#421342

Topic: Huygen's Principle

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.

Solution

(a) Reflected light: (wavelength, frequency, speed same as incident light)

Since, $\lambda = 589nm,\ c = 3.00\times10^{8} m\, s^{-1}$

Now, $\nu = \dfrac{c}{\lambda} = \dfrac{3\times10^{8}}{589\times10^{-9}}$ = $5.09\times10^{14}s^{-1}$

(b) Refracted light: (frequency same as the incident frequency)

$\nu = 5.09\times10^{14}Hz,\ v = (c/n) = 2.26\times10^{8}ms^{-1}, \lambda = (v/\nu) = 444nm$

#421346

Topic: Huygen's Principle

What is the shape of the wavefront 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 wavefront of light from a distant star intercepted by the Earth.

Solution

(a) Spherical. The shape of the wavefront in light diverging from a point source is spherical.

(b) Plane. The shape of the wavefront in case of a light emerging out of a convex lens when a point source is placed at its focus is a parallel grid.

(c) Plane (a small area on the surface of a large sphere is nearly planar). The portion of the wavefront of light from a distant star intercepted by the Earth is a plane.

#421434

Topic: Interference

In a Youngs 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 brigh fringe is measured to be 1.2 cm. Determine the wavelength of light used in the experiment.

Solution

Distance between the slits, $d = 0.28\times10^{-3}\ m$

Distance between the slits and the screen, $D = 1.4m$

Distance between the central fringe and the fourth $(n=4)$ fringe,

$u = 1.2\times10^{-2}\ m$

In case of a constructive interference, we have the relation for the distance between the two fringes as:

$u = n\lambda D/d$

$\Rightarrow \lambda = ud/nD = 6\times10^{-7}m = 600nm$

#421437

Topic: Interference

In Youngs 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 λ/3?

Solution

For monochromatic light, $I_1 + I_2$ is the intensity.

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

Phase difference is $2\pi \times path\ difference/\lambda$

$\phi = 2\pi\times\lambda/\lambda = 2\pi \Rightarrow I' = 4I_1$

given $I' = K, I_1 = K/4, path\ difference = \lambda/3$

phase difference is $2\pi\times1/3$

Hence, $I = I_1 + I_2 + 2\sqrt{I_1 I_2}cos2\pi/3$

$\Rightarrow I = I_1 = K/4$

#421441

Topic: Interference

A beam of light consisting of two wavelengths, 650 nm and 520 nm, is used to obtain interference fringes in a Youngs 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?

Solution

(a). $\lambda_1 = 650nm; \lambda_2 = 520nm$

Distance between slits and the screen is D.

Distance between two slit is d

Let the nth bright fringe on the screen from the central maximum is given by $x = n\lambda_1 D/d$

now, $n = 3$

$\Rightarrow x = 1950D/d\,mm$

The value of $D\ and\ d$ is not given in the question.

(b). Let nth fringe due to wavelength λ_2 and (n-1)th due to λ_1 coincide on screen.

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

$\Rightarrow n = 5$

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

$x = n\lambda_2 D/d = 2600D/d$

No value of D and d are given.

#421450

Topic: Interference

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 wid of the fringe if the entire experimental apparatus is immersed in water? Take refractive index of water to be 4/3.

Solution

Distance of screen from slits $D = 1m$

$\lambda_1 = 600nm$

Angular width of fringe in air, $\theta_1 = 0.2^0$

Angular width of fringe in air, θ_2

$\mu = 4/3$

Refractive index is related to angular width by,

$\mu = \frac{\theta_1}{\theta_2} \Rightarrow \theta_2 = 0.15^o$

#421452

Topic: Polarisation

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

Solution

$\mu = 1.5$

brewster angle is θ

$tan\theta = \mu$

Brewster angle $\theta = 56.31^o$

#421455

Topic: Diffraction

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

Solution

Fresnel distance $2f = a^2/\lambda = 40m$

where $a = 4\times10^{-3}, \lambda = 400\times10^{-9}m$

The distance for which the ray optics is a good approximation is 40m.

#421464

Topic: Doppler Effect

The 6563 $\mathring{A}$ H_α line emitted by hydrogen in a star is found to be red-shifted by 15 $\mathring{A}$. Estimate the speed with which the star is receding from the Earth.

Solution

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

$\lambda^{'} - \lambda = 15\mathring{A} = 15 \times 10^{-10}m$

From the given values, $v = 6.86 \times 10^5 ms^{-1}$

#421471

Topic: Huygen's Principle

You have learnt in the text how Huygens principle leads to the laws of reflection and refraction. Use the same principle to deduce directly that a point object placed in front of a plane mirror produces a virtual image whose distance from the mirror is equal to the object distance from the mirror.

Solution

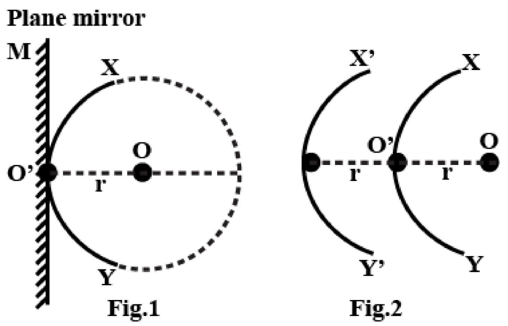
Let an object at O be placed in front of a plane mirror MO' at a distance r, (as shown in the given figure 1).

A circle is drawn from the centre (O) such that it just touches the plane mirror at point O'.

According to Huygens' Principle, XY is the wavefront of incident light.

If the mirror is absent, then a similar wavefront X'Y' (as XY) would form behind O' at distance r (as shown in the given figure 2).

X'Y' can be considered as a virtual reflected ray for the plane mirror. Hence, a point object placed in front of the plane mirror produces a virtual image whose distance from the mirror is equal to the object distance (r).



#421490

Topic: Doppler Effect

For sound waves, the Doppler formula for frequency shift differs slightly between the two situations: (i) source at rest; observer moving, and (ii) source moving; observer at rest. The exact Doppler formulas for the case of light waves in vacuum are, however, strictly identical for these situations. Explain why this should be so. Would you expect the formulas to be strictly identical for the two situations in case of light travelling in a medium?

Solution

No.

Sound waves can propagate only through a medium. The two given situations are not scientifically identical because the motion of an observer relative to a medium is different in the two situations. Hence, the Doppler formulas for the two situations cannot be the same.

In case of light waves, sound can travel in a vacuum. In a vacuum, the above two cases are identical because the speed of light is independent of the motion of the observer and the motion of the source. When light travels in a medium, the above two cases are not identical because the speed of light depends on the wavelength of the medium.

#421492

Topic: Interference

In double-slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1°. What is the spacing between the two slits?

Solution

Wavelength of light used, $\lambda = 600 \times 10^{-9}m$

Angular width of fringe, $\theta = 0.1^o = 0.1\pi/180$

Angular width of a fringe is related to slit spacing as $d = \lambda/\theta = 3.44 \times 10^{-4}m$

So, the spacing between the slits is $3.44 \times 10^{-4}m$

#421497

Topic: Diffraction

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?

Solution

(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.

#421514

Topic: Diffraction

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?

Solution

Distance between the towers is 40km.

Height of the line joining the hills is $d = 50m$.

Thus, the radial spread of the radio waves should not exceed 50 m.

Since the hill is located halfway between the towers, Fresnel's distance can be obtained.

$Z_P = 20km$

Aperture is $a = d = 50m$

Fresnel's distance is given by the relation,

$Z_P = a^2/\lambda = 2 \times 10^4$

$\lambda = a^2/Z_P = 12.5cm$

#421517

Topic: Diffraction

A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m away. It is observed that the first minimum i at a distance of 2.5 mm from the centre of the screen. Find the width of the slit.

Solution

Wavelength of light beam, λ

Distance of the screen from the slit, $D = 1m$

For first minima, $n = 1$

Distance between the slits is d

Distance of the first minimum from the centre of the screen can be obtained as, $x = 2.5mm = 2.5 \times 10^{-3}$

Now, $n\lambda = xd/D$

$\Rightarrow d = n\lambda D/x = 0.2mm$

Therefore, the width of the slits is 0.2 mm.

#421519

Topic: Interference

Answer the following questions:

(a) When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.

(b) 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?

Solution

(a) Weak radar signals sent by a low flying aircraft can interfere with the TV signals received by the antenna. As a result, the TV signals may get distorted. Hence, when a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen.

(b) The principle of linear superposition of wave displacement is essential to our understanding of intensity distributions and interference patterns. This is because superpositic follows from the linear character of a differential equation that governs wave motion. If $y_1 \ and \ y_2$ are the solutions of the second order wave equation, then any linear combination of $y_1 \ and \ y_2$ will also be the solution of the wave equation.

#421537

Topic: Diffraction

In deriving the single slit diffraction pattern, it was stated that the intensity is zero at angles of nλ/a. Justify this by suitably dividing the slit to bring out the cancellation.

Solution

Consider that a single slit of width d is divided into n smaller slits.

Width of each slit, $d_1 = d/n$

Angle of diffraction is given by the relation,

$\theta = (d\lambda/d_1)/d = \lambda/d_1$

Now, each of these infinitesimally small slit sends zero intensity in direction θ. Hence, the combination of these slits will give zero intensity.