow \boxed{\beta_2 = 3mm}$

21. Ans. (2)

As for first minima

$a \sin \theta = \lambda$

$\Rightarrow a \sin 30° = 600 \times 10^{-9}$

$\Rightarrow a = 1200 \times 10^{-9}\ m$

$\Rightarrow a = 1.2\ \mu m$

EXERCISE - JEE (Advanced) PYQ

1. **Ans. (B)**

$$\frac{I_{max}}{2} = I_{max}\cos^2\left(\frac{\pi}{\lambda}\Delta x\right)$$

$$\cos^2\left(\frac{\pi}{\lambda}\Delta x\right) = \frac{1}{2}$$

$$cos\left(\frac{\pi}{\lambda}\Delta x\right) = \pm\frac{1}{\sqrt{2}}$$

$$\frac{\pi}{\lambda}\Delta x = n\pi \pm \frac{\pi}{4}$$

$$\Delta x = \left(n \pm \frac{1}{4}\right)\lambda$$

2. **Ans. (ABC)**

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

$\beta_2 > \beta_1$

$$y = m_1\frac{D\lambda_1}{d} = m_2\frac{D\lambda_2}{d}$$

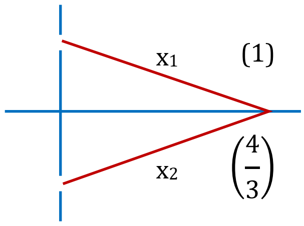
$$\frac{nD\times\lambda_2}{d} = \left(n' + \frac{1}{2}\right)\frac{D\lambda_1}{d}$$

$$\Rightarrow \quad 600\,n = \left(n' + \frac{1}{2}\right)\times 400$$

3. **Ans. (3)**

$$x_1 = \sqrt{x^2 + d^2}$$

$$x_2 = \frac{4}{3}\sqrt{x^2 + d^2}$$



$$\Delta x = \left(\frac{4}{3} - 1\right)\sqrt{x^2 + d^2} = n\lambda$$

$$\frac{1}{3}\sqrt{x^2 + d^2} = n\lambda$$

$(x^2 + d^2) = 9n^2\lambda^2$

$\therefore \quad (P = 3)$

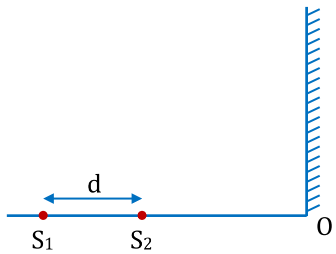
4. **Ans. (BC)**

Path difference at point $O = d = 0.6003\ mm = 600300\ nm$, $d = n\lambda = \Delta x$

$$\Delta x = 1000\lambda + \frac{\lambda}{2}$$

$\Rightarrow$ Minima form at point O

Line S_1S_2 and screen are $\perp$ to each other so fringe pattern is circular (semi-circular because only half of screen is available)



5. **Ans. (CD)**

At point P_2 ; $\Delta x = d = 1.8\ mm = 3000\ \lambda$

Hence a (bright fringe) will be formed at P_2

Now, $\Delta x = d\cos\theta = n\lambda$

$$\cos\theta = \frac{n\lambda}{d}$$

$$-\sin\theta\,\Delta\theta = (\Delta n)\frac{\lambda}{d}$$

$$\Delta\theta = -(\Delta n)\frac{\lambda}{d\sin\theta}$$

$\Delta\theta$ increases as θ decreases

At P_2, the order of fringe will be maximum.

For total no. of bright fringes $d = n\lambda \Rightarrow n = 3000$

$\therefore$ Total number of fringes = 3000

6. **Ans. (C)**

(A) $\Delta x = d\sin\alpha$

$= d\alpha$ (as α is very small)

$$\alpha = \frac{.36}{180} = (2\times 10^{-3})rad$$

$$\frac{\Delta x}{\lambda} = \frac{(3\times10^{-4})(2\times10^{-3})}{6\times10^{-7}} = 1$$

So constructive interference

(B) $\beta = \frac{D\lambda}{d}$

(C) $\Delta x_p = d\alpha + \frac{dy}{D}$

$= 3\times10^{-4}(2\times10^{-3} + 11\times10^{-3})$

$= 39\times10^{-7}$

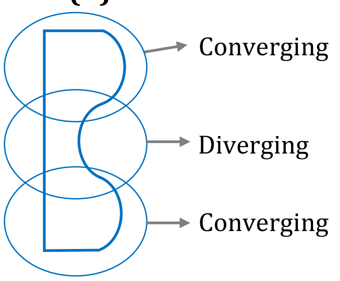
$$\frac{\Delta x_p}{\lambda} = \frac{39\times10^{-7}}{6\times10^{-7}} = 6.5 \text{ so destructive}$$

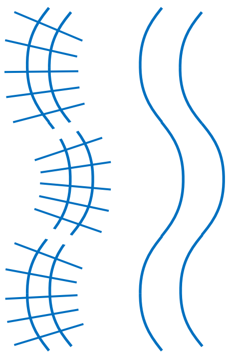
(D) $\Delta x_p = \frac{dy}{D} = (3\times10^{-4})\times 11\times10^{-3}$

$= 33\times10^{-7}$

$$\frac{\Delta x_p}{\lambda} = \frac{33\times10^{-7}}{6\times10^{-7}} = 5.5 \Rightarrow \text{destructive}$$

7. **Ans. (A)**





Answer is (A)

8. **Ans. (BD)**

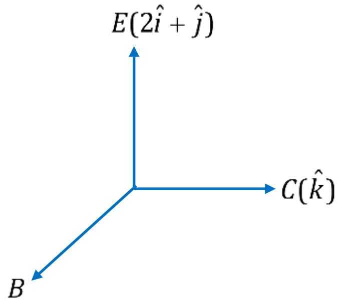
$\vec{S} = [\vec{E} \times \vec{B}]\dfrac{1}{\mu_0}$

S is pointing vector denotes flow of energy per unit area per unit time

$$\vec{S} = \frac{\text{watt}}{m^2}$$

Hence B, D are correct.

9. **Ans. (AD)**

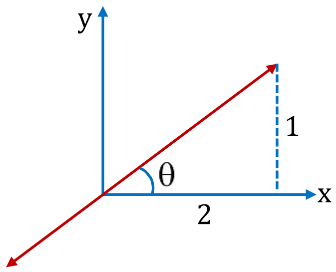


$C_{\text{medium}} = \dfrac{5\times10^{14}}{10^7/3} = 1.5 \times 10^8\ m/s \ \therefore\ \mu = 2$

$C_{\text{medium}} = \dfrac{E}{B} \Rightarrow B = \dfrac{E}{C_m} = \dfrac{30\sqrt{5}}{1.5\times10^8} = 2\sqrt{5}\times10^{-7}$

$\vec{B}_{direction} \equiv \hat{k}\times(2\hat{i}+\hat{j}) \equiv \dfrac{2\hat{j}-\hat{i}}{\sqrt{5}}$

$\therefore \quad \vec{B} = 2\times10^{-7}(-\hat{i}+2\hat{j})\sin\left[27\left(5\times10^{17}t - \dfrac{10^7}{3}z\right)\right]$



$\tan\theta = \dfrac{1}{2}$

JEE (Main) Practice Paper

SECTION–A

1. **Ans. (2)**

$i_C = i_d = \dfrac{dq}{dt} = \dfrac{d(CV)}{dt} = C\dfrac{dV}{dt}$

$\dfrac{dV}{dt} = \dfrac{i_d}{C}$

2. **Ans. (4)**

$i_d = \epsilon_0 \dfrac{d\phi_E}{dt}$

$\therefore$ More the rate of change of electric field.

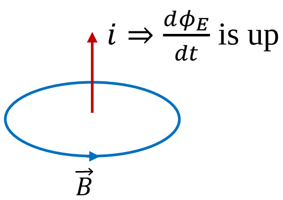
More is the displacement current.

3. **Ans. (3)**

$i = \varepsilon_0 \dfrac{d\phi_E}{dt}$

$\dfrac{d\phi_E}{dt} = A\dfrac{dE}{dt}$

$\Rightarrow \dfrac{dE}{dt}$ is up; but $\vec{E}$ is down: E is decreasing.



If we see carefully; both figure (a) and (b) are same.

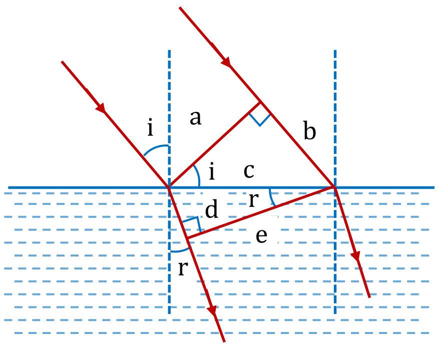
4. Ans. (1)

$B = \frac{E}{C}$

5. Ans. (4)

$B_0 = \frac{E_0}{C}$ and $\vec{V}$ should be || to $\vec{E} \times \vec{B}$

6. Ans. (3)



$\sin i = b/c$

$\sin r = d/c$

$\sin i = \mu \sin r$

$\mu = b/d$

7. Ans. (2)

$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \Delta\phi$

$I_A = I + 4I + 4I \times (0)$

$I_A = 5I$

$I_B = I + 4I + 4I(-1) = I$

$I_A - I_B = 4I$

8. Ans. (3)

$I_1 = I, I_2 = 4I$

$I_{\max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$

$I_{\min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$

9. Ans. (2)

$d \sin \theta = n\lambda$

$-1 < \sin \theta = \frac{n\lambda}{d} < 1$

$-1 < \frac{n\lambda}{d} < 1$

$-\frac{d}{\lambda} < n < \frac{d}{\lambda}$

$-\frac{7}{2} < n < \frac{7}{2}$

$n = 0, \pm 1, \pm 2, \pm 3$

10. Ans. (4)

Central bright fringe is a white spot. Surrounding CBF is a colourful pattern.

11. **Ans. (2)**

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

$\lambda_R > \lambda_G$

$\lambda_G > \lambda_B$

12. **Ans. (2)**

$\frac{nD\lambda_R}{d} = \frac{(n+1)D\lambda_B}{d}$

13. **Ans. (4)**

Path difference: $\Delta x = \left(n + \frac{1}{2}\right)\lambda$

$(l_1 + l_3) - (l_2 + l_4) = \left(n + \frac{1}{2}\right)\lambda$

14. **Ans. (2)**

At the mid-point of screen

$I_1 = 4\ I_0$: coherent sources

$I_2 = 2\ I_0$: incoherent sources

$\frac{I_1}{I_2} = 2$

15. **Ans. (3)**

$I_1 = 4I_0 = I$: Constructive interference

$I_2 = I_0 = \frac{I}{4}$: No interference.

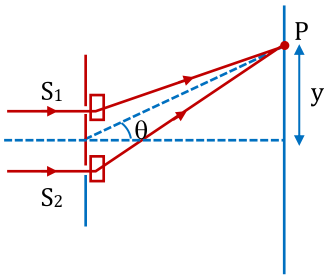
16. **Ans. (2)**

$[S_2P + (\mu_2 - 1)\ t_2] - (S_1P + (\mu_1 - 1)\ t_1) = n\lambda = 0$

$(S_2P - S_1P) = (\mu_1 - 1)\ t_1 - (\mu_2 - 1)\ t_2$

$= (2\mu - 1)\ t - (\mu - 1)2t$

$= -t + 2t = t$



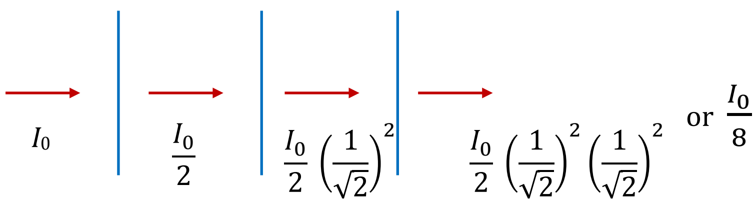
$d \sin \theta = t$

$d \tan \theta = t$

$\frac{dy}{D} = t$

$y = \frac{Dt}{d}$

17. **Ans. (4)**



18. **Ans. (2)**

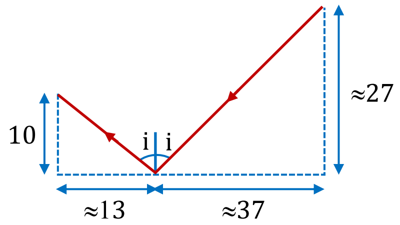
Brewster's law

$\theta_B = \tan^{-1}(\mu)$

19. Ans. (1)

Use Brewster's law

$\tan i = \mu \Rightarrow i = 53°$



20. Ans. (4)

θ for II dark fringe is $\dfrac{2\lambda}{a}$

$\therefore \quad s = \left(\dfrac{2\lambda}{a}\right) D = \dfrac{2(600\times10^{-9})2}{4\times10^{-4}} = 0.006\ m$

SECTION-B

1. Ans. (153)

$E = CB = 3 \times 10^8 \times 510 \times 10^{-9} = 153\ N/C.$

2. Ans. (15)

Given: Frequency of wave $f = 5\ GHz$

$= 5 \times 10^9\ Hz$

Relative permittivity, $\in_r = 2$

and Relative permeability, $\mu_r = 2$

Since speed of light in a medium is given by,

$v = \dfrac{1}{\sqrt{\mu\in}} = \dfrac{1}{\sqrt{\mu_r\mu_0 \cdot \in_r\in_0}}$

$v = \dfrac{1}{\sqrt{\mu_r\in_r}} \dfrac{1}{\sqrt{\mu_0\in_0}} = \dfrac{C}{\sqrt{\mu_r\in_r}}$

Where C is speed of light is vacuum

$\therefore \quad v = \dfrac{3\times10^8}{\sqrt{4}} = \dfrac{30\times10^7}{2}\ m/s$

$= 15 \times 10^7\ m/s$

Ans. is 15

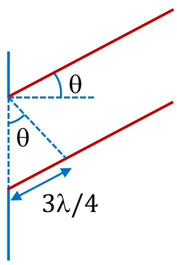
3. Ans. (8)

$\beta = \dfrac{\pi\omega\sin\theta}{\lambda} = \dfrac{3\pi}{4}$

$\omega\sin\theta = \dfrac{3\lambda}{4}$

$I = I_0\dfrac{\sin^2\beta}{\beta^2}$

$\dfrac{I}{I_0} = \dfrac{\sin^2\dfrac{3\pi}{4}}{\dfrac{9\pi^2}{16}} = \dfrac{16}{9\pi^2\times2}$



4. **Ans. (9)**

$\frac{2\lambda_1 D}{a}$ = 4.5 cm

$\frac{4.5cm}{\lambda_1 \frac{D}{d}}$ = 9

When blue colour is used

$\frac{\frac{2\lambda_2 D}{a}}{\lambda_2 \frac{D}{d}}$ = 9

5. **Ans. (6)**

$\ell_{min} \frac{0.61\lambda}{NA} \Rightarrow NA = \frac{0.61\times6\times10^{-7}}{0.61\times10^{-6}} = 0.6 = 6 \times 10^{-1}$

6. **Ans. (125)**

Case–1:

$(x + \lambda/2) - (D - x) = \lambda$

$2x - D = \lambda/2$

Case–2:

$(D - x) - (x + \lambda/2) = \lambda$

$D - 2x - \lambda/2 = \lambda$

$D - 2x = 3\lambda/2$

Lowest of the above two values of x is the answer.

7. **Ans. (7)**

$S_2P + x - (S_1P + \sqrt{(0.01)^2 + x^2}\,) = 0$

$(d \sin\theta + x)^2 = (0.01)^2 + x^2$

$(d \sin\theta)^2 + 2\, dx \sin\theta = 10^{-4} \times 1$

$2 \times 1 \times 10^{-2} \times x \times \frac{y}{D} = 10^{-4}$

$y = \frac{10^{-2}}{2} \times \frac{1}{x}$

$y = 5 \times 10^{-3} \times \frac{1}{x}$

$\frac{dy}{dt} = -\frac{5\times10^{-3}}{x^2}\frac{dx}{dt}$

$\frac{dy}{dt} = -\frac{5}{(0.5)^2} \times 10^{-3} \times 1 \times 10^{-3}$

$= -\frac{1}{5} \times 10^2 \times 10^{-6} = -0.2 \times 10^{-4}$

$\frac{dy}{dt} = -2 \times 10^{-5}$

$\alpha = 2, \beta = 5$

$\alpha + \beta = 7$

8. **Ans. (50)**

From figure we have

1. $\rightarrow \frac{2}{3}\left(\frac{2}{3}I\right)$

2. $\frac{1}{9} \times \left(\frac{2}{3}\right)\left(\frac{2}{3}I\right)$

3. $\frac{1}{81}\left(\frac{2}{3}\right)\left(\frac{2}{3}I\right)$

On adding all the equation we have

$$1 + 2 + 3 + \ldots \infty$$

$$\frac{4}{9}I + \frac{1}{9}\left(\frac{4I}{9}\right) + \frac{1}{81}\left(\frac{41}{9}\right)\ldots\infty$$

$$\frac{4I}{9}\left(+\frac{1}{9}+\frac{1}{81}\ldots\infty\right)$$

$$\frac{4I}{9}\left(\frac{1}{1-\frac{1}{9}}\right) - \frac{4I}{9} \times \frac{9}{8}$$

$$= I/2$$

9. **Ans. (500)**

$$\frac{9D\lambda}{d} - \frac{3}{2}\frac{D\lambda}{d} = 7.5\,mm, \lambda = 0.5 \times 10^{-6}$$

$$\frac{D\lambda}{d}[9 - 1.5] = 7.5\,mm, \lambda = 5 \times 10^{-7}$$

$$\frac{D\lambda}{d} = 1\,mm, \lambda = 5000\ \text{Å}$$

$$\frac{1 \times \lambda}{0.5 \times 10^{-3}} = 1 \times 10^{-3}$$

10. **Ans. (35)**

$$y = \frac{nD\lambda}{d} = \frac{mD\lambda'}{d}$$

JEE (Advanced) Practice Paper

1. **Ans. (A)**

$$\Delta\phi = \frac{2\pi}{\lambda_2}\Delta x$$

$$\Delta x = (n_{\text{rel}} - 1)t = \left(\frac{n_3}{n_2} - 1\right)t$$

$$\frac{\lambda_2}{\lambda_1} = \frac{n_1}{n_2}$$

$$\lambda_2 = \frac{n_1}{n_2}\lambda_1$$

$$\Delta\phi = \frac{2\pi}{n_1\lambda_1}(n_3 - n_2)t$$

2. Ans. (B)

For transparent media

$\Rightarrow \quad \mu_r = 1$

$n = \sqrt{\varepsilon_r \mu_r}$

$\Rightarrow \quad n = \sqrt{\varepsilon_r}$

$\therefore \quad \varepsilon_r = n^2$

$I_{\text{before}} = I_{\text{after}}$ = Since there is no loss

$$\Rightarrow \quad \frac{1}{2} C\varepsilon_0 E_0^2 = \frac{1}{2}\frac{C}{n} . \varepsilon_r \varepsilon_0 E^2$$

$$\Rightarrow \quad \frac{E_0}{E} = \sqrt{n}$$

$$\Rightarrow \quad \frac{B_0^2}{2\mu_0} . C = \frac{B^2}{2\mu_0} . \frac{c}{n}$$

$$\Rightarrow \quad \frac{B_0}{B} = \frac{1}{\sqrt{n}}$$

3. Ans. (ABC)

$$\frac{\partial E}{\partial x} = -\frac{\partial B}{\partial t}$$

$$\frac{\partial B}{\partial x} = -\frac{1}{C^2}\frac{\partial E}{\partial t}$$

$$\& \ \frac{E}{B} = C$$

(A) $E_{\text{at } x = 0} \begin{cases} 10^{11} t \\ -5 \times 10^{10} t + 150 \end{cases}$

$$\Rightarrow \quad E = \begin{cases} 10^{11}(t - \alpha x) \\ 150 - 5 \times 10^{10}(t - \alpha x) \end{cases}$$

$$B = \frac{E}{c} = \begin{cases} \dfrac{10^{11}}{c}(t - \alpha x) \\ \dfrac{150 - 5\times 10^{10}(t - \alpha x)}{c} \end{cases}$$

$t - \alpha x = \text{cont.} \Rightarrow 1 - \alpha C = 0 \ \therefore \ \alpha = \dfrac{1}{c}$

(B) At $x = 3 \times 10^9\ m$

$$E = \begin{cases} 10^{11}\left(t - \dfrac{3\times 10^9}{3\times 10^8}\right) = 10^{11}(t - 10) \\ 150 - 5 \times 10^{10}\left(t - \dfrac{3\times 10^9}{3\times 10^8}\right) = 150 - 5 \times 10^{10}(t - 10) \end{cases}$$

(C) At $t = 3ns$

$$E = \begin{cases} 10^{11}\left(3 \times 10^{-9} - \dfrac{x}{3\times 10^8}\right) = 300 - \dfrac{1000x}{3} \\ 150 - 5 \times 10^{10}\left[3 \times 10^{-9} - \dfrac{x}{3\times 10^8}\right] = \dfrac{500x}{3} \end{cases}$$

4. Ans. (ABC)

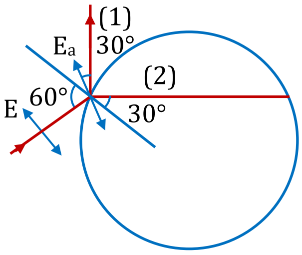
(A) $E = \rho J = 1.61 \times 10^{-8} \times \frac{100}{5 \times 10^{-6}} = 0.324\ V/m$

(B) $I_d = \varepsilon_0 \frac{d\phi_E}{dt} = \varepsilon_0 A \frac{dE}{dt} = \varepsilon_0 A \frac{d(\rho J)}{dt} = \varepsilon_0 \rho \frac{di}{dt} = 2.87 \times 10^{-16}\ A.$

(C) $B \propto I \Rightarrow \frac{B_d}{B_I} = \frac{I_d}{I} = \frac{2.87 \times 10^{-16}}{100} = 2.87 \times 10^{-18}$

5. Ans. (ABCD)

After refraction, E_a rotates by 30°.



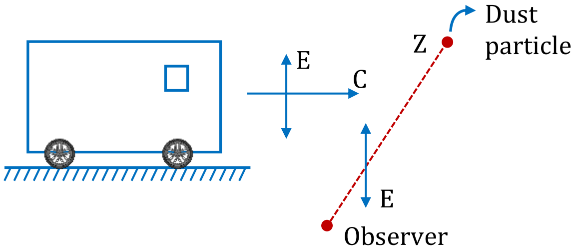
∴ Its component becomes along the reflected light '1'.

∴ Ray 1 is completely polarized.

⇒ Ray 2 is partially polarized.

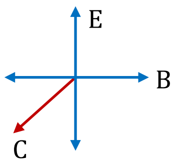
Similar argument applies on ray 4 and 3.

6. Ans. (BC)



Also; for the observer

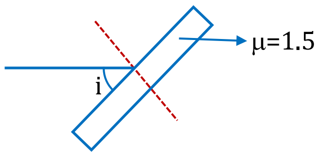
∴ B has to be horizontal



7. Ans. (ABC)

tan (90° – i) = μ = 1.5

∴ $\tan i = \frac{2}{3}$



8. Ans. (AC)

Shift: $\Delta y = \frac{D}{d}(\mu - 1)t$

Shift is towards A

9. Ans. (AD)

$\vec{B} = \frac{E}{C}\hat{k}\sin(\pi x - 3\pi \times 10^8 t) = 10^{-5} T\hat{k}(\sin(\pi x - \omega t))$

$\phi = \int B dA = 2\int_1^2 B dx$

$= 2 \times 10^{-5}\left[\int_1^2 \sin(\pi x - \omega t)\,dx\right]$

$= 2 \times 10^{-5}\left[-\cos\frac{(\pi x - \omega t)|_1^2}{\pi}\right] = \frac{-2 \times 10^{-5}}{\pi}[2\cos\omega t] = -\frac{4}{\pi} \times 10^{-5}\cos\omega t$

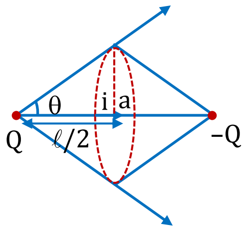
$e = \frac{d\phi}{dt} = -\frac{4}{\pi} \times 10^{-5} \times 3\pi \times 10^8 \sin\omega t = -12000\sin\omega t$

10. **Ans. (AC)**

$\phi_E = \frac{Q}{2\epsilon_0}(1-\cos\theta)\times 2$

$\epsilon_0 \frac{d\phi_E}{dt} = i_d$

$i_d = \frac{dQ}{dt}(1-\cos\theta)$



Since Q is decreasing $= i(1-\cos\theta)$

i_d is to left.

$\oint \vec{B}.d\vec{\ell} = \mu_0(i + i_d) = \mu_0[i - i(1-\cos\theta)]$

$B \times 2\pi a = \mu_0 i \cos\theta$

$= \mu_0 i \times \frac{\ell/2}{\sqrt{a^2+\frac{\ell^2}{4}}}$

$B = \frac{\mu_0 i\ell}{4\pi a\sqrt{a^2+\frac{\ell^2}{4}}}$

11. **Ans. (BC)**

$F = -QE_0\,\hat{i}\sin\omega t = m\frac{dv}{dt}$

$v = -\frac{QE_0}{m\omega}\cos\omega t\Big|_0^t$

$= \frac{QE_0}{m\omega_0}(1-\cos\omega t)\hat{j}$

$\vec{B} = \frac{E_0}{c}\hat{k}\sin(kx-\omega t)$

At $x = 0$

$\vec{B} = -\frac{E_0}{c}\hat{k}\sin(\omega t)$

$\vec{F} = Q\vec{v}\times\vec{B} = -\frac{Q^2E_0^2}{m\omega_0 c}\hat{i}\,(\sin\omega t - \sin\omega t\cos\omega t)$

$F_{av} = \frac{Q^2E_0^2}{m\omega_0 C}\;\frac{\cos 2\omega t}{\frac{2\omega}{T}}\Bigg|_0^T = 0$

12. **Ans. (ACD)**

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

At CBF all the wavelengths produces their maxima

For CBF, $\Delta x = nl$

$n = 0$

$\Delta x = 0$

13. **Ans. (ABD)**

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

Angular fringe width: $w = \frac{\beta}{D} = \frac{\lambda}{d}$

14. **Ans. (BD)**

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

Positions of minima : $y_n = \left(n+\frac{1}{2}\right)\frac{D\lambda}{d}$

15. Ans. (D)

$\Delta x_{net} = t(\mu - 1) + d \sin\theta - d\sin\theta = nl$

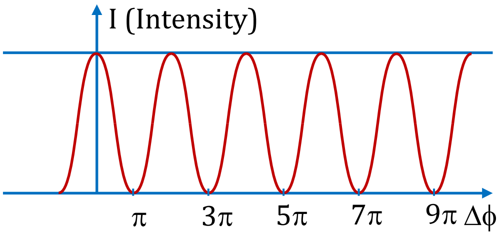
16. Ans. (A)

For *CBF* to be at *O*

$\Delta x_{net} = 0$ and $\theta' = 0$

$d \sin\theta = (\mu - 1)t$

17. Ans. (C)



18. Ans. (A)

(A) Central maxima will shift upward

$$\beta = \frac{D\lambda}{d} = 0.8mm$$

No. of fringes crossing central maxima

$$N = \frac{D/d(\mu-1)t}{D\lambda/d} = \frac{(\mu_1-1)t_1}{\lambda} = 5000$$

$A \rightarrow Q, R, S$

(B) $\Delta x = (\mu_1 - 1)t_1 - (\mu_2 - 1)t_2 = [(2 - 1) \times 2 - (3 - 1) \times 1] \times 10^{-3}$

$\Delta x = 0$

Central maxima at C

$$\beta = \frac{D\lambda}{d} = 0.8mm$$

$B \rightarrow P, R$

(C) $\Delta x = (\mu_1 - 1)t_1 + (\mu_3 - 1)t_3 - (\mu_2 - 1)t_2$

$$= \left(\frac{3}{2} - 1\right) \times 4 \times 10^{-3} = 2 \times 10^{-3}$$

Central maxima above C

$\beta = D\lambda/d = 0.8\ mm$

No. of fringes crossing central maxima

$$N = \frac{(\mu_3-1)t_3}{\lambda} = \frac{0.5\times4\times10^{-3}}{4\times10^{-7}} = 5000$$

19. Ans. (C)

(A) $\Delta x = (\mu_B - 1)t = (2.5 - 1) \times 1.5 \times 10^{-6}$

$\Delta x = 1.5 \times 1.5 \times 10^{-6}$

$\Delta x = 2.25 \times 10^{-6} = \left(n + \frac{1}{2}\right) \times 5 \times 10^{-7}$

$22.5 = (n + 0.5)5$

$4.5 = n + 0.5$

$n = 4$

(B) $\Delta x = (\mu_A - 1)t_A - (\mu_C - 1)t_C$

$= [(1.5 - 1) \times 5 - (2 - 1) \times 0.25] \times 10^{-6}$

$\Delta x = (0.5 \times 5 - 0.25] \times 10^{-6} = 0$

CBF is obtained at *P*

(C) $\Delta x = (\mu_A - 1)t_A - \{(\mu_B - 1)t_B + (\mu_C - 1)t_C\}$

(D) $\Delta x = [(\mu_A - 1)t_A + (\mu_C - 1)t_C] - (\mu_B - 1)t_B$

20. **Ans. (A-P,R,S,T), (B-Q,R,S,T), (C-R), (D-P,R,S,T)**

(A) $S_1P - (S_2P + d\sin\alpha) = n\lambda$

$d\sin\theta - d\sin\alpha = 0$

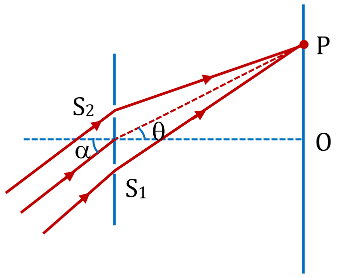
$\theta = \alpha$

After introduction of sheet

$-(\mu - 1)t + d\sin\theta - d\sin\alpha = 0$

when $\theta = 0$, $-(\mu - 1)t = d\sin\alpha$

not possible



* $\beta = \dfrac{D\lambda}{d}$

* $d\sin\theta - d\sin\alpha = (n + \frac{1}{2})\,\lambda$: Minima

* Put $n = 0$ in above equation

$d\sin\theta - d\sin\alpha = \dfrac{\lambda}{2}$: Least order minima

(B) * $S_1P + (\mu_1 - 1)t - [S_2P + (\mu_2 - 1)t] = n\lambda$

$d\sin\theta + (\mu_1 - \mu_2)t = n\lambda$

$n = 0$

$d\sin\theta = -(\mu_1 - \mu_2)t$

zero order max. lies below O

* $d\sin\theta + (\mu' - 1)t' - (\mu_2 - \mu_1)\,t = 0$

for $\theta = 0°$

$(\mu' - 1)t' = (\mu_2 - \mu_1)t$

* $\beta = \dfrac{D\lambda}{d}$

* Point O can be minima

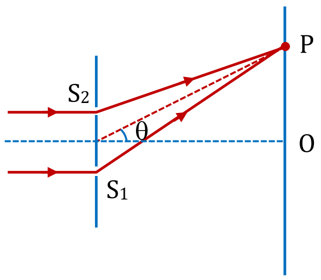
* Point O can be least order minima

(C) * $S_1P - [S_2P + (\mu - 1)t] = n\lambda$

$d\sin\theta - (\mu - 1)t = 0 : CBF$

$\sin\theta = \dfrac{(\mu-1)t}{d} : CBF$

* $\beta = \dfrac{D\lambda}{d}$



(D)