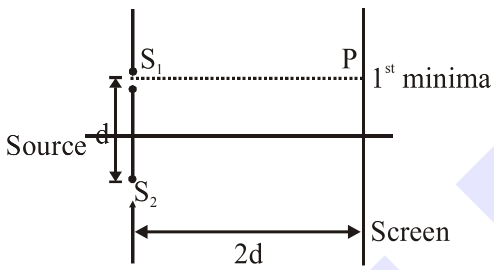
WAVE OPTICS

1. In a Young's double slit experiment, the slits are placed 0.320 mm apart. Light of wavelength $\lambda = 500$ nm is incident on the slits. The total number of bright fringes that are observed in the angular range $-30° \le \theta \le 30°$ is:

(1) 320 (2) 641

(3) 321 (4) 640

2. Consider a Young's double slit experiment as shown in figure. What should be the slit separation d in terms of wavelength λ such that the first minima occurs directly in front of the slit (S_1) ?



(1) $\frac{\lambda}{2(5-\sqrt{2})}$ (2) $\frac{\lambda}{(5-\sqrt{2})}$

(3) $\frac{\lambda}{(\sqrt{5}-2)}$ (4) $\frac{\lambda}{2(\sqrt{5}-2)}$

3. In a Young's double slit experiment with slit separation 0.1 mm, one observes a bright fringe at angle $\frac{1}{40}$ rad by using light of wavelength λ_1. When the light of wavelength λ_2 is used a bright fringe is seen at the same angle in the same set up. Given that λ_1 and λ_2 are in visible range (380 nm to 740 nm), their values are :

(1) 380 nm, 500 nm (2) 625 nm, 500 nm

(3) 380 nm, 525 nm (4) 400 nm, 500 nm

4. In a double-slit experiment, green light (5303 Å) falls on a double slit having a separation of 19.44 μm and a width of 4.05 μm. The number of bright fringes between the first and the second diffraction minima is :-

(1) 09 (2) 10 (3) 04 (4) 05

5. In a Young's double slit experiment, the path different, at a certain point on the screen, between two interfering waves is $\frac{1}{8}$th of wavelength. The ratio of the intensity at this point to that at the centre of a brigth fringe is close to :

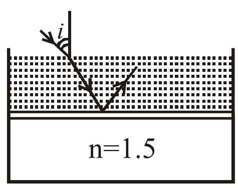
(1) 0.94 (2) 0.74 (3) 0.85 (4) 0.80

6. A light wave is incident normally on a glass slab of refractive index 1.5. If 4% of light gets reflected and the amplitude of the electric field of the incident light is 30V/m, then the amplitude of the electric field for the wave propogating in the glass medium will be:

(1) 10 V/m (2) 24 V/m

(3) 30 V/m (4) 6 V/m

7. Consider a tank made of glass(reiractive index 1.5) with a thick bottom. It is filled with a liquid of refractive index μ,. A student finds that, irrespective of what the incident angle *i* (see figure) is for a beam of light entering the liquid, the light reflected from the liquid glass interface is never completely polarized. For this to happen, the minimum value of μ is :



(1) $\frac{3}{\sqrt{5}}$ (2) $\frac{5}{\sqrt{3}}$ (3) $\sqrt{\frac{5}{3}}$ (4) $\frac{4}{3}$

8. Young's moduli of two wires A and B are in the ratio 7 : 4. Wire A is 2 m long and has radius R. Wire B is 1.5 m long and has radius 2 mm. If the two wires stretch by the same length for a given load, then the value of R is close to :-

(1) 1.9 mm (2) 1.7 mm
(3) 1.5 mm (4) 1.3 mm

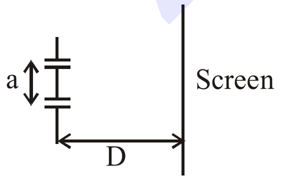
9. In an interference experiment the ratio of amplitudes of coherent waves is $\frac{a_1}{a_2}=\frac{1}{3}$. The ratio of maximum and minimum intensities of fringes will be :

(1) 4 (2) 2 (3) 9 (4) 18

10. Two cars A and B are moving away from each other in opposite directions. Both the cars are moving with a speed of 20 ms^{-1} with respect to the ground. If an observer in car A detects a frequency 2000 Hz of the sound coming from car B, what is the natural frequency of the sound source in car B ? (speed of sound in air = 340 ms^{-1}) :-

(1) 2250 Hz (2) 2060 Hz
(3) 2150 Hz (4) 2300 Hz

11. The figure shows a Young's double slit experimental setup. It is observed that when a thin transparent sheet of thickness t and refractive index μ is put in front of one of the slits, the central maximum gest shifted by a distance equal to n fringe widths. If the wavelength of light used is λ, t will be :



(1) $\frac{2D\lambda}{a(\mu-1)}$ (2) $\frac{D\lambda}{a(\mu-1)}$

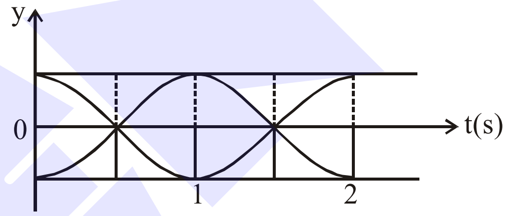
(3) $\frac{2nD\lambda}{a(\mu-1)}$ (4) $\frac{nD\lambda}{a(\mu-1)}$

12. In a Young's doubble slit experiment, the ratio of the slit's width is 4 : 1. The ratio of the intensity of maxima to minima, close to the central fringe on the screen, will be :

(1) $(\sqrt{3}+1)^4 : 16$ (2) 9 : 1

(3) 4 : 1 (4) 25 : 9

13. The correct figure that shows, schematically, the wave pattern produced by superposition of two waves of frequencies 9 Hz and 11 Hz is :

(1)


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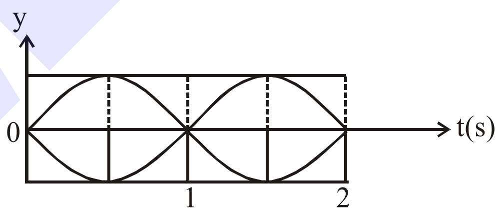
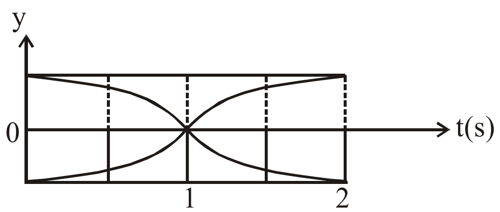
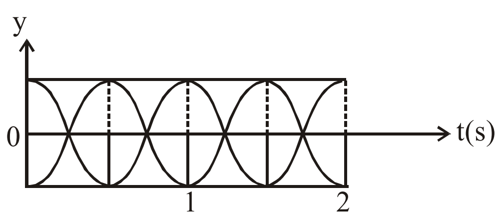


(3)


(4)


14. A system of three polarizers P_1, P_2, P_3 is set up such that the pass axis of P_3 is crossed with respect to that of P_1. The pass axis of P_2 is inclined at 60° to the pass axis of P_3. When a beam of unpolarized light of intensity I_0 is incident on P_1, the intensity of light transmitted by the three polarizers is I. The ratio (I_0/I) equals (nearly) :

(1) 16.00 (2) 1.80

(3) 5.33 (4) 10.67

15. In a double slit experiment, when a thin film of thickness t having refractive index μ is introduced in front of one of the slits, the maximum at the centre of the fringe pattern shifts by one fringe width. The value of t is (λ is the wavelength of the light used) :

(1) $\frac{\lambda}{2(\mu-1)}$ (2) $\frac{\lambda}{(2\mu-1)}$

(3) $\frac{2\lambda}{(\mu-1)}$ (4) $\frac{\lambda}{(\mu-1)}$

16. Calculate the limit of resolution of a telescope objective having a diameter of 200 cm, if it has to detect light of wavelength 500 nm coming from a star :-

(1) 305×10^{-9} radian

(2) 152.5×10^{-9} radian

(3) 610×10^{-9} radian

(4) 457.5×10^{-9} radian

17. Diameter of the objective lens of a telescope is 250 cm. For light of wavelength 600nm. coming from a distant object, the limit of resolution of the telescope is close to :-

(1) 1.5×10^{-7} rad (2) 2.0×10^{-7} rad

(3) 3.0×10^{-7} rad (4) 4.5×10^{-7} rad

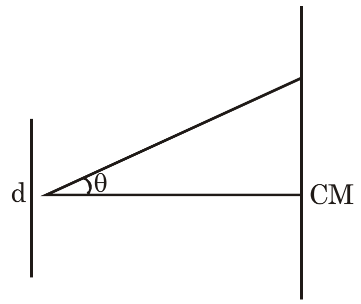
18. The value of numerical aperature of the objective lens of a microscope is 1.25. If light of wavelength 5000 Å is used, the minimum separation between two points, to be seen as distinct, will be :

(1) 0.24 μm (2) 0.48 μm

(3) 0.12 μm (4) 0.38 μm

SOLUTION

1. Ans. (2)



Pam difference

$d\sin\theta = n\lambda$

where d = seperation of slits

λ = wave length

n = no. of maximas

$0.32 \times 10^{-3} \sin 30 = n \times 500 \times 10^{-9}$

n = 320

Hence total no. of maximas observed in angular range $-30° \le \theta \le 30°$ is

maximas = 320 + 1 + 320 = 641

2. Ans. (4)

$$\sqrt{5}d - 2d = \frac{\lambda}{2}$$

3. Ans. (2)

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

$$= 0.1 \times \frac{1}{40}\text{ mm} = 2500\text{nm}$$

or bright fringe, path difference must be integral multiple of λ.

$\therefore$ $2500 = n\lambda_1 = m\lambda_2$

$\therefore$ $\lambda_1 = 625$, $\lambda_2 = 500$ (from m=5)

(for n = 4)

4. Ans. (4)

According to JEE-Mains Ans. key (3)

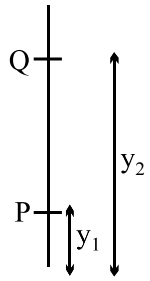
For diffraction

location of 1st minime

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

location of 2nd minima

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



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 & Q is

5, 6, 7, 8, 9

So 5 bright fringes all present between P & Q.

5. Ans. (3)

$$\Delta x = \frac{\lambda}{8}$$

$$\Delta\phi = \frac{(2\pi)}{\lambda}\frac{\lambda}{8} = \frac{\pi}{4}$$

$$I = I_0 \cos^2\left(\frac{\pi}{8}\right)$$

$$\frac{I}{I_0} = \cos^2\left(\frac{\pi}{8}\right)$$

6. Ans. (2)

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

$$\Rightarrow K_2 A_t^2 = \frac{96}{100}K_1 A_i^2$$

$$\Rightarrow r_2 A_t^2 = \frac{96}{100}r_1 A_i^2$$

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

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

7. Ans. (1)

$C < i_b$

here i_b is "brewester angle" and c is critical angle

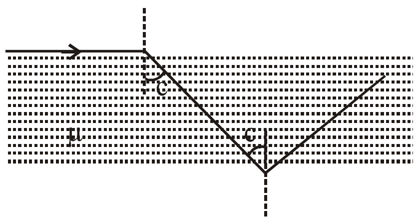
$\sin_c < \sin i_b$ since $\tan i_b = \mu_{0_{rel}} = \frac{1.5}{\mu}$

$\frac{1}{\mu} < \frac{1.5}{\sqrt{\mu^2 + (1.5)^2}}$ $\therefore \sin i_b = \frac{1.5}{\sqrt{\mu^2 + (1.5)^2}}$

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

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

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



slab $\mu = 1.5$

8. Ans. (2)

Sol. Given

$\frac{Y_A}{Y_B} = \frac{7}{4}$ $L_A = 2m$ $A_A = \pi R^2$

$L_B = 1.5m$ $A_B = \pi(2mm)^2$

$\frac{F}{A} = Y\left(\frac{\ell}{L}\right)$

given F and ℓ are same $\Rightarrow \frac{AY}{L}$ is same

$\frac{A_A Y_A}{L_A} = \frac{A_B Y_B}{L_B}$

$\Rightarrow \frac{(\pi R^2)\left(\frac{7}{4}Y_B\right)}{2} = \frac{\pi(2mm)^2 . Y_B}{1.5}$

$R = 1.74$ mm

9. Ans. (1)

Sol. Given $\frac{a_1}{a_2} = \frac{1}{3}$

Ratio of intensities, $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{1}{9}$

Now, $\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 = \left(\frac{1+3}{1-3}\right)^2 = 4$

10. Ans. (1)

Sol. 20m/s f ←• A(observer) f_0 20m/s •→ B(source)

Applying Doppler effect for sound

$f = \frac{v + v_0}{v - v_s} f_0$ (v_0 & v_s is taken ⊕ when approaching each other)

$2000 = \frac{340 + (-20)}{340 - (-20)} f_0$

$f_0 = 2250$ Hz.

11. Allen Answer (Bonus)

Final Ans. by NTA (4)

Sol. Path difference at central maxima $\Delta x = (\mu - 1)t$, whole pattern will shift by same amount which will be given by

$(\mu - 1)t \frac{D}{d} = n\frac{\lambda D}{d}$, according to the question

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

no option is matching, therefore question should be awarded bonus.

$\therefore$ Correct Option should be (Bonus)

12. Ans. (2)

Sol. $I_1 = 4I_0$

$I_2 = I_0$

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

$= (2\sqrt{I_0} + \sqrt{I_0})^2 = 9I_0$

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

$= (2\sqrt{I_0} - \sqrt{I_0})^2 = I_0$

$\therefore \frac{I_{max}}{I_{min}} = \frac{9}{1}$

13. Ans. (4)

Sol. $f_{beat} = 11 - 9 = 2$ Hz

$\therefore$ Time period of oscillation of amplitude

$$= \frac{1}{f_{beat}} = \frac{1}{2}\text{Hz}$$

Although the graph of oscillation is not given, the equation of envelope is given by option (4)

14. Ans. (4)

Sol. Since unpolarised light falls on $P_1 \Rightarrow$ intensity of light transmitted from $P_1 = \frac{I_0}{2}$

Pass axis of P_2 will be at an angle of 30° with P_1

$\therefore$ Intensity of light transmitted from

$$P_2 = \frac{I_0}{2}\cos^2 30° = \frac{3I_0}{8}$$

Pass axis of P_3 is at an angle of 60° with P_2

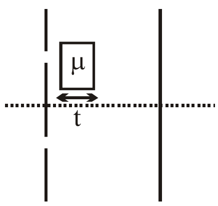
$\therefore$ Intensity of light transmitted from

$$P_3 = \frac{3I_0}{8}\cos^2 60° = \frac{3I_0}{32}$$

$$\therefore \left(\frac{I_0}{I}\right) = \frac{32}{3} = 10.67$$

15. Ans. (4)

Sol.



$\Delta X = (\mu - 1)t = 1\lambda$

for one maximum shift

$$\boxed{t = \frac{\lambda}{\mu - 1}}$$

16. Ans. (1)

Sol. Limit of resolution of telescope $= \frac{1.22\lambda}{D}$

$$\theta = \frac{1.22 \times 500 \times 10^{-9}}{200 \times 10^{-2}} = 305 \times 10^{-9} \text{ radian}$$

17. Ans. (3)

Sol. Limit of resolution $= \frac{1.22\,\lambda}{d}$

$$= \frac{1.22 \times 600 \times 10^{-9}}{250 \times 10^{-2}}$$

$= 2.9 \times 10^{-7}$ rad.

18. Ans. (1)

Sol. Numerical aperature of the microscope is given as

$$NA = \frac{0.61\lambda}{d}$$

Where d = minimum sparation between two points to be seen as distinct

$$d = \frac{0.61\lambda}{NA} = \frac{(0.61) \times (5000 \times 10\text{m}^{-10})}{1.25}$$

$= 2.4 \times 10^{-7}$ m

$= 0.24$ μm