Wave Optics **Marks: 25**

ANSWER KEY

Physics

Q.1 D	Q.2 B	Q.3 D	Q.4 D	Q.5 B	Q.6 C	Q.7 B	Q.8 C
Q.9 C	Q.10 B	Q.11 C	Q.12 A	Q.13 C	Q.14 C	Q.15 C	Q.16 C
Q.17 A	Q.18 A	Q.19 A	Q.20 A	Q.21 B	Q.22 C	Q.23 C	Q.24 D
Q.25 A							

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SOLUTION

Physics

Q.1 In a single slit diffraction experiment, slit of width 'a' and incident light of wavelength 5600 Å, the first minimum is observed at angle 30°. The first secondary maximum is observed at angle (Sin 30° = 0.5)

Correct option: (D)

For n^{th} secondary minimum,

path difference = a sin θ_n = nλ and for n^{th} secondary maximum,

path difference = a sin $\theta_n = (2n + 1)\frac{\lambda}{2}$

∴ For 1st minimum, a sin 30° = λ ….(i)

For 2nd maximum, a sin $\theta_n = (2 + 1)\frac{\lambda}{2}$ ….(ii)

∴ Dividing equations (i) by equation (ii),

$\frac{1/2}{\sin\theta_n} = \frac{2}{3} \Rightarrow \theta_n = \sin^{-1}\left(\frac{3}{4}\right)$

Q.2 Diffraction pattern is obtained using red light. What will happen if it is replaced by violet light?

Correct option: (B)

The width of the diffraction bands is inversely proportional to the wavelength of light. Violet light has a shorter wavelength than red light. Therefore, when red light is replaced by violet light, the diffraction bands will become *narrower*.

Q.3 In a Young's experiment, two coherent sources are placed 0.90 mm apart and the fringes are observed one metre away. If it produces the second dark fringe at a distance of 1 mm from the central fringe, the wavelength of monochromatic light used would be

Correct option: (D) 6×10^{-5} cm

Distance of n^{th} dark fringe from central fringe,

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

$\therefore y_2 = \frac{(2\times 2-1)\lambda D}{2d} = \frac{3\lambda D}{2d}$

$\therefore 1\times 10^{-3} = \frac{3\times\lambda\times 1}{2\times 0.9\times 10^{-3}} \Rightarrow \lambda = 6\times 10^{-5}$ cm

Q.4 Which one of the following is the correct statement between the ray of light and the wave front?

Correct option: (D)

Q.5 Of the two slits producing interference in Young's experiment, one is covered with glass so that light intensity passing is reduced to 50%. Which of the following is correct?

Correct option: (B)

The intensity of bright fringe decreases and dark fringe increases when one slit is covered. The reason behind this is that the bright fringes are produced when the amplitudes from both slits are in phase and added constructively.

Q.6 In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case

Correct option: (C)

Both the blue and red light have different wavelengths and for interference fringes to be seen, we require coherent light sources.

Q.7 In Young's double slit experiment, a minimum is obtained when the phase difference of superimposing waves is

Correct option: (B)

When the phase difference is odd multiple of π, then destructive interference is obtained, i.e., (2n – 1) π.

Q.8 In a double slit experiment, the monochromatic source of light is used. When the distance between the slits is increased ten times and their distance from the screen is halved, then the fringe width

Correct option: (C)

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W = $\frac{\lambda D}{d}$ and W′ = $\frac{\lambda D'}{d'}$

But d′ = 10d and D′ = $\frac{D}{2}$

∴ W′ = $\frac{\lambda\left(\frac{D}{2}\right)}{10d} = \frac{1}{20}\frac{\lambda D}{d} = \frac{1}{20}$ W

∴ Fringe width will become $\frac{1}{20}^{th}$ -times the original.

Q.9 In the far field diffraction pattern of a single slit under polychromatic illumination, the first minimum with the wavelength λ_1 is found to be coincident with the third maximum at λ_2. So

Correct option: (C)

Position of first minima = Position of third maxima

∴ $\frac{1 \times \lambda_1 D}{d} = \frac{(2 \times 3 + 1)}{2}\frac{\lambda_2 D}{d}$

∴ $\lambda_1 = 3.5\ \lambda_2$

Q.10 In Young's double slit experiment, the ratio of intensities of bright and dark bands is 16 which means

Correct option: (B)

$$\frac{Intensity\,of\,bright\,band}{Intensity\,of\,dark\,band} = \frac{16}{1}$$

But I ∝ a^2

⇒ amplitude of bright band a_b = 4 and amplitude of dark band a_d = 1

∴ Intensity of individual sources,

$I_{max} = (a_b + a_d)^2 = (4 + 1)^2 = 25$

$I_{min} = (a_b - a_d)^2 = (4 - 1)^2 = 9$

Q.11 While obtaining coherent sources using Lloyd's mirror, light from a source is made to fall

Correct option: (C)

In Lloyd's mirror experiment, two coherent sources are created. One is a real source and the other is a virtual image of the source formed by reflection from the mirror. For maximum interference, the path difference between the waves from these two sources must be an integral multiple of the wavelength. If light falls at a grazing angle on the mirror, then the path difference is maximum and hence the interference fringes are most prominent.

Therefore, to obtain coherent sources using Lloyd's mirror, light from a source is made to fall at a grazing angle on the plane mirror.

Q.12 Resolving power of telescope increases when

Correct option: (A)

R. P. of telescope = $\frac{D}{1.22\lambda}$

∴ R. P. ∝ $\frac{1}{\lambda}$

As λ decreases, R. P. increases.

Q.13 A parallel beam of light of wavelength 'λ' is incident normally on a narrow slit. A diffraction pattern is formed on a screen placed perpendicular to the direction of incident beam. At the second minimum of the diffraction pattern, the phase difference between the rays coming from the two edges of slit is

Correct option: (C)

For nth minimum, the path difference $= n\lambda$

and phase difference $= 2n\pi$

For n =2,

phase difference = 2 × 2 × π = $4\pi^c$

Q.14 Two coherent sources S_1 and S_2 produce interference pattern on the screen. At point 'P' on the screen, 4^{th} dark band is formed. Wavelength of light used is 600 nm. The path difference between S_1P and S_2P is

Correct option: (C)

The path difference is given by:

$S_2P - S_1P = (2n-1)\frac{\lambda}{2}$

$= [2(4) - 1]\frac{\lambda}{2}$

$= (8-1)\frac{\lambda}{2}$

$= \frac{7\lambda}{2}$

$= \frac{7 \times 600 \times 10^{-9}}{2}$

$= 21 \times 10^{-7}\text{m}$

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Q.15 If initial fringe width is W, the distance between screen and slits is increased by 25% and distance between two slits is halved, then how many times does fringe width increase?

Correct option: (C)

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

$\therefore$ W $\propto \frac{D}{d}$ ….(i)

W′ $\propto \frac{D'}{d'}$ ….(ii)

Dividing equation (ii) by equation (i),

$\frac{W'}{W} = \frac{D'}{d'}\frac{d}{D}$

But D′ = 1.25 D; d′ = $\frac{d}{2}$

$\therefore \frac{W'}{W} = \frac{(1.25\,D)(d)}{(d/2)D}$

$\therefore$ W = 2.5 W

Q.16 Young's double slit experiment is performed in water, instead of air, then fringe width

Correct option: (C)

W = $\frac{D\lambda}{d}$ and $\lambda \propto \frac{1}{\mu}$

W $\propto \lambda \propto \frac{1}{\mu}$

$\therefore$ W $\propto \frac{1}{\mu}$

Q.17 'n' polarising sheets are arranged such that each makes an angle 45^o with the proceeding sheet. An unpolarised light of intensity I is incident into this arrangement. The output intensity is I/64. The value of n will be $\left(\cos 45^\circ = 1/\sqrt{2}\right)$

Correct option: (A)

By using Malus' law,

I′ = Icos$^2\theta$

$\therefore$ I′ = 1 cos^2 45^o = $1\left(\frac{1}{\sqrt{2}}\right)^2$

$\Rightarrow$ I′ = $\frac{I}{2}$

Since the subsequent sheets also make an angle of 45° with the proceeding sheets, the intensity of light after passing through 'n' sheets will be:

I_n= I(cos^2 45^o) (cos^2 45^o) (cos^2 45^o) …(n times)

$\therefore$ $I_n = I\left(\frac{1}{2}\right)^n$ …(i)

$\because$ $I_n = \frac{I}{64}$ …(ii)

From equations (i) and (ii), we get:

$\frac{I}{64} = I\left(\frac{1}{2}\right)^n \Rightarrow \frac{I}{64} = \frac{I}{2^n}$

$\therefore$ $\frac{1}{64} = \frac{1}{2^n} \Rightarrow 2^n = 64 = 2^6 \Rightarrow n = 6$

Q.18 A beam of light is incident on a glass plate at an angle of 60°. The reflected ray is polarized. If angle of incidence is 45° then angle of refraction is

Correct option: (A)

According to Brewster's law,

tan θ_B = n

$\therefore$ tan 60° = n

$\therefore$ n = $\sqrt{3}$

Now, $\frac{\sin i}{\sin r}$ = n

$\therefore$ sin r = $\frac{\sin i}{n}$

$\therefore$ sin r = $\frac{\sin 45^\circ}{\sqrt{3}}$

$\therefore$ sin r = $\frac{1}{\sqrt{6}}$ ….($\because$ sin 45° = $\frac{1}{\sqrt{2}}$)

$\therefore$ r = $\sin^{-1}\left(\frac{1}{\sqrt{6}}\right)$

Q.19 Diameter of the objective of a telescope is 400 cm. What is the resolving power of a telescope? Take wavelength of light = 5000 Å.

Correct option: (A)

R.P. = $\frac{D}{1.22\,\lambda} = \frac{4}{1.22\times 0.5\times 10^{-6}} = 6.56 \times 10^6$

Q.20 A double-slit apparatus is immersed in liquid of refractive index μ_m. The distance between the slits is d and distance between plane of slits and screen as D (D >> d). The slits are illuminated by parallel beam of wavelength λ′. The smallest thickness of

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a sheet of refractive index μ_p to bring adjacent minima on the axis is,

Correct option: (A)

For Young's double slit experiment, the position of minima is;

$y = \left(n + \frac{1}{2}\right)\frac{D\lambda'}{d}$

Adjacent minimum is the 1st minima or n = 0

$\therefore y_1 = \left(0 + \frac{1}{2}\right)\frac{D\lambda'}{d} = \frac{D\lambda'}{2d}$

When immersed in liquid, $\lambda = \frac{\lambda'}{\mu_m}$

$\therefore y_1 = \left(\frac{D\lambda'}{2\,\mu_m d}\right)$

Now fringe shift due to introduction of sheet on the path of one of the beams is W.

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

The requirement is, minimum must appear on the axis.

$\therefore W = y_1$ or $\frac{D}{d}\left(\frac{\mu_p}{\mu_m} - 1\right)t = \frac{D\lambda'}{2\mu_m d}$

$\therefore t = \frac{\lambda'}{2(\mu_p - \mu_m)}$

Q.21 In the Young's double slit experiment, angular width of fringes is $0 \cdot 20^\circ$ for sodium light of wavelength 5890Å. If the complete system is dipped in water, then the angular width of fringes will be [Refractive index of water $= \frac{4}{3}$]

Correct option: (B)

Angular width is given by $\theta = \frac{\lambda}{d}$

$\therefore \frac{\theta_2}{\theta_1} = \frac{\lambda_2}{\lambda_1} = \frac{3}{4}$

$\frac{\theta_2}{\theta_1} = \frac{3}{4} \Rightarrow \theta_2 = \frac{3}{4}\theta_1 = \frac{3}{4} \times 0.2 = 0.15^\circ$

Q.22 In a Young's double slit experiment set up, slits are kept 0.4 mm apart from each other and screen is kept 2 m apart from slit. The fringe for a given monochromatic light is 0.8 mm. If the whole set up is kept in medium of refractive index 1.6, the fringe width becomes

Correct option: (C)

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

$W_{med} = \frac{W_{air}}{\mu_{med}} = \frac{0.8}{1.6} = 0.5$ mm

Q.23 In Young's double slit experiment, in an interference pattern, second minimum is observed exactly in front of one slit. The distance between the two coherent sources is 'd' and the distance between the source and screen is 'D'. The wave length of light (λ) used is

Correct option: (C)

Second minimum is exactly in front of one slit indicates, $y_2' = \frac{d}{2}$

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

For n = 2

$\therefore \frac{d}{2} = \frac{(2 \times 2 - 1)\lambda D}{2d}$

$\therefore \lambda = \frac{d^2}{3D}$

Q.24 A microscope will have maximum resolving power, if to illuminate the specimen, it uses light of

Correct option: (D)

Resolving power $\propto \frac{1}{\lambda}$

$\therefore$ Blue colour which has minimum wavelength, gives maximum resolving power.

Q.25 In interference experiment, intensity at a point is $\left(\frac{1}{4}\right)^{\text{th}}$ of the maximum intensity. The angular position of this point is at (sin30° = cos60° = 0.5, λ = wavelength of light, d = slit width)

Correct option: (A)

For any point in interference pattern,

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

$\therefore \quad \frac{I_{max}}{4} = I_{max} \cos^2 \frac{\phi}{2}$

$\therefore \quad \cos^2 \frac{\phi}{2} = \frac{1}{4}$

$\therefore \quad \cos \frac{\phi}{2} = \frac{1}{2}$

$\therefore \quad \frac{\phi}{2} = 60° = \frac{\pi}{3}$

$\therefore \quad \phi = \frac{2\pi}{3}$

We know that,

$\phi = \left(\frac{2\pi}{\lambda}\right)\Delta x$, where Δx is path difference.

and $\Delta x = d \sin \theta$

$\therefore \quad \frac{2\pi}{3} = \frac{2\pi}{\lambda}(d \sin \theta)$

$\therefore \quad \frac{\lambda}{3d} = \sin \theta$

$\therefore \quad \theta = \sin^{-1}\left(\frac{\lambda}{3d}\right)$

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