CBSE Test Paper-05

Class - 12 Physics (Wave Optics)

1. A parallel beam of light in air makes an angle of 47.5° with the surface of a glass plate having a refractive index of 1.66. What is the angle between the reflected part of the beam and the surface of the glass?
   a. 41.5°
   b. 43.5°
   c. 45.5°
   d. 47.5°
2. Approximate Doppler shift formula for light is
   a. $\frac{\Delta v}{v} = -\frac{v_{rad}}{c}$
   b. $\frac{\Delta v}{v} = 2\frac{v_{rad}}{c}$
   c. $\frac{\Delta v}{v} = \frac{v_{rad}}{c}$
   d. $\frac{\Delta v}{v} = -\frac{v_{rad}}{2c}$
3. Two waves have intensity ratio 25 : 4. What is the ratio of maximum to minimum intensity?
   a. $\frac{9}{49}$
   b. $\frac{16}{25}$
   c. $\frac{49}{9}$
   d. $\frac{25}{4}$
4. A viewing screen is separated from a double-slit source by 1.2 m. The distance between the two slits is 0.030 mm. The second-order bright fringe m = 2 is 4.5 cm from the center line. Distance between adjacent bright fringes is
   a. 2.28 cm
   b. 2.26 cm
   c. 2.24 cm
   d. 2.25 cm
5. In general the term diffraction is used
   a. if single source is multiplied by scalar
   b. if two sources are added algebrically.
   c. if two sources are added vectorially

d. bending of waves round an obstacle

6. How would the angular separation of interference fringes in Young's double slit experiment change when the distance between the slits and screen is halved?
7. Draw the wavefront coming out from a convex lens, when a point source of light is placed at its focus.
8. State Huygens' principle of diffraction of light?
9. When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.
10. Compare the interference pattern observed in Young's double slit experiment with single slit diffraction pattern, pointing out two distinguishing features.
11. If the angle between the axis of polariser and the analyser is 45°; write the ratio of the intensities of original light and the transmitted light after passing through the analyser.
12. i. Describe briefly, with the help of suitable diagram, how the transverse nature of light can be demonstrated by the phenomenon of polarisation?
    ii. When unpolarised light passes from air to a transparent medium, under what condition does the reflected light get polarised?
13. The $6563\,\overset{o}{\mathrm{A}}\ H_{\alpha}$ line emitted by hydrogen in a star is found to be red shifted by $15\overset{o}{\mathrm{A}}$. Estimate the speed with which the star is receding from the Earth.
14. Two coherent light sources of intensity ratio 25 : 4 are employed in an interference experiment what is the ratio of the intensities of the maxima and minima in the interference pattern?
15. i. A plane wavefront approaches a plane surface separating two media. If medium 1 is optically denser and medium 2 is optically rarer, using Huygens' principle, explain and show how a refracted wavefront is constructed?
    ii. Verify Snell's law.
    iii. When a light wave travels from a rarer to a denser medium, the speed decreases. Does it imply a reduction in its energy? Explain.

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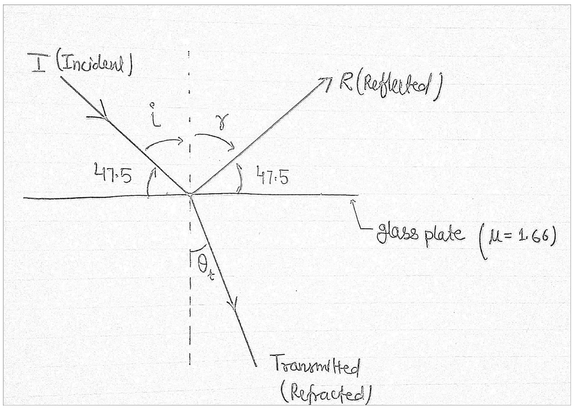
Answers

1. d. 47.5°

   Explanation: Let x is the angle between the reflected part of the beam and the surface of the glass.

   from diagram,

   i + 47.5 = 90°

   i = 42.5°

   by law of reflection,

   i = r = 42.5°

   from figure

   x + r = 90°

   $\Rightarrow$ x = 47.5°

2. a. $\frac{\Delta v}{v}=-\frac{v_{rad}}{c}$

   Explanation: The fractional change in frequency ΔV/V is given by $-V_{radial}/c$, where V_{radial} is the component of the source velocity along the line joining the observer to the source relative to the observer; V_{radial} is considered positive when the source moves away from the observer.

3. c. $\frac{49}{9}$

   Explanation: $\frac{I_{max}}{I_{min}}=\frac{(A1+A2)^2}{(A1-A2)^2}$

   $=\frac{(5+2)^2}{(5-2)^2}=\frac{49}{9}$

4. d. 2.25 cm

Explanation: $\frac{xd}{D} = 2\lambda$

Given D = 1.2m

d = .030mm

x = 4.5cm

Distance between adjacent bright fringe is $x = \frac{1\lambda D}{d}$

so the distance is half of 4.5cm.

5. d. bending of waves round an obstacle

   Explanation: The bending of waves takes place whenever the size of obstacle is comparable to wavelength of waves.

6. In young's double slit experiment, Angular separation is given by,

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

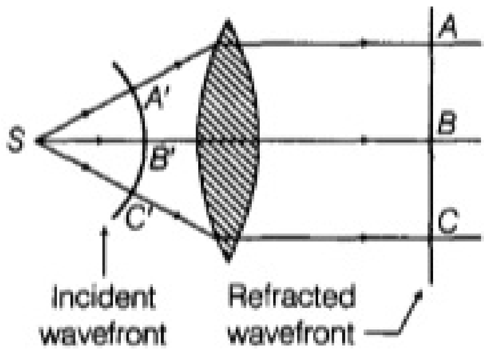
   The angular separation of interference fringes in Young's double slit experiment becomes double when separation between slits and screen is 1 halved as angular separation, $\theta \propto \frac{1}{d}$

   Where, d is distance between two slits.

   Angular separation does not depend on D i.e., the distance of separation between slits and screen.

   Therefore, θ remains unaffected.

7. The wavefront coming out from a convex lens, when a point source of light is placed at its focus is shown in figure below :

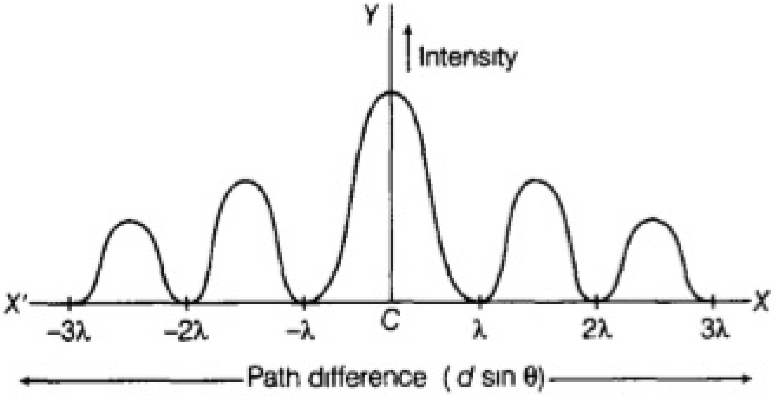


8. When a wavefront strikes to the corner of an obstacle, light wave bends around the corner because every point on wavefront again behaves like a new light source and emit secondary wavelets in all directions and behave as secondary wavefronts (from Huygens' wave theory) including the region of geometrical shadow. This explains diffraction. i.e. bending of light from the edge of any obstacle is known as diffraction.

This is one of the basic properties of light wave.

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

10. In case of single slit , The diffraction pattern obtained on the screen consists of a central bright band having alternate dark and weak bright band of decreasing intensity on both sides.
The diffraction pattern can be graphically represented as



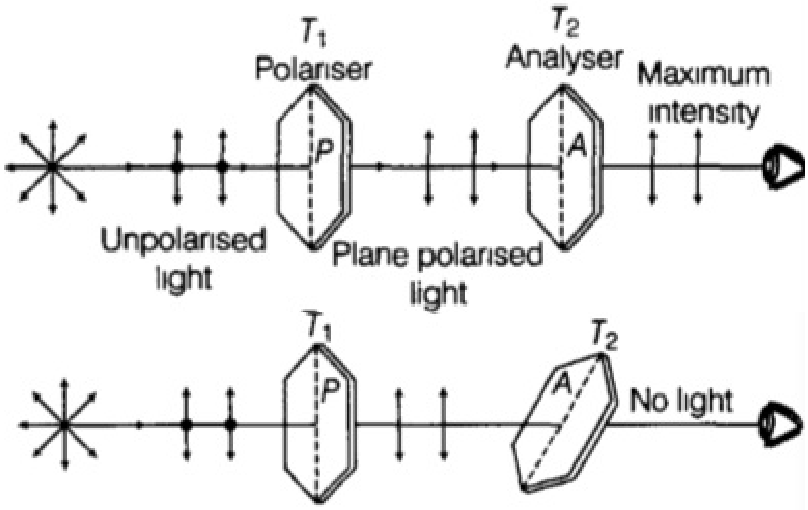
Points to compare the intensity distribution between interference and diffraction.

a. In the interference,it is produced due to two different wave fronts, but in diffraction, it is produced due to different parts of same wave fronts.
b. In the interference, fringe width is same size, but in diffraction, central fringe is twice as wide as other fringes.
c. In the interference, all bright fringes have same intensity, but in diffraction, all the bright fringes are not of the same intensity.
d. In interference, the widths of all the fringes are same but in diffraction, fringes are of different widths. The point C corresponds to the position of central maxima and the position$-3\lambda, 2\lambda, -\lambda, \lambda, 2\lambda, 3\lambda.....$ are secondary minima. The above conditions for diffraction maxima and minima are exactly reverse of mathematical conditions for interference maxima and minima.

11. The intensity of light transmitted by polariser becomes half of intensity of incident unpolarised light. i.e. Intensity of transmitted light through polariser is = $\frac{I_0}{2}$
given ,
angle between the axis of polariser and the analyser is 45°.
We know that , $I = (I_0)\cos^2\theta$

Thus, $I=\left(\frac{I_0}{2}\right)\cos^2 45^\circ$
$=\frac{I_0}{2}\times\frac{1}{2}=\frac{I_0}{4}$
$\Rightarrow\frac{I}{I_0}=\frac{1}{4}$
$\therefore\ I:I_0=1:4$

12. i. When an unpolarised light incident on a tourmaline crystal T_1 (polariser), then intensity of transmitted light passing through T_1, cut to its half. Let, another crystal, T_2 be placed in the path of transmitted light by T_1 and one full rotation is given to it. Gradually change in intensity of the transmitted light is observed with the rotation of the second crystal. The intensity of the transmitted light is maximum when the axes of the two crystals, T_1 and T_2 are parallel to each other and minimum when their axes are perpendicular to each other.
Since, the intensity of polarised light on passing through a tourmaline crystal changes with the relative orientation of its crystallographic axis with that of polariser, which implies that light wave must be of transverse in nature. Because a transverse wave containing electric and magnetic filed components vibrating perpendicular to each other and also perpendicular to the direction of propagation of the wave, can only be polarised.



ii. It happens when angle of incidence is equal to the polarising angle falling on a transparent surface, then reflected light is completely polarised. In this situation, refractive index of the refracting surface is given by $\mu = \tan i_p$. This is also called Brewster's law, which states that the tangent of the polarising angle for a transparent medium is equal to the refractive index of the medium. Also, the reflected and refracted light wave are mutually perpendicular to each other.

13. $\lambda = 6563\overset{o}{\text{A}} = 6563 \times 10^{-10} m$

$\lambda' - \lambda = 15\overset{o}{\text{A}} = 15 \times 10^{-10}$

$\lambda' - \lambda = \frac{V_s \lambda}{c}$

$V_s = \frac{c}{\lambda}(\lambda' - \lambda)$

$= \frac{3.0 \times 10^8}{6563 \times 10^{-10}} \times 15 \times 10^{-10}$

$= 6.8566 \times 10^5 ms^{-1}$

$V_s = 6.86 \times 10^5 ms^{-1}$

14. Let I_1 and I_2 be the intensities of the two coherent beams and A_1 and A_2 their respective amplitudes.

Now,

Intensity ratio, $\frac{I_1}{I_2} = \frac{25}{4}$ therefore $\frac{A_1}{A_2} = \sqrt{\frac{I_1}{I_2}}$

Amplitude ratio $\frac{A_1}{A_2} = \sqrt{\frac{25}{4}} = \frac{5}{2}$

i.e. A_1 = 5 units

and A_2 = 2 units

At maxima : $A_{max} = A_1 + A_2$ = 7 units

At minima : $A_{min} = A_1 - A_2$ = 3 units

Hence, $\frac{I_{\max}}{I_{\min}} = \frac{A_{\max}^2}{A_{\min}^2}$

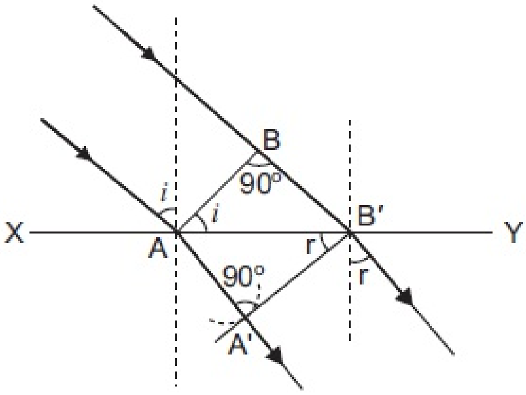
$\Rightarrow \frac{I_{\max}}{I_{\min}} = \frac{(7)^2}{(3)^2}$

$\Rightarrow I_{\max} : I_{\min} = 49 : 9$

15. i. When a wave starting from one homogeneous medium enters the another homogeneous medium, it is deviated from its path. This phenomenon is called refraction.

In transversing from first medium to another medium, the frequency of wave remains unchanged but its speed and the wavelength both are changed.

Let XY be a surface separating the two media ‘1’ and ‘2’. Let$v_1 \ \ and \ \ v_2$ be the speeds of waves in these media. wave to reach from B to C,



Suppose a plane wavefront AB in first medium is incident obliquely on the boundary surface XY and its end A touches the surface at A at time t = 0 while the other end B reaches the surface at point B' after time-interval t.

Clearly $BB' = v_1 t$. As the wavefront AB advances, it strikes the points between A and B' of boundary surface.

According to Huygen's principle, secondary spherical wavelets originate from these points, which travel with speed v_1 in the first medium and speed v_2 in the second medium.

First of all secondary wavelet starts from A, which traverses a distance $AA' = v_2 t$ in second medium in time t.

In the same time-interval t, the point of wavefront traverses a distance $BB' = v_1 t$ in first medium and reaches B', from, where the secondary wavelet now starts.

Clearly $AA' = v_2 t$ and $BB' = v_1 t$, Assuming A as centre, we draw a spherical arc of radius $AA' = v_2 t$ and draw tangent B' A' on this arc from B'.

As the incident wavefront AB advances, the secondary wavelets start from points between A and B', one after the other and will touch A' B' simultaneously.

According to Huygen's principle A' B' is the new position of wavefront AB in the second medium.

Hence A'B' will be the refracted wavefront.

ii. As AB, A' B' and surface XY are in the plane of paper, therefore the perpendicular drawn on them will be in the same plane.

As the lines drawn normal to wavefront denote the rays, therefore we may say that the incident ray, refracted ray and the normal at the point of incidence all lie in the same plane.

Let the incident wavefront AB and refracted wavefront A' B' make angles i and r respectively with refracting surface XY.

Now, in $\Delta ABB'$,

$\sin i=\frac{BB'}{AB}=\frac{v_1 t}{AB'}$

In $\Delta AA'B'$,

$\sin r=\frac{AA'}{AB'}=\frac{v_2 t}{AB'}$

dividing equation (i) by (ii) , we get :

$\frac{\sin i}{\sin r}=\frac{v_1 t/AB'}{v_2 t/AB'}$

$\frac{\sin i}{\sin r}=\frac{v_1}{v_2}=\text{ constant }={}^1\mu_2$

where, ${}^1\mu_2$ = refractive index of second medium w.r.t. first medium.

The ratio of sine of angle of incidence and the sine of angle of refraction is a constant and is equal to the ratio of velocities of waves in the two media. This is called the Snell's law.

Hence, Snell's law of refraction is verified.

iii. No, the energy carried by the wave does not depend on its speed instead, it depends on the frequency of the wave.