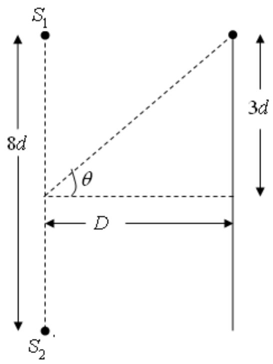
PHYSICS MODULE-17 – Single Choice Solutions
Wave Optics

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

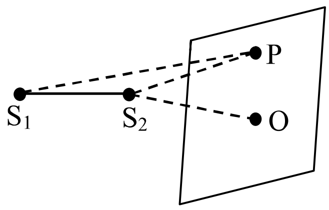
   $\Delta x = t_B - t_A$

2.



3. (C)

   P is a point on screen such that S_1 P–S_2 P=constant, then P locus of P Will be circle with center O.



4. The net path difference is $\left[(d\sin\theta \;\; \pm(\mu-1)t\right]$ depending upon the values of μ, t, θ the central bright fringe lies below or above or at O.

5.

   The path difference $\frac{3\lambda}{2}$ corresponds to a phase difference of 540^0

   Thus total phase difference $= 540 + 180 = 720^0 = 4\pi$

6. $I_{\text{Res}} = I_o \cos^2 \delta/2 \quad I_{\text{Res}} = \frac{3I_o}{4} \Rightarrow \delta = \pi/3 \Rightarrow \Delta x \frac{\lambda}{6} \Rightarrow x = \frac{\Delta x D}{d} = \beta/6$

7. angular fringe width = $\frac{\beta}{D} = \frac{\lambda}{d}$

8. Intensity of slits S_1 & S_2 starts differing.

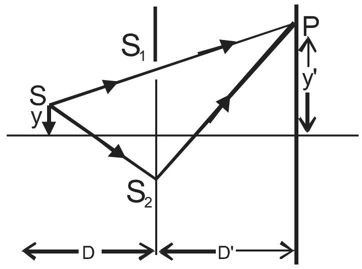
9.

$$S = \frac{D}{d}(\mu - 1)t$$

$$x = \frac{D}{d}(1.5 - 1)t \qquad ---(1)$$

$$\frac{3x}{2} = \frac{D}{d}(\mu - 1)t$$

10. $y' = \frac{d}{2}$ at point P exactly infront of S_1



$\therefore \Delta x = \frac{yd}{D} + \frac{d^2}{2D'}$

For minimum intensity $\therefore \Delta x = (2n-1)\frac{\lambda}{2}\ (n=1)$

Putting the value we get

$(0.5\sin\pi t)\times 10^{-6} + 0.25\times 10^{-6} = \frac{500}{2}\times 10^{-9} \qquad 0.5\sin\pi t + 0.25 = \frac{0.5}{2}$

$\sin\pi t = 0 \Rightarrow \pi t = 0, \pi, 2\pi, \ldots\ldots \Rightarrow t = 1s$

11. Let I = 100
Intensity of light after reflecting from 1st plate

$I_1 = 25$

Amplitude $A_1 = \sqrt{I_1} = 5\,units$

After reflecting from 2nd surface intensity $= \frac{75\times 25}{100} = \frac{75}{4}$

75% of this light pass through 1 after reflection .

$\therefore I_2 = \frac{75}{4}\times\frac{75}{100} = \frac{225}{16}$

$A_2 = \sqrt{\frac{225}{16}} = \frac{15}{4} = 3.75$

$\frac{I_{max}}{I_{min}} = \left(\frac{5+3.75}{5-3.75}\right)^2 = 49:1$

12. $\Delta x = m\lambda$ and m can be equal to 0,1,2,3,4, as maximum path difference is 4λ. m=0 is for central maximum on one side of AB. There are two maxima for all other values of m on both side of central maxima making total number 9 in one half circle. m=4 maxima overlapping for both sides.

13. Path difference $\Delta = d\sin\theta = \frac{\lambda}{4}\sin\theta$

Phase difference $\phi = \frac{2\pi}{\lambda}\Delta = \frac{2\pi}{\lambda}\times\frac{\lambda}{4}\sin\theta = \frac{\pi}{2}\sin\theta$

$I_\theta = I_1 + I_2 + 2\sqrt{I_1 I_2 \cos\phi} = I_0 + I_0 + 2\sqrt{I_0 . I_0}\ \cos\left(\frac{\pi}{2}\sin\theta\right)$

$= 2I_0 + 2I_0\cos\left(\frac{\pi}{2}\sin\theta\right) = 2I_0\left[1+\cos\left(\frac{\pi}{2}\sin\theta\right)\right] = 2I_0\times 2\cos^2\left(\frac{\pi}{4}\sin\theta\right) = 4I_\theta^2\cos^2\left(\frac{\pi}{4}\sin\theta\right)$

14. $\Delta y = \frac{\beta}{\lambda}(\mu-1)t$

$\Rightarrow 30\beta = \frac{\beta}{\lambda}(\mu-1)t$

$\Rightarrow t = \frac{30\lambda}{\mu-1} = \frac{30\times 4800\times 10^{-10}}{(1.6-1)} = 24\times 10^{-6}\,\text{m.}$

15. $PN = d, PO = d\sec\theta$

$CO = PO\cos 2\theta = d\sec\theta\cos 2\theta$

Path difference $= CO + PO = d\sec\theta + d\sec\theta\cos 2\theta$

$= d\sec\theta(1+\cos 2\theta) = \dfrac{d}{\cos\theta}\times 2\cos^2\theta = 2d\cos\theta.$

The ray AO is incident on denser medium, so reflected ray suffers a phase difference of π or a path differences of $\dfrac{\lambda}{2}$

$\therefore$ Effective path difference $\Delta = 2d\cos\theta + \dfrac{\lambda}{2}$

For constructive interference path difference $\Delta = n\lambda.$

$\Rightarrow \quad 2d\cos\theta + \dfrac{\lambda}{2} = n\lambda$ or $2d\cos\theta = (2n-1)\dfrac{\lambda}{2}$

16. $$R = \frac{I_{max}-I_{min}}{I_{max}+I_{min}} = \frac{(a_1+a_2)^2-(a_1-a_2)^2}{(a_1+a_2)^2+(a_1-a_2)^2} = \frac{4a_1a_2}{2(a_1^2+a_2^2)} = \frac{2a_1a_2}{a_1^2+a_2^2} = \frac{2\left(\frac{a_2}{a_1}\right)}{1+\left(\frac{a_2}{a_1}\right)^2}$$

Given $\left(\dfrac{a_2}{a_1}\right)^2 = \alpha$

$\therefore\ R = \dfrac{2\sqrt{\alpha}}{1+\alpha}.$

17. (C)

There can be three minima from central point to ∞ corresponding to $\dfrac{\lambda}{2}, \dfrac{3\lambda}{2}, \dfrac{5\lambda}{2}$

Path differences.

$\therefore total\ number of\ \min ima = 2n_{\max} = 6$

18. $PN = d, PO = d\sec\theta$

$CO = PO\cos 2\theta = d\sec\theta\cos 2\theta$

Path difference $= CO + PO = d\sec\theta + d\sec\theta\cos 2\theta$

$= d\sec\theta(1+\cos 2\theta) = \dfrac{d}{\cos\theta}\times 2\cos^2\theta = 2d\cos\theta.$

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$\Rightarrow \quad 2d\cos\theta + \dfrac{\lambda}{2} = n\lambda$ or $2d\cos\theta = (2n-1)\dfrac{\lambda}{2}$

19. Path difference at the both the points is zero, but since 2nd point is farther than 1st point, $I_2 < I_1$

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

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

$\Rightarrow \quad \sin\phi + \sin\theta = \dfrac{m\lambda}{d}$

PHYSICS MODULE-17 – Multiple Choice Solutions

Wave Optics

1. $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 \quad I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$

   $I_1 \neq I_2$

2. ABC

   A) All the wavelengths will have 0 phase diff. at central point and thus would be a bright white fringe.

   B) After first order fringes, different wavelength maxima and minima overlap and thus clear fringes are only observed in first order.

   C) Since, fringe width W = $\frac{\lambda D}{d}$. And, d of violet is less than red, thus first order violet fringes are closed.

3. Position of minima

   $$y_n = \left(n - \frac{1}{2}\right)\frac{D\lambda}{d}$$

   Here $D \to d$ and $d \to b$, $y_n = \frac{b}{2}$

   $$\therefore \quad \frac{b}{2} = \left(n - \frac{1}{2}\right)\frac{d\lambda}{b}$$

   $$\Rightarrow \quad \lambda = \frac{b^2}{(2n-1)d}, n = 1, 2, 3, ...$$

   $$\therefore \quad \lambda = \frac{b^2}{d}, \frac{b^2}{3d}, \frac{b^2}{5d}, ...$$

   i.e., alternatives (a) and (c) are correct.

4. For microwaves $\lambda = \frac{c}{f} = \frac{3 \times 10^8}{10^6} = 300\text{ m}.$

   Path difference $\delta = d\sin\theta$

   $$\therefore \quad \text{Phase difference } \delta = \frac{2\pi}{\lambda}\Delta = \frac{2\pi}{\lambda}(d\sin\theta) = \frac{2\pi}{300}(150\sin\theta) = \pi\sin\theta$$

   Intensity $\quad I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\delta$

   when $\quad I_1 = I_2, \delta = \pi\sin\theta$

   $$I = 2I_1(1 + \cos(\pi\sin\theta)) = 4I_1\cos^2\left(\frac{\pi\sin\theta}{2}\right)$$

   I will be maximum when $\cos^2\left(\frac{\pi\sin\theta}{2}\right)$ is maximum = 1.

   $\therefore I_{max} = 4I_1 = I_0$ (given)

So $I = I_0 \cos^2\left(\frac{\pi \sin\theta}{2}\right)$

(a) when $\theta = 0, I = I_0 \sin^2 0 = I_0$

(b) when $\theta = 30°, I = I_0 \cos^2\left(\frac{\pi \sin 30°}{2}\right) = I_0 \cos^2 \frac{\pi}{4} = \frac{I_0}{2}.$

(c) when $\theta = 90°, I = I_0 \cos^2\left(\frac{\pi \sin 90°}{2}\right) = I_0 \cos^2 \frac{\pi}{2} = 0.$

i.e, (a) and (c) are correct.

5. (a,b,c,d)

For maxima d = $n\lambda$

For minima d = $(n+1/2)\lambda$

For intensity $\frac{3}{4}th$ of maximum d = $\left(n \pm \frac{1}{3}\right)\frac{\lambda}{2}$

$At\ \Delta x = 11\frac{\lambda}{6}$

$\delta = \frac{2\pi}{\lambda} \times \frac{11\lambda}{6} = \frac{11\pi}{3}$

$I = I_{max} \cos^2\left(\frac{\delta}{2}\right) = \frac{3I_{max}}{4}$

6. AC

(A) For coherent sources, central maxima would be same (at the center)

(C) For bright fringes of the 2 wavelength to coincide

$n_1 d_1 = n_2 d_2$

$n_1(4500) = n_2(6000)$

$n_1 = 4$ and $n_3 = 3$

7. (a) the maximum path difference will be less than λ for $d = \lambda$. Thus, only maximum will be observed.

(b) for $\lambda < d < 2\lambda$, maximum path difference will be less than 2λ thus, 3 maximum will be observed

(c) Initially $I_1 = 4I_0\ and\ I_2 = I_0$

So, $I_{max} = 9I_0 ; I_{min} = I_0$

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

For maximum intensity cos $(\Delta\phi) = 1$

Minimum intensity cos $(\Delta\phi) = -1$

$I_1' = I_0 \ and \ I_2' = I_0 \ (given)$

So, $Thus, I'_{max} = 4I_0 \ and \ I'_{min} = 0 \ (decreases)$

$(d) \quad I_1' = 4I_0 \ and \ I_2' = 4I_0 \ (given)$

$so, I'_{max} = 16I_0 \ and \ I'_{min} = 0$

8. order of maxima are 3,2,1,0,1,2,3

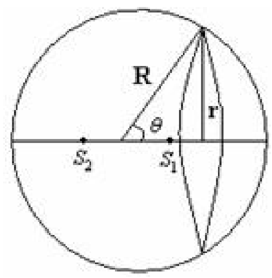
Along x-axis : $\left(\frac{d}{2}+x\right)-\left(\frac{d}{2}-x\right)=n\lambda$

$2x = n\lambda$

$x_1 = \frac{\lambda}{2} \ x_2 = \frac{2\lambda}{2} \ x_3 = \frac{3\lambda}{3}$

hence $x_2 - x_1 = x_3 - x_2$ also

$$d\cos\theta = n\lambda$$
$$3\lambda\cos\theta = 2\lambda$$
$$\cos\theta = \frac{2}{3}$$
$$\sin\theta = \frac{\sqrt{5}}{3}$$



$r = R\sin\theta$

$r = \frac{R\sqrt{5}}{3}$

9. a) fringes come closer

b) fringe width decreases in the ratio $5/7$.

d) seventh bright fringe due to blue light take the position of fifth bright fringe due to red light.

Fringe width, W = $\frac{\lambda D}{d}$

If red light is replaced by blue light, d is reduced.

$\therefore$ fringe width decreases and fringes would come closer.

$W_1 = \frac{7000D}{d}$ and $W_2 = \frac{5000D}{d}$

$\Rightarrow$ fringe width decreases in the ratio 5/7 And since $5(d_{red}) = 7(d_{blue})$
7^{th} blue fringe takes place of 5^{th} red fringe.

10.
Decreased the, $\beta = \frac{\lambda D}{d}$ also decreases
Then consecutive fringes will come close
When fringe width (β) is decreased, the number of maxima on te screedn increases

PHYSICS MODULE-17 – Matrix Match Type Solutions

Wave Optics

1. We know, fringe width, w = $\frac{\lambda D}{d}$

Angular fringe width, tanθ = $\frac{\lambda}{d}$

A) If D is decreased – fringe width decreases and position of central maxima remains unchanged until there is path difference between slits.
B) If the source is moved towards slit, λ, D and d remains unchanged, thus angular fringe width and fringe width remains unchanged and position of central maxima also remains unchanged.
C) If d is decreased, fringe width increases and $\left(w \propto \frac{1}{d}\right)$ position of central maxima remains unchanged.
D) If the apparatus is immersed in liquid, λ decreases and thus, fringe width and angular fringe width is decreased.

2. $(\mu-1)t = n\lambda$

Path difference due to a strip of thickness 't' and refractive index μ is
Δx = (μ – 1)t

A) Strip B is placed over slit 1 – the central bright fringe shift down.
Path difference Δx = (2.5 – 1)(1.5)10^{-6} m
= 2.25 × 10^{-6} m.
Δx is a multiple of λ/2 the point P is dark fringe.
$$2.25\times10^{-6} = (2n-1)\frac{\lambda}{2} = (2n-1)\left(\frac{500\times10^{-9}}{2}\right)$$
∵ n = 5 ⇒ P if fifth dark fringe

B) Path difference, Δx = {(5 – 1) (5) – (2 – 1) (0.25)} × 10^{-6}
= 2.25 × 10^{-6}
∵ Δx is a multiple of λ/2 the point P is dark fringe.
$$2.25\times10^{-6} = (2n-1)\left(\frac{500\times10^{-9}}{2}\right)$$
⇒ n = 5 ⇒ P if fifth dark fringe

C) Path difference Δx = (1.5 – 1)(5) – (2.5 – 1)(1.5) – (2 – 1)(0.25)
= 0
∵ There is no path difference, point P is central bright fringe.

D) Path difference, Δx = {(1.5 – 1)(5) + (2 – 1)(0.25) – (2.5 – 1) (1.5)} × 10^{-6} m
= (2.5 + 0.25 – 2.25)10^{-6} m
= 0.5 × 10^{-6} m
∵ Δx is a multiple of λ, it is a bright fringe
0.5 × 10–6 = nλ = n(500.10^{-9})
⇒ n = 1 ⇒ P is first bright fringe

3. Fringe width $w = \frac{D\lambda}{d}$

A) If d is doubled, w is halved.

B) If green light is replaced by yellow light, d is increased, thus w is increased.

C) If D is doubled, w is doubled.

D) If one slit is closed, there is no interference and hence fringes disappear.

PHYSICS MODULE-17 – Passage Type Solutions
Wave Optics

1. (a)

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

At S_4, $\frac{\Delta x}{d} = \frac{z}{D}$

$\Rightarrow \quad \Delta x = \frac{\lambda D}{2d}\frac{d}{D} = \frac{\lambda}{2}$

Hence, minima at S_4 and maxima at S_3 (intensity $4I_o$).

Hence, $\frac{I_{max}}{I_{min}} = 1$

2. (c)

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

Δx at S_4; $\Delta x = \frac{\lambda D}{d}\frac{d}{D} = \lambda$

Hence, maxima at S_4 as well as S_3.

Resultant intensity at S_4, $I = 4I_o$

$\therefore \quad \frac{I_{max}}{I_{min}} = \frac{\left[(4I_o)^{1/2} + (4I_o)^{1/2}\right]^2}{\left[(4I_o)^{1/2} - (4I_o)^{1/2}\right]^2} = \infty$

3. (d)

$z = \frac{\lambda D}{4d}$

$\Delta x = y\frac{d}{D} = \frac{\lambda D}{4d}\frac{d}{D} = \frac{\lambda}{4}$

$\phi = \frac{2\pi}{\lambda}\left(\frac{\lambda}{4}\right) = \frac{\pi}{4}$

Intensity at S_4; $I_4 = 2I_o\left(I + \cos\frac{\pi}{2}\right) = 2I_o$

Intensity at S_3; $I_3 = 4I_o$

$\therefore \quad \frac{I_{max}}{I_{min}} = \frac{\left[(4I_o)^{1/2} + (2I_o)^{1/2}\right]^2}{\left[(4I_o)^{1/2} - (2I_o)^{1/2}\right]^2} = \left[3 + 2\sqrt{2}\right]^2$

4. For point P path difference is $\Delta x = \mu_2 d\sin\theta + (\mu_1 - 1)t$, where $\sin\theta = \frac{d/2}{D}$

Phase difference is $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$ and intensity is $I = I_0 + I_0 + 2I_0\cos(\Delta\phi)$

5. Path difference is $\Delta x - \mu_2 d\sin\theta + (\mu_1 - 1)t$, where $\sin\theta = \frac{9d/8}{D}$

6. For point R path difference is $\Delta x = \mu_2 d\sin\theta + (\mu_1 - 1)t$, where $\sin\theta = \frac{3d}{D}$

On substituting all values we will get $\Delta x = \frac{5d^2}{D} = \lambda$

7. 8. 9.

$$\mu_l (S_1P)_{air} = (S_1P - t)_{air}\, \mu_l + \mu_s t$$

$$(s_1p - s_2p)_{air} = \frac{yd}{D}$$

$$y = \frac{tD}{d}\left(\frac{\mu_q}{\mu_l} - 1\right)$$

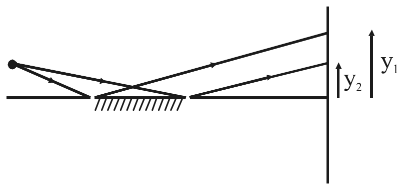
$$y = \frac{tD}{d}\left(\frac{T-4}{10-T}\right)$$

$$y(T=0) = -\frac{2}{5}\left(\frac{Dt}{d}\right)$$

Velocity v $= \dfrac{dy}{dt} = \dfrac{Dt}{d}\dfrac{6}{(10-T)^2}$

Y=0 at T= 4sec

10. (B) $\dfrac{y_1}{195\text{cm}} = \dfrac{1\text{mm}}{5\text{cm}}$



$y_1 = 39$ mm

$\dfrac{y_2}{190\text{cm}} = \dfrac{1\text{mm}}{10\text{cm}}$

y_2 = 19 mm

width = 20 mm = 2 cm.

11. (B)

Fringe width $= \dfrac{\lambda D}{d} = \dfrac{5\times10^{-7}\times 2}{2\times10^{-3}}$

$= 5\times10^{-4}$ m

Number of fringes $= \dfrac{2\times10^{-2}}{5\times10^{-4}} = 40$

12. (B) $(\mu-1)t\dfrac{D}{d} = y_2$

$(1.5-1)t\dfrac{2}{2\times10^{-3}} = 19\times10^{-3}$

t = 38 × 10^{-6} m

t = 38 μm.

PHYSICS MODULE-17 –INTEGER TYPE Questions
Wave Optics

1. Actual path difference for ray four S_1 and S_3 is

$$\Delta x_1 = 2(S_1P - S_3P) = \frac{4d}{3} \Rightarrow \text{phase difference}, \phi_1 = \frac{4\lambda}{3} \times \frac{2\pi}{\lambda} = \frac{8\pi}{3}$$

And, for ray four S_1 and S_2 is

$$\Delta x_2 = 2(S_1P - S_3P) = \frac{\lambda}{3}$$

$\Rightarrow$ Path difference for ray from S_2 and S_3 is

$\Delta x_3 = 2(S_1P - S_2P) - 2(S_1P - S_2P)\ \lambda \Rightarrow$ phase difference $= 2\pi$

$\Rightarrow$ Resultant, $E_{res} = \sqrt{4E^2 + E^2 + 2E(2E)\cos\left(8\pi/3\right)} = \sqrt{3}E$

We know, intensity $I \propto E^2$

$\therefore$ New intensity, $I' \propto 3E^2$

$\therefore$ $I' = 3I$

2. $$= \Delta x = \frac{5\lambda/2(5\lambda)}{10\lambda} = \frac{5\lambda}{4}$$

$$i.e\, \Delta\Phi = \frac{\pi}{2}$$

$$I = I_0 C\theta \frac{1}{2} = I_{0/2}$$

3. 3

Angular width = $\lambda/d = 10^{-3}$ (given)

Number of fringes within 0.12^o will be n = $\frac{0.12 \times \pi}{360 \times 10^{-3}} \cong [2.09]$

The number of bright spots will be three.

4. $$\left(\frac{\mu_1}{\mu_0} - 1\right)t_1 = \left(\frac{\mu_2}{\mu_0} - 1\right)t_2$$

5.

$$I^{|} = I + I + 2\sqrt{I^2}\cos\theta$$

$$\frac{3}{4}(4I) = 2I[1 + \cos\theta]$$

$$3 = 4\cos^2\frac{\theta}{2}$$

$$\cos^2\frac{\theta}{2} = \frac{3}{4} \ or\ \cos\frac{\theta}{2} = \frac{\sqrt{3}}{2}$$

$\therefore \ \frac{\theta}{2} = \frac{\pi}{6}$

$\therefore \theta = \frac{\pi}{3}$

$\frac{0.12 \times \pi}{360 \times 10^{-3}} \cong [2.09]$

$E_{\mathbf{res}} = \sqrt{4E^2 + E^2 + 2E(2E)\cos\left(8\pi/3\right)} = \sqrt{3}E$