NCERT Solutions for Class-XII Physics

Chapter-10

NCERT Physics Class 12

1. 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 of water is 1.33.

1. Wavelength of incident monochromatic light, $\lambda = 589$ nm $= 589 \times 10^{-9}$ m

Speed of light in air, $c = 3 \times 10^8$ m/s

Refractive index of water, $\mu = 1.33$

(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,

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

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

$= 5.09 \times 10^{14}$ Hz

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.

(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, $v = 5.09 \times 10^{14}$ Hz

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

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

$$v' = \frac{3\times10^8}{1.33} = 2.26\times10^8 \text{ m/s}$$

Wavelength of light in water is given by the relation,

$$\lambda = \frac{v}{v}$$

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

$= 444.007 \times 10^{-9}$ m
$= 444.01$ nm
Hence, the speed, frequency and wavelength of refracted light are 2.26×10^{8} m/s, 444.01 nm and 5.09×10^{14} Hz respectively.

2. What is the shape of the wave-front in each of the following cases:
(a) Light diverging from a point source.
(b) Light emerging out of a convex lens when a point source is placed at its focus.
(c) The portion of the wave-front of light from a distant star intercepted by the Earth.

2. (a) Wave-front:
The locus of all the particles of the medium vibrating in the same phase at a given instant is called wave-front.
In case of light diverging from a point source, the shape of wave-front is a circle.

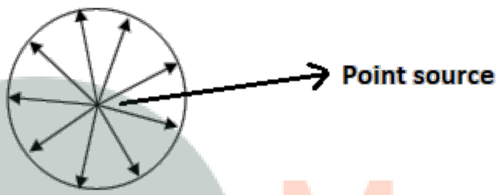


Figure of wave-front formed by a point source.
(b) In case of light emerging out of a convex lens when a point source is placed at its focus, the wave-front is a parallel grid.

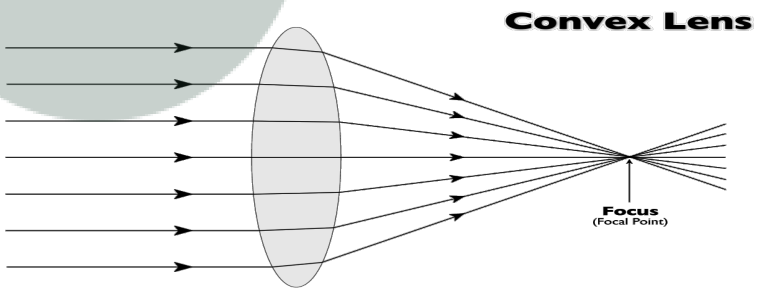


Fig: Light rays passing through a convex lens.

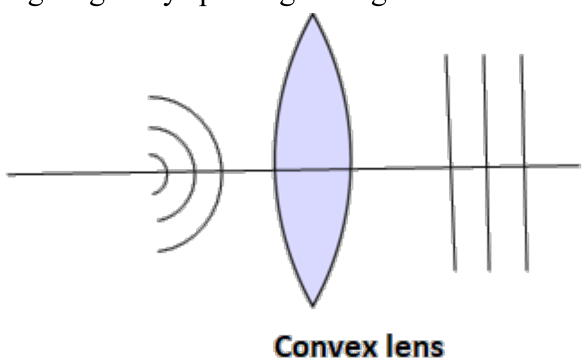
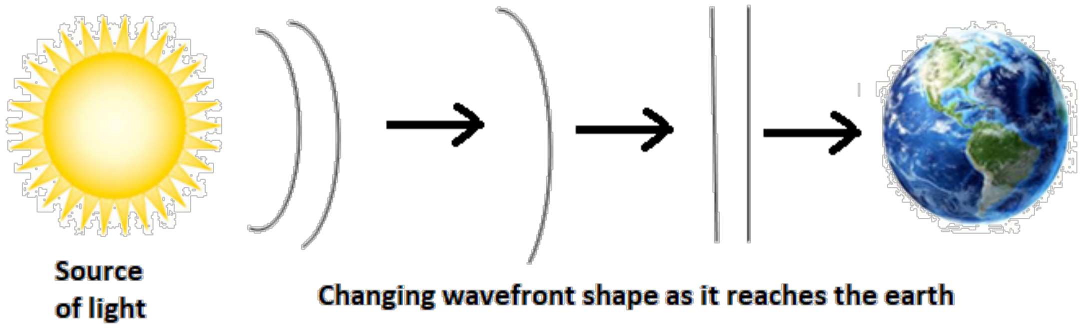


Figure of wave-front formed by a convex lens when point source is at its focus.
(c) When light source is a distance star intercepted by earth, the wave-front formed is a plane.



3. (a) The refractive index of glass is 1.5. What is the speed of light in glass? (Speed of light in vacuum is 3.0×10^8 m s^{-1})
(b) Is the speed of light in glass independent of the colour of light? If not, which of the two colours red and violet travels slower in a glass prism?

3. (a) Refractive index of glass, $\mu = 1.5$
Speed of light, $c = 3 \times 10^8$ m/s
Speed of light in glass is given by the relation,

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

$$= \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \, m/s$$

Hence, the speed of light in glass is 2×10^8 m/s.
(b) The speed of light in glass is not independent of the colour of light.
The refractive index ofc a violet component of white light is greater than the refractive index of a red component. Hence, the speed of violet light is less than the speed of red light in glass. Hence, violet light travels slower than red light in a glass prism.

4. In a Young's double-slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and the fourth bright fringe is measured to be 1.2 cm. Determine the wavelength of light used in the experiment.

4.

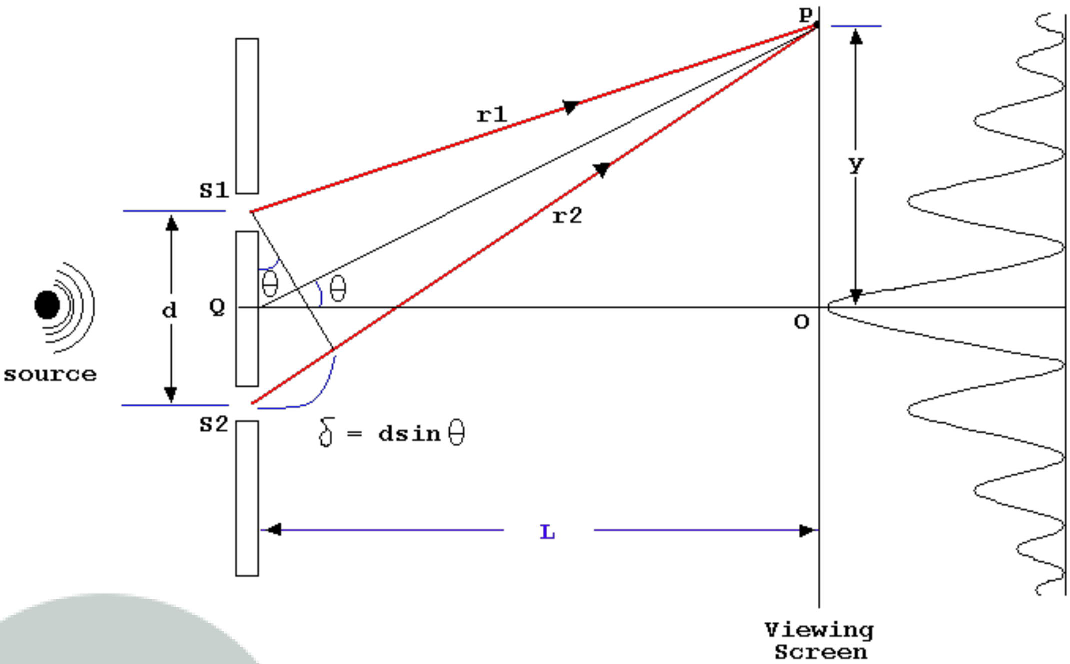


Figure showing bright fringes in Young's double slit experiment.

Given:

Distance between the slits (d) = 0.28 mm

Distance between the slits and the screen (D) = 1.4 m

Distance between the central bright fringe and fourth bright fringe (y_n) = 1.2 cm

where n is the order of the fringe, here, n = 4

λ = Wavelength of light used

From the formula,

$$\frac{dy_n}{D} = n\lambda$$

$$\Rightarrow \frac{0.28 \times 10^{-3}\,m}{\left(\frac{1.2 \times 10^{-2}\,m}{1.4\,m}\right)} = 4\lambda$$

λ = 142.8 nm

Hence, the wavelength of light used is 142.8 nm.

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

5. 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,

$I_1 = I_2$

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

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

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

Since path difference = λ,

Phase difference, $\phi = 2\pi$

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

Given, I' = K

Therefore, $I_1 = \frac{K'}{4}$ … (1)

When path difference = $\lambda/3$, the phase difference, $\phi = \frac{2\pi}{3}$

Hence, resultant intensity, $I'_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\frac{2\pi}{3}$

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

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 $\lambda/3$ is K/4 units.

6. 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?

6. Distance of n^{th} fringe from central maxima, $X_n = n\lambda D/d$

Where, λ is wavelength of light

D is distance from slits to screen

d is slit width

(a) We need to find distance of 3^{rd} from central maxima for wavelength 650 nm

n = 3

$x_3 = 3 \times (650 \text{ nm}) D/d$

(b) The distance of n^{th} bright fringe from central maxima for two wavelengths, say λ_1 and λ_2, are

$X_n = n\lambda_1 D/d$

$Y_n = n\lambda_2 D/d$

When bright fringe due to two wavelength coincide, their distance from central maxima is same

i.e., $X_n = Y_n$

$n_1\lambda_1 D/d = n_2\lambda_2 D/d$

$n_1\lambda_1 = n_2\lambda_2$

$n_1/n_2 = \lambda_2/\lambda_1$

$= 520 / 650 = 8/10$

Therefore, the bright fringe due to two wavelength coincide when n_1 is integer multiple of 8 and n_2 is integer multiple of 10.

Thus least distance for which they coincide,

$S = n_1 \lambda_1 D/d$

$= 8 \times (650 \text{ nm}) D/d$

[The question is not complete. This question cannot be answered completely without the values of d and D.]

7. In a double-slit experiment the angular width of a fringe is found to be 0.2° on a screen placed 1 m away. The wavelength of light used is 600 nm. What will be the angular width of the fringe if the entire experimental apparatus is immersed in water? Take refractive index of water to be 4/3.

7. Distance of the screen from the slits, D = 1 m

Wavelength of light used, $\lambda_1 = 600$ nm

Angular width of the fringe in air, $\theta_1 = 0.2°$

Angular width of the fringe in water = θ_2

Refractive index of water, $\mu = \frac{4}{3}$

Refractive index is related to angular width as:

$$\mu = \frac{\theta_1}{\theta_2}$$

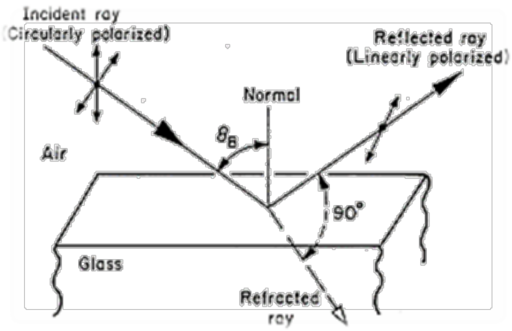
$$\theta_2 = \frac{3}{4}\theta_1$$

$$= \frac{3}{4} \times 0.2 = 0.15$$

Therefore, the angular width of the fringe in water will reduce to 0.15°.

8. What is the Brewster angle for air to glass transition? (Refractive index of glass = 1.5.)

8. Brewster's angle is angle of incidence of light on a refracting surface for which refracted and reflected light are linearly polarised. They are also perpendicular to each other.



According to Brewster's law when angle of incidence is Brewster angle, say θ_B,

$\tan(\theta_B) = \mu$

where μ is refractive index of the refracting medium

i.e., $\tan(\theta_B) = 1.5$

$\theta = \tan^{-1}(1.5)$

$= 56.3°$

9. Light of wavelength 5000 Å falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?

9. Wavelength of incident light, $\lambda = 5000$ Å $= 5000 \times 10^{-10}$ m

Speed of light, $c = 3 \times 10^8$ m

Frequency of incident light is given by the relation,

$$v = \frac{c}{\lambda} = \frac{3\times10^8}{5000\times10^{-10}} = 6\times10^{14}\,\text{Hz}$$

The wavelength and frequency of incident light is the same as that of reflected ray. Hence, the wavelength of reflected light is 5000 Å and its frequency is 6×10^{14} Hz.

When reflected ray is normal to incident ray, the sum of the angle of incidence, i and angle of reflection, r is 90°.

According to the law of reflection, the angle of incidence is always equal to the angle of reflection. Hence, we can write the sum as:

$\angle i + \angle r = 90$

$\angle i + \angle i = 90$

$$\angle i = \frac{90}{2} = 45°$$

Therefore, the angle of incidence for the given condition is 45°.

10. Estimate the distance for which ray optics is good approximation for an aperture of 4 mm and wavelength 400 nm.

10. An aperture illuminated by beam of light sends diffracted light. The distance travelled by diffracted beam at which, width of spread of central maxima ($z\lambda/a$) equals the size of the aperture (a) is called the Fresnel distance(Z_F). Beyond this distance, ray optics is good approximation for an optical measurement.

For a light wave of given wavelength, say λ, and an aperture of length 'a' length, Fresnel distance,

$Z_F = a^2/\lambda$

a = size of aperture

λ = wavelength of light

Given,

$a = 4 \text{ mm} = 4 \times 10^{-3}$ m

$\lambda = 400 \times 10^{-9}$ m

Thus, $Z_F = (4 \times 10^{-3})^2 / 400 \times 10^{-9}$

= 40 m

For distance greater than 40 m, ray optics is valid.