Class: 12
Subject: Physics
Topic: Wave Optics
No. of Questions: 30

1. Two convex lenses of same focal length but of aperture A_1 and A_2 ($A_2 < A_1$) are used as the objective lenses in two astronomical telescopes having identical eye pieces. What is the ratio of their resolving power? Which telescope will you prefer and why? Give reason.

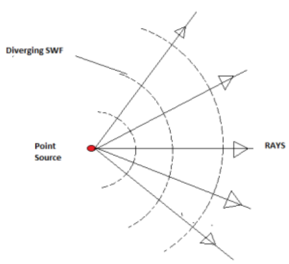
   Sol.

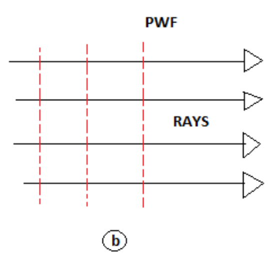
   As is known, R.P $\frac{D}{1.22\lambda}$, which varies directly as aperture D of objective lens. Therefore, $\frac{RP_1}{RP_2} = \frac{A_1}{A_2}$

   As $A_2 < A_1$ or $A_1 > A_2$, therefore, the first astronomical telescope (with aperture A_1) has higher resolving power than the second astronomical telescope (with aperture A_2). Obviously, we shall) prefer to use the first astronomical telescope.

2. What is the shape of the wavefront in each of following cases?
   A. Light diverging from point source.
   B. Light emgerging out of a convex lens when a point source is placed at its forcus.
   C. The portion of the wavefront of light from a distant star intercepted by earth.

   Sol.





   A. The geometrical shape of the wave front would be diverging in spherical wave front, as shown in Fig. (a).
   B. When a point source is placed at the focus of a convex lens, the rays emerging from the lens are parallel. Therefore, the wave front must be plane, as shown in Fig. (b)
   C. As the star (i.e. source of light) is very far off i.e. at infinity, the wave front intercepted by earth must be a plane wave front as shown in Fig. (b).

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

3. Answer the following questions:

A. In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band?

Sol.

When width of single slit is made double, the half angular width of central maximum which is reduces to half. The intensity of central maximum will become 4 times. This is cecause area of central diffraction band would become $1/4^{th}$.

4. In what way is diffraction from each slit related to interference pattern in a double slit experiment?

Sol.
If width of each slit is of the order of λ, then interference pattern in the double slit experiment is modified by the diffraction pattern from each of the two slits.

5. When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why?

Sol.
This is because waves diffracted from the edges of circular obstacle interfere constructively at the centre of the shadow resulting in the formation of a bright spot.

6. Two students are separated by a 7 m partition wall in a room 10 high. If both light and sound waves can bend round corners, how is it that the students are unable to see each other even though they can converse easily?

Sol.

For diffraction of waves by obstacle/aperture :
Through a large angle, the size of obstacle/aperture should be comparable to wavelength. This follows from sin $\theta =$
For light, $= 10^{-8}$ m and size of wall a = 10 m.

$\therefore \quad \text{Sin} = \frac{\lambda}{a} = \frac{10^{-7}}{10} = 10^{-8} \qquad \therefore \quad \theta \longrightarrow 0,$

i.e. light goes almost unbent. The students are thus unable to see each other.

For sound waves of frequency $= 1000\ Hz.$ $\quad \lambda = \frac{v}{n} = \frac{330}{1000} = 0.33\ m$

$\text{Sin}\ \theta = \frac{\lambda}{a} = \frac{0.33}{10} = 0.033$

$\therefore \theta$ has a definite value i.e. sound waves bend around the partition. Hence students can converse easily.

7. Ray optics is based on the assumption that light travels in a straight line. Diffraction effects this assumption. Yet the ray optics assumption is so commonly used in understanding location and several other properties of images in optical instruments. What is the justification?

   Sol.

   The ray optics assumption is used in understanding location and several other properties of images in optical instruments. This is because typical sizes of apertures involved in ordinary optical instruments are much larger than the wavelength of light. Therefore. Diffraction or bending of waves is of no significance.

8. Answer the following questions:
   When a low flying aircrafts passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.

   Sol.

   A low flying aircraft reflects the T.V. signal. The slight shaking on the T.V. screen may be due to interference between the direct signal and the reflected signal.

9. As you have learnt in the text, the principle of linear superposition of wave displacement is basic to understanding intensity distributions in diffraction and interference patterns. What is the justification of this principle?

   Sol.

   Superposition principle follows from the linear character of the differential equation governing wave motion. If y_1 and y_2 are solutions of the wave equation, so is any linear combination of y_1 and y_2. When amplitudes are large (e.g. high intensity laser beams) and non-linear effects are important, the situation is far more complicated.

10. When a sheet of transparent plastic is placed between two crossed polarizers, no light is transmitted. When the sheet is stretched in one direction, some light passes through the crossed polirizers. What is happening?

    Sol.

    A transparent plastic sheet is NOT a polaroid. As the two polarizers are crossed, no light is transmitted whether the plastic sheet is placed between them or not.

    But when the plastic sheet is stretched, the polymer molecules in it make it a polaroid with its own polaroid axis. This axis will be at certain angel with the axes of two polaroids. Therefore some light would pass through the crossed polaroids.

11. In Young's double slit experiment, if the distance between the slits and the screen is doubled and the separation between the slits is reduced to half, the fringe width

A. is doubled
B. becomes four times
C. is halved
D. remains unchanged

Right Answer Explanation:

Since $\beta = \lambda D/d$, if D is doubled and d is halved, the fringe width β will become four times. Hence the correct choice is (2).

12. In Young's double slit experiment, sodium light composed of two wavelengths λ_1 and λ_2 close to each other (with λ_2 greater than λ_1) is used. The order n up to which the fringes can be seen on the screen is given by

A. $n = \frac{\lambda_2}{\lambda_2 - \lambda_1}$
B. $n = \frac{\lambda_1}{\lambda_2 - \lambda_1}$
C. $n = \frac{\lambda_2}{2(\lambda_2 - \lambda_1)}$
D. $n = \frac{\lambda_1}{2(\lambda_2 - \lambda_1)}$

Right Answer Explanation:

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

If an interference experiment is performed using two wavelengths close to each other, two interference patterns corresponding to the two wavelengths are obtained on the screen. The fringe system remains distinct upto a point on the screen where the nth order maximum of one wavelength, say λ_1 = 5890 Å falls on the nth order minimum of the other wavelength λ_2 = 5895 Å. Thus, interference pattern can be seen upto a distance y_n from the centre of the screen if

$$y_n = \frac{n\lambda_1 D}{d}; \text{ (}n\text{th maximum)} \quad (1)$$

$$= \left(n - \frac{1}{2}\right)\frac{\lambda_2 D}{d}; \text{ (}n\text{th minimum)} \quad (2)$$

or $\quad n\lambda_1 = \left(n - \frac{1}{2}\right)\lambda_2$ or $2n\lambda_1 = (2n-1)\lambda_2$

which gives

$$n = \frac{\lambda_2}{2(\lambda_2 - \lambda_1)},$$ which is choice (3).

13. In Young's double slit experiment, the two slits act as coherent sources of equal amplitude A and of wavelength λ. In another experiment with the same set up, the two slits are sources of equal amplitude A and wavelength λ, but are incoherent. The ratio of the intensity of light at the midpoint of the screen in the first case to that in the second case is

A. 1 : 1
B. 1 : 2
C. 2 : 1
D. $\sqrt{2}$: 1

Right Answer Explanation:

If the two sources are coherent, the resultant amplitude at the midpoint of the screen due to interference $= A + A = 2A$. Therefore, intensity is $I_1 \propto (2A)^2$ or $I_1 = k \times 4A^2$ where k is a constant of proportionality. But if the sources are not coherent, their intensities simply add up at the midpoint, i.e.

$$I_2 \propto (A^2 + A^2) \text{ or } I_2 = k \times 2A^2$$

$$\therefore \quad \frac{I_1}{I_2} = \frac{4kA^2}{2kA^2} = 2$$

14. How is the interference pattern affected if the Young's experiment was performed in still water than in air?

A. Fewer fringes will be visible.
B. Fringes will be broader.
C. Fringes will be narrower.
D. No fringes will be observed.

Right Answer Explanation:
Since the refractive index of water is greater than that of the air, the speed of the light used in the experiment will be less in water than in air. Since the frequency of light is the same in water and in air, it follows from the relation $\lambda = v/\nu$ that the wavelength λ in water is less than in air. Since fringe width $\beta \propto \lambda$, the value of β will decrease.

15. What is the effect on the interference fringes in Young's double slit experiment if the widths of the two slits are increased?

A. The fringe width decreases.
B. The fringe width increases.
C. The bright fringes are equally bright and equally spaced.
D. The bright fringes are no longer equally bright and equally spaced.

Right Answer Explanation:
The single slit diffraction effects at the two slits becomes important and as a result, the interference fringe pattern will be modified. The bright fringes will not now be equally bright and equally spaced.

16. The fact that light can be polarized establishes that light

A. travels in the form of particles
B. is an electromagnetic wave
C. is a transverse wave
D. is a longitudinal wave

Right Answer Explanation:
The correct choice is (3).

17. In a single slit diffraction experiment, the width of the slit is made double its original width. Then the central maximum of the diffraction pattern will become

A. narrower and fainter
B. narrower and brighter
C. broader and fainter
D. broader and brighter

Right Answer Explanation:
The angular width of the central maximum is $2\lambda/a$ where a is the width of the slit. If the value of a is doubled, the angular width of the central maximum decreases to half its earlier value. This implies that the central maximum becomes much sharper. Furthermore if a is doubled, the intensity of the central maximum becomes four times. Thus the central maximum becomes much sharper and brighter.

18. The dispersion of light in a medium implies that

A. lights of different wavelengths travel with different speeds in the medium
B. lights of different frequencies travel with different speeds in the medium
C. the refractive index of the medium is different for different wavelengths of light
D. all of the above

Right Answer Explanation:
The correct choice is (4).

19. Which one of the following statements is correct?

A. The refractive index of a given piece of glass is less for violet than for red light.
B. The refractive index of a given piece of glass is more for blue than for green light.
C. The refractive index of a given piece of glass is less for green than for yellow light.
D. The refractive index of a given piece of glass is the same for all colours of light.

Right Answer Explanation:
The refractive index of glass decreases with increase in wavelength. In VIBGYOR, the wavelength of violet light is the shortest and that of the red light is the longest. Hence, the correct choice is (2).

20. Choose the only WRONG statement. The speed of light in a given glass plate is

A. greater for violet than for red light
B. less for green than for yellow light
C. less for blue than for green light

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

D. the same for all colours of light

Right Answer Explanation:
Statement (3) is wrong.

21. In Young's double slit experiment using two identical slits, the intensity of the maximum at the centre of the screen is I. What will be the intensity at the centre of the screen if one of the slits is closed?

A. I
B. $\frac{I}{2}$
C. $\frac{I}{4}$
D. None of these

Right Answer Explanation:
Let I_0 be the intensity at the centre of the screen due to each slit. Then, for the central maximum, the intensity is

$$I = I_0 + I_0 + 2\sqrt{I_0 I_0} = 4I_0$$

or $$I_0 = \frac{I}{4}.$$

22. Two waves of intensities I and 4I superpose, then the maximum and minimum intensities are

A. 5 I, 3 I
B. 9 I, I
C. 9 I, 3 I
D. 5 I, I

Right Answer Explanation:
Given $I_1 = I$ and $I_2 = 4I$. Now

$$I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}$$
$$= I + 4I + 2\sqrt{4I^2} = 9I$$

and $$I_{min} = I_1 + I_2 - 2\sqrt{I_1 I_2} = 5I - 4I = I$$

Hence the correct choice is (2).

23. When one of the slits in Young's experiment is covered with a transparent sheet of thickness 3.6 $\times$ 10^{-3} cm, the central fringe shifts to a position originally occupied by the 30th bright fringe. If λ = 6000 Å, then the refractive index of the sheet is

A. 1.50
B. 1.60
C. 1.55
D. 1.65

Right Answer Explanation:

The position of the 30th bright fringe is given by

$$y_{30} = 30\ \frac{\lambda D}{d}$$

Hence the shift of the central fringe is

$$y_0 = 30\ \frac{\lambda D}{d}$$

But $\quad y_0 = \frac{D}{d}\ (\mu - 1)t$

$$\therefore\ 30\ \frac{\lambda D}{d} = \frac{D}{d}\ (\mu - 1)t$$

or $\quad (\mu - 1) = \frac{30\lambda}{t} = \frac{30 \times (6000 \times 10^{-10})}{(3.6 \times 10^{-5})} = 0.5$

$$\therefore\quad \mu = 1.5$$

24. In an interference experiment, 20th order maximum is observed at a point on the screen when light of wavelength 480 nm is used. If this light is replaced by light of wavelength 600 nm, the order of the maximum at the same point will be

A. 16
B. 14
C. 12
D. 10

Right Answer Explanation:

The position of the nth order maximum is given by

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

For a given point y_n is fixed. Since D and d are also fixed, $n\lambda$ = constant, i.e. $n_1\ \lambda_1 = n_2\ \lambda_2$. Hence

$n_2 = n_1 \frac{\lambda_1}{\lambda_2} = \frac{20 \times 480}{600} = 16$, which is choice (1).

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

25. In Young's double slit experiment, the fringe width with light of wavelength 6000 Å is found to be 4.0 mm. What will be the fringe width if light of wavelength 4800 Å is used?

A. 2.8 mm
B. 3.2 mm
C. 4.0 mm
D. 4.8 mm

Right Answer Explanation:

Given $\beta = 4.0$ mm and $\lambda = 6000$ Å.
We know that the fringe width is given by

$$\beta = \frac{\lambda D}{d} \qquad \text{(i)}$$

for $\lambda' = 4800$ Å, the fringe width will be

$$\beta' = \frac{\lambda' D}{d} \qquad \text{(ii)}$$

From (i) and (ii) we have

$$\beta' = \beta \frac{\lambda'}{\lambda} = \frac{4.0\,\text{mm} \times 4800\,\text{Å}}{6000\,\text{Å}} = 3.2\,\text{mm}$$

26. In Young's double slit experiment, the fringe width with light of wavelength 6000 Å is found to be 4.0 mm, what will be the fringe width using light of wavelength 6000 Å if the entire apparatus is immersed in a transparent liquid of refractive index 4/3?

A. 2.0 mm
B. 3.0 mm
C. 4.0 mm
D. 5.0 mm

Right Answer Explanation:

Transweb Educational Services Pvt Ltd
B -147, Sector -6 Noida, UP - 201301,
www.askiitians.com
Email: info@askiitians.com
Tel: 1800-2000-838

Wavelength in air is $\lambda_a = 6000$ Å. Let its speed in air be v_a. When the apparatus is immersed in a liquid the frequency of the wave remains unchanged but its wavelength and speed both will change. Let λ_l be the wavelength and v_l be the speed in the liquid. Since $v = \nu\lambda$, we have

$$\nu = \frac{v_a}{\lambda_a} = \frac{v_l}{\lambda_l}$$

or $$\lambda_l = \frac{\lambda_a v_l}{v_a} = \lambda_a \frac{v_l}{c}\frac{c}{v_a}$$

(c is the speed of light in vacuum). Now the refractive index of a medium is $n = c/v$. Hence

$$\lambda_l = \lambda_a \frac{n_a}{n_l} = \frac{\lambda_a}{n_l} \qquad (\because n_a = 1)$$

Given $\lambda_a = 6000$ Å and $n_l = 4/3$. Therefore

$$\lambda_l = \frac{6000\text{ Å}}{4/3} = 4500\text{ Å}$$

Hence the fringe width in liquid will be

$$\beta_l = \frac{\beta_a \lambda_l}{\lambda_a} = \frac{4.0\text{ mm} \times 4500\text{ Å}}{6000\text{ Å}} = 3.0\text{ mm}$$

27. What is the effect on the interference fringes in Young's double slit experiment if the width of the source slit is increased?

A. The fringe width increases.
B. The fringe width decreases.
C. The fringes become more distinct.
D. The fringes become less distinct.

Right Answer Explanation:

Let x be the width of the source slit and X the distance between the source slit and the plane of the two slits. For interference fringes to be distinctly visible, the condition $x/X < \lambda/d$ should be satisfied. If x is too large (i.e. the source slit is too wide) or if X is too small (X is the distance between the source slit and the two slits) the requirement $x/X < \lambda/d$ may be violated and fringes will no longer be distinct. The reason is that the interference patterns due to various parts of the source slit overlap. Consequently, the minima will not be totally dark and fringe pattern becomes indistinct. However, as long as the fringe pattern remains visible, a change in x or X has no effect on the fringe width β.

28. Monochromatic light rays are refracted from air into glass of refractive index μ. The ratio of the wavelengths of the incident and refracted rays is

A. 1 : 1
B. 1 : μ
C. μ : 1
D. μ^2 : 1

Right Answer Explanation:
Since the frequency n of the light does not change as light travels from air into glass, we have

$$v_a = n\,\lambda_a \text{ and } v_g = n\,\lambda_g$$

Therefore $\dfrac{\lambda_a}{\lambda_g} = \dfrac{v_a}{v_g} = \mu$

29. The wavelength of sodium light is 589 nm in air. What will be the wavelength of sodium light if it travels in glass of refractive index 1.5?

A. 589 nm
B. 589 $\times$ 1.5 nm
C. $\frac{589}{1.5}$ nm
D. None of these

Right Answer Explanation:
The frequency of a wave does not change when it goes from one medium into another. Thus

$$\nu = \frac{v_a}{\lambda_a} = \frac{v_g}{\lambda_g}$$

$$\therefore \quad \frac{\lambda_g}{\lambda_a} = \frac{v_g}{v_a} = \frac{v_g}{c} \times \frac{c}{v_a} = \frac{\mu_a}{\mu_g}$$

$$\therefore \quad \lambda_g = \frac{\mu_a\,\lambda_a}{\mu_g} = \frac{1}{1.5} \times 589 = \frac{589}{1.5} \text{ nm}$$

30. In Young's double slit experiment, the 10th maximum of wavelength λ_1 is at a distance y_1 from its central maximum and the 5th maximum of wavelength λ_2 is at a distance y_2 from its central maximum. The ratio y_1/ y_2 will be

A. $\frac{2\lambda_1}{\lambda_2}$

B. $\frac{2\lambda_2}{\lambda_1}$

C. $\frac{\lambda_1}{2\lambda_2}$

D. $\frac{\lambda_2}{2\lambda_1}$

Right Answer Explanation:

We know that $y_m = \frac{m\lambda D}{d}$. Therefore, for wavelength λ_1,

$$y_1 = \frac{10\lambda_1 D}{d}$$

and for wavelength λ_2,

$$y_2 = \frac{5\lambda_2 D}{d}$$

$$\therefore \quad \frac{y_1}{y_2} = \frac{2\lambda_1}{\lambda_2}$$