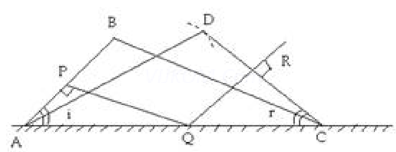
IMPORTANT QUESTIONS CLASS – 12 PHYSICS CHAPTER – 10 WAVE OPTICS

1.(a) State Huygens's principle for constructing wavefronts?
(b) Using Huygens's principle deduce the laws of reflection of light?
(c) What changes in diffraction pattern of a single slit will you observe. when the monochromatic source of light is replaced by a source of white light?

Ans.(a) According to Huygens's principle
(1) Each source of light spreads waves in all directions.
(2) Each point on the wavefront give rise to new disturbance which produces secondary wavelets which travels with the speed of light.
(3) Only forward envelope which encloses the tangent gives the new position of wavefront.
(4) Rays are always perpendicular is the wavefront.
(b) A plane wave front AB incident at A hence every point on AB give rise to new waves. Time taken by the ray to reach from P to R



$$t = \frac{PQ}{v} + \frac{QR}{v} ------(1)$$

$$In\ \Delta PAQ \sin i = \frac{PQ}{AQ}$$

$$PQ = AQ \sin i$$

$$In\ \Delta RCQ \sin r = \frac{QR}{QC}$$

$$QR = QC \sin r$$

Substituting in equation (1)

$$t = \frac{AQ \sin i}{v} + \frac{QC \sin r}{v}$$

$$t = \frac{AQ \sin i}{v} + \frac{(AC - AQ)\sin r}{v}$$

$$t = \frac{AQ \sin i}{v} + \frac{QC \sin r}{v} - \frac{AQ \sin r}{v}$$

$$\frac{AQ(\sin i - \sin r)}{v} + \frac{AC \sin r}{v}$$

Since all the secondary wavelets takes the same
time to go form the incident wavefront to the reflected wavefront
so it must be independent of Q
i.e sin i– sin r = O
sin i= sin r
or i = r $\rightarrow$ law of Reflection of light
(c) (1) The diffracted light consists of different colours.
(2) It results in overlapping of different colours.

2.(a) Coloured spectrum is seen, when we look through a muslin cloth. Why?
(b) What changes in diffraction pattern of a single slit will you observe. when the monochromatic source of light is replaced by a source of white light?
Ans. (a) Muslin cloth consist of very fine threads which acts as fine slits and when light pass through it, light gets diffracted giving rise to a coloured spectrum.
(b) (i) Diffracted lights consist of different colours
(ii) It results in overlapping of different colours.

3.A slit of width 'a' is illuminated by light of wavelength. For what value of 'a' will the :-
(i) First maximum fall at an angle of diffraction of?
(ii) First minimum fall at an angle of diffraction?
Ans. $\lambda = 6000A^{\circ} = 6000\times10^{-10}$m

θ 1=30°, m=1

(1) For first maximum

$$\sin Q_m = \frac{\left(m+\frac{1}{2}\right)\lambda}{a}$$

$$\sin Q_1 = \frac{3\lambda}{2a}$$

$$or\ a = \frac{3\lambda}{2\sin\theta_1} = \frac{3\times6\times10^{-7}}{2\times\sin30^{\circ}}$$

(2) For first minimum

$$\sin Q_m = \frac{m\lambda}{a}$$

$$or \sin Q_1 = \frac{\lambda}{a}$$

$$a = \frac{\lambda}{\sin\theta_1}$$

$$a = \frac{6 \times 10^{-7}}{\sin 30^{\circ}}$$

$$A = 1.2 \times 10^{-6} m$$

4.(a) Derive all expression for the fringe width in young's double slit experiment?
(b) If the two slits in young's double slit experiment have width ratio 4:1, deduce the ratio of intensity of maxima and minima in the interference pattern?

Ans. Path difference between

$S_1P \text{ and } S_2P$

$$\Delta x = S_2P - S_1P \text{ ———(A)}$$

$In\ \Delta S_2BP$

$$(S_2P) = \left[(S^2B)^2 + (PB^2)\right]^{\frac{1}{2}}$$

——(1)

$$S_2P = D\left[1 + \frac{\left(y + \frac{d}{2}\right)}{D^2}\right]^{\frac{1}{2}}$$

Using Binomial theorem expand equation. (1) and neglect higher terms

Similarity ——(2)

Substituting equation (1) & (2) in equation (A)

$$S_2P = D + \frac{\left(y + \frac{d}{2}\right)^2}{2D}$$

$$S_1P = D + \frac{\left(y - \frac{d}{2}\right)^2}{2D}$$

$$\Delta x = \frac{2yd}{2D}$$

$$\Delta x = \frac{yd}{D}$$

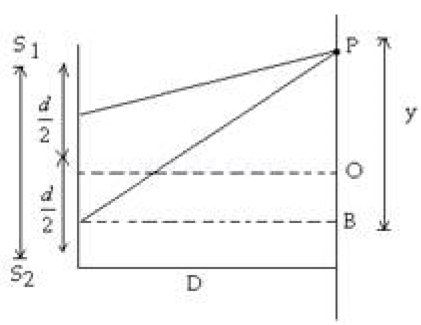
For bright fringes

Path difference = $x\lambda$

$$x\lambda = \frac{yd}{D}$$

$$i.e\ y = \frac{x\lambda D}{d}$$

$$n = 2 \quad y_2 = \frac{\lambda D}{d}$$



For fringe width

$$\beta = y_2 - y_1$$

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

(b) $\frac{a_1^2}{a_2^2} = \frac{w_1}{w_2} = \frac{4}{1}$

$$\Delta x = \frac{\left(y+\frac{d}{2}\right)^2 - \left(y-\frac{d}{2}\right)^2}{2D}$$

$\frac{a_1}{a_2} = \frac{2}{1}$

$or\ a_1 = 2a_2$

Using

$$\Delta x = \frac{y^2 + \frac{d^2}{4} + yd - y^2 - \frac{d^2}{4} + yd}{2D}$$

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

form =1 $y_1 = \frac{\lambda D}{d}$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$$

$$\frac{I_{max}}{I_{min}} = \frac{(2a_1+a_2)^2}{(2a_1-a_2)^2} = \left(\frac{3a_2}{a_2}\right)^2$$

5.Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (a) reflected, and (b) refracted light? Refractive index o
f water is 1.33.

Ans. Wavelength of incident monochromatic light,

λ = 589 nm = $589 \times 10^{-9}\ m$

Speed of light in air, $c = 3 \times 108$ m/s

Refractive index of water, μ = 1.33

(a) The ray will reflect back in the same medium as that of incident ray. Hence, the wavelength, speed, and frequency of the reflected ray will be the same as that of the incident ray.

Frequency of light is given by the relation,

$$V = \frac{c}{\lambda}$$

$$\angle i + \angle r = 90^0$$
$$\angle i + \angle i = 90^0$$

$$= \frac{3\times10^8}{5000\times10^{-10}} = 6\times10^{14} Hz$$

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

$$Z_F = \frac{(4\times10^{-3})^2}{400\times10^{-9}} = 40m$$

$$\frac{v}{c}=\frac{\sin i}{\sin r}=\mu$$

$$(\lambda'-\lambda)=15\overset{0}{A}=15\times10^{-10}m$$

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

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

$$\therefore\lambda=\frac{a^2}{Z_P}$$

$$\theta=0.1^0=0.1\times\frac{\lambda}{180}=\frac{3.14}{1800}rad$$

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

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

$$=\frac{600\times10^{-9}}{\frac{3.14}{1800}}=3.44\times10^{-4}m$$

$$=\frac{3\times10^8}{589\times10^{-9}}$$

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

Hence, the speed, frequency, and wavelength of the reflected light are 3×10^8 m/s, 5.09×10^{14} Hz, and 589 nm respectively.

$$=5.09\times10^{14}Hz$$

(b) Frequency of light does not depend on the property of the medium in which it is travelling. Hence, the frequency of the refracted ray in water will be equal to the frequency of the incident or reflected light in air.

$\therefore$ Refracted frequency, $\nu = 5.09\times10^{14}$ Hz

Speed of light in water is related to the refractive index of water as:

$$V=\frac{c}{\mu}$$

Wavelength of light in water is given by the relation,

$$V=\frac{3\times10^8}{1.33}=2.26\times10^8m/s$$

$$\lambda=\frac{V}{\nu}$$

$$=\frac{2.26\times10^8}{5.09\times10^{14}}$$

$$=444.01nm$$

$$=444.007\times10^{-9}m$$

Hence, the speed, frequency, and wavelength of refracted light are respectively.

$2.26\times10^8\ m/s,$

$444.01nm,\ and\ 5.09\times10^{14}\ Hz$

6.In Young's double-slit experiment using monochromatic light of wavelength , the intensity of light at a point on the screen where path difference is ,
is *K* units. What is the intensity of light at a point where path difference is /3?

Ans. Let I_1 *and* I_2 be the intensity of the two light waves. Their resultant intensities can be obtained as:

$$I' = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

Where,

ϕ = Phase difference between the two waves

For monochromatic light waves,

$I_1 = I_2$

$$\therefore I' = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$$

$$= 2I_1 + 2I_1\cos\phi$$

Phase difference = $\frac{2\pi}{\lambda} \times path\ difference$

Since path difference = λ ,

Phase difference, $\phi = 2\pi$

$$\therefore I' = 2I_1 + 2I_1 = 4I_1$$

Given,

$I' = K$

$\therefore I' = \frac{K}{4}$ ...(1)

When path difference $= \frac{\lambda}{3}$,

Phase difference, $\phi = \frac{2\pi}{3}$

Hence, resultant intensity, $I_R' = I_1 + I_1 + 2\sqrt{I_1 I_1}\cos\frac{2\pi}{3}$

$$= 2I_1 + 2I_1\left(-\frac{1}{2}\right) = I_1$$

Using equation (1), we can write:

$I_R = I_1 = \frac{K}{4}$

Hence, the intensity of light at a point where the path difference is $\frac{\lambda}{3}$ is $\frac{K}{4}$ units.

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7. A beam of light consisting of two wavelengths, 650 nm and 520 nm, is used to obtain interference fringes in a Young's double-slit experiment.
(a) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 650 nm.
(b) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?

Ans. Wavelength of the light beam,

$$\therefore x = 3 \times 650 \frac{D}{d} = 1950\left(\frac{D}{d}\right) nm$$

$n\lambda_2 = (n-1)\lambda_1$

$\lambda_1 = 650nm$

$\therefore n = 5$

Wavelength of another light beam, $\lambda_2 = 520nm$

Distance of the slits from the screen = D

Distance between the two slits = d

(a) Distance of the *n*th bright fringe on the screen from the central maximum is given by the relation,

$$x = n\lambda_1\left(\frac{D}{d}\right)$$

For third bright fringe. N=3

$$\therefore x = 3 \times 650 \frac{D}{d} = 1950\left(\frac{D}{d}\right) nm$$

(b) Let the *n*th bright fringe due to wavelength λ_2 and (*n* – 1)th bright fringe due to wavelength λ_1 coincide on the screen. We can equate the conditions for bright fringes as:

$$n\lambda_2 = (n-1)\lambda 1$$

520n=650n-650

650=130n

$\therefore n = 5$

Hence, the least distance from the central maximum can be obtained by the relation:

$$x = \lambda_2 \frac{D}{d}$$

Note: The value of *d* and *D* are not given in the question.

$$= 5 \times 520 \frac{D}{d} = 260 \frac{D}{d} nm$$

8.Explain how Corpuscular theory predicts the speed of light in a medium, say, water, to be greater than the speed of light in vacuum. Is the prediction confirmed by experimental determination of the speed of light in water? If not, which alternative picture of light is consistent with experiment?

Ans. No; Wave theory

Newton's corpuscular theory of light states that when light corpuscles strike the interface of two media from a rarer (air) to a denser (water) medium, the particles experience forces of attraction normal to the surface. Hence, the normal component of velocity increases while the component along the surface remains unchanged.

Hence, we can write the expression:

C sin i=v sin r

C sin i=v sin r

Where,

i = Angle of incidence

r = Angle of reflection

c = Velocity of light in air
v = Velocity of light in water
We have the relation for relative refractive index of water with respect to air as:

$$\mu = \frac{v}{c}$$

Hence, equation (i) reduces to

$$\frac{v}{c} = \frac{\sin i}{\sin r} = \mu$$

But, $\mu > 1$
Hence, it can be inferred from equation (ii) that $v > c$. This is not possible since this prediction is opposite to the experimental results of $c > v$.
The wave picture of light is consistent with the experimental results.

9.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?
(b) In what way is diffraction from each slit related to the interference pattern in a double-slit experiment?
(c) 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?
(d) Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily.
(e) Ray optics is based on the assumption that light travels in a straight line. Diffraction effects (observed when light propagates through small apertures/slits or around small obstacles) disprove 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?
Ans.(a) In a single slit diffraction experiment, if the width of the slit is made double the original width, then the size of the central diffraction band reduces to half and the intensity of the central diffraction band increases up to four times.
(b) The interference pattern in a double-slit experiment is modulated by diffraction from each slit. The pattern is the result of the interference of the diffracted wave from each slit.
(c) 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. This is because light waves are diffracted from the edge of the circular obstacle, which interferes constructively at the centre of the shadow. This constructive interference produces a bright spot.
(d) Bending of waves by obstacles by a large angle is possible when the size of the obstacle is comparable to the wavelength of the waves.

On the one hand, the wavelength of the light waves is too small in comparison to the size of the obstacle. Thus, the diffraction angle will be very small. Hence, the students are unable to see each other. On the other hand, the size of the wall is comparable to the wavelength of the sound waves. Thus, the bending of the waves takes place at a large angle. Hence, the students are able to hear each other.
(e) The justification is that in ordinary optical instruments, the size of the aperture involved is much larger than the wavelength of the light used.

10.Two towers on top of two hills are 40 km apart. The line joining them passes 50 m above a hill halfway between the towers. What is the longest wavelength of radio waves, which can be sent between the towers without appreciable diffraction effects?
Ans. Distance between the towers, *d* = 40 km
Height of the line joining the hills, *d* = 50 m.
Thus, the radial spread of the radio waves should not exceed 50 km.
Since the hill is located halfway between the towers, Fresnel's distance can be obtained as:
Z_P = 20 km = 2×10^4 m
Aperture can be taken as:
a = *d* = 50 m
Fresnel's distance is given by the relation,

$$Z_P = \frac{a^2}{\lambda}$$

Where,
λ = Wavelength of radio waves

$$\therefore \lambda = \frac{a^2}{Z_P}$$

$$= \frac{(50)^2}{2\times10^4} = 1250\times10^{-4}$$

$$= .1250m = 12.5cm$$

Therefore, the wavelength of the radio waves is 12.5 cm.Search