NCERT solutions for class 11 Physics Chapter 15 Waves

Q.15.1 A string of mass $2.50\ kg$ is under a tension of $200\ N$. The length of the stretched string is $20.0\ m$. If the transverse jerk is struck at one end of the string, how long does the disturbance take to reach the other end?

Answer:

Mass per unit length of the string is

$$\mu = \frac{M}{l}$$
$$= \frac{2.50}{20}$$
$$= 0.125\ kg\ m^{-1}$$

The velocity of the transverse wave in the string will be

$$v = \sqrt{\frac{T}{\mu}}$$
$$= \sqrt{\frac{200}{0.125}}$$
$$= \sqrt{1600}$$
$$= 40\ m\ s^{-1}$$

Time taken by the disturbance to travel from one end to the other is

$$t = \frac{l}{v}$$
$$= \frac{20}{40}$$
$$= 0.5\ s$$

Q.15.2 A stone dropped from the top of a tower of height $300\ m$ splashes into the water of a pond near the base of the tower. When is the splash heard at the top given that the speed of sound in air is $340\ m\ s^{-1}$? $(g = 9.8\ m\ s^{-2})$

Answer:

Time taken by the stone to the pond can be calculated using the second equation of motion

s = 300 m

u = 0

a = 9.8 m s $^{-2}$

$$s = ut_1 + \frac{1}{2}at_1^2$$
$$300 = 4.9t_1^2$$
$$t_1 = 7.82\ s$$

Time taken by the wave to propagate from the pond to the top of the tower is

$$t_2 = \frac{300}{340}$$
$$t_2 = 0.88\ s$$

$t_1 + t_2 = 8.7$ s

The splash is heard at the top of the tower after a time of 8.7 seconds.

Q.15.3 A steel wire has a length of $12.0\ m$ and a mass of $2.10\ kg$. What should be the tension in the wire so that speed of a transverse wave on the wire equals the speed of sound in dry air at $20^oC = 343\ m\ s^{-1}$.

Answer:

Mass per unit length od the wire is

$$\mu = \frac{M}{l}$$
$$= \frac{2.10}{12}$$
$$= 0.175\ kg\ m^{-1}$$

The speed of a transverse wave in a wire is given by

$$v = \frac{T}{\mu}$$
$$343 = \sqrt{\frac{T}{01.175}}$$
$$T = 343^2 \times 0.175$$
$$T = 2.059 \times 10^4\ N$$

The tension in the wire should be $2.059 \times 10^4\ N$ such that the speed of the transverse wave in it is equal to 343 m s $^{-1}$.

Q.15.4 (a) Use the formula $v = \sqrt{\frac{\gamma P}{\rho}}$ to explain why the speed of sound in air is independent of pressure

Answer:

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

Where $\gamma\ and\ \rho$ are the Bulk's modulus and the density respectively

As we know

$$\rho = \frac{M}{V}$$

where M is molecular weight of air and V is the volume of 1 mole of air

$$v = \sqrt{\frac{\gamma P}{\rho}}$$
$$v = \sqrt{\frac{\gamma PV}{M}}$$

From the ideal gas equation PV=nRT

since we are talking about 1 mole we take n = 1

PV=RT

The expression for the speed of sound becomes

$$v = \sqrt{\frac{\gamma RT}{M}}$$

γ , M and R are constant therefore at constant Temperature the speed of sound in the air do not change and it is clear that speed is independent of velocity.

Q.15.4 (b) Use the formula $v = \sqrt{\frac{\gamma P}{\rho}}$ to explain why the speed of sound in air increases with temperature.

Answer:

From the equation $v = \sqrt{\frac{\gamma RT}{M}}$ it is clear that the speed of sound is linearly proportional to the square root of the temperature and therefore it will increase with the increase in temperature.

Q.15.4 (c) Use the formula $v = \sqrt{\frac{\gamma P}{\rho}}$ to explain why the speed of sound in air

(c) increases with humidity.

Answer:

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

As the humidity of air increases, the proportion of water molecules(M=18) increases and that of Oxygen(M=32) and Nitrogen(M=28) decreases thus reducing the density of air and as the speed of sound is inversely proportional to the square root of density of air, the speed will increase as the density increases and thus it increases with an increase in humidity.

Q.15.5 (a) You have learnt that a travelling wave in one dimension is represented by a function $y = f(x, t)$ where x and t must appear in the combination $x - v\ t$ or $x + v\ t$, i.e. $y = f(x \pm v\ t)$. Is the converse true? Examine if the following functions for y can possibly represent a travelling wave :

$(a)\ (x - vt)^2$

Answer:

No, the given function cannot represent a wave as x or t approach infinity the function won't be converging to a constant value and therefore the converse is not true.

Q.15.5 (b) You have learnt that a travelling wave in one dimension is represented by a function $y = f(x, t)$ where x and t must appear in the combination $x - v\ t$ or $x + v\ t$, i.e. $y = f(x \pm v\ t)$. Is the converse true? Examine if the following functions for y can possibly represent a travelling wave :

$(b) log\ [(x+vt)/x_0]$

Answer:

No, the given function cannot represent a travelling wave because as x and t become zero the given function won't be converging to a constant value and therefore the converse is not true.

Q.15.5 (c) You have learnt that a travelling wave in one dimension is represented by a function $y = f(x, t)$ where x and t must appear in the combination $x - v\ t$ or $x + v\ t$, i.e. $y = f(x \pm v\ t)$. Is the converse true? Examine if the following functions for y can possibly represent a travelling wave :

$(c) 1/(x+vt)$

Answer:

No, the given function cannot represent a travelling wave because as x and t become zero the given function won't be converging to a constant value and therefore the converse is not true.

Q.15.6 A bat emits ultrasonic sound of frequency $1000\ kHz$ in air. If the sound meets a water surface, what is the wavelength of (a) the reflected sound, (b) the transmitted sound? Speed of sound in air is $340\ m\ s^{-1}$ and in water $1486\ m\ s^{-1}$.

Answer:

(a) The wavelength of the reflected sound wave which will be travelling in air is

$$\lambda_a = \frac{v_a}{\nu}$$
$$\lambda_a = \frac{340}{10^6}$$
$$\lambda_a = 3.4 \times 10^{-4}\ m$$

(b) The frequency of the transmitted sound wave would not change.

The wavelength of the transmitted sound wave which will be travelling in water is

$$\lambda_w = \frac{v_w}{\nu}$$
$$\lambda_w = \frac{1486}{10^6}$$
$$\lambda_w = 1.49 \times 10^{-3}\ m$$

Q.15.7 A hospital uses an ultrasonic scanner to locate tumours in a tissue. What is the wavelength of sound in the tissue in which the speed of sound is $1.7\ km\ s^{-1}$? The operating frequency of the scanner is $4.2\ MHz$.

Answer:

The wavelength of the sound in the tissue is

$$\lambda = \frac{V}{\nu}$$
$$\lambda = \frac{1.7 \times 10^3}{4.2 \times 10^6}$$
$$\lambda = 4 \times 10^{-4}\ m$$

Q.15.8 (a) A transverse harmonic wave on a string is described by

$$y(x,t) = 3.0\ \sin(36\ t + 0.018\ x + \pi/4)$$

where x and y are in cm and t in s. The positive direction of x is from left to right.

(a) Is this a travelling wave or a stationary wave? If it is travelling, what are the speed and direction of its propagation?

Answer:

The wave is travelling.

$$y(x,t) = Asin(kx + \omega t + \phi)$$

The wave is travelling in the negative x-direction i.e. from right to left.

$$\omega = 36\ rad\ s^{-1}$$
$$k = 0.018\ cm^{-1}$$

Speed of the wave is

$$v = \frac{\omega}{k}$$
$$v = \frac{36 \times 10^{-2}}{0.018}$$
$$v = 20\ m\ s^{-1}$$

Q.15.8 (b) A transverse harmonic wave on a string is described by

$$y(x,t) = 3.0\ \sin(36\ t + 0.018\ x + \pi/4)$$

where x and y are in cm and t in s. The positive direction of x is from left to right.

(b) What are its amplitude and frequency?

Answer:

Amplitude A is 3.0 cm.

Frequency is

$$\nu = \frac{\omega}{2\pi}$$
$$\nu = \frac{36}{2\pi}$$
$$\nu = 5.73\ Hz$$

Q.15.8 (c) A transverse harmonic wave on a string is described by

$y(x,t) = 3.0\ \sin(36\ t + 0.018\ x + \pi/4)$

where x and y are in cm and t in s. The positive direction of x is from left to right.

(c) What is the initial phase at the origin?

Answer:

The initial phase of the wave at the origin (at x = 0 and t = 0) is $\frac{\pi}{4}$

Q.15.8 (d) A transverse harmonic wave on a string is described by

$y(x,t) = 3.0\ \sin(36\ t + 0.018\ x + \pi/4)$

where x and y are in cm and t in s. The positive direction of x is from left to right.

(d) What is the least distance between two successive crests in the w ave?

Answer:

The difference between two consecutive crests is equal to the wavelength of the wave.

$$\lambda = \frac{2\pi}{k}$$
$$\lambda = \frac{2\pi \times 10^{-2}}{0.018}$$
$$\lambda = 3.49\ m$$

Q.15.9 For the wave described in Exercise 15.8, plot the displacement (y) versus (t) graphs for $x = 0$, 2 and 4 cm. What are the shapes of these graphs? In which aspects does the oscillatory motion in travelling wave differ from one point to another: amplitude, frequency or phase?

Answer:

$y(x,t) = 3.0sin(36t + 0.018x + \frac{\pi}{4})$

for x = 0

$$y(t) = 3.0sin(36t + \frac{\pi}{4})$$

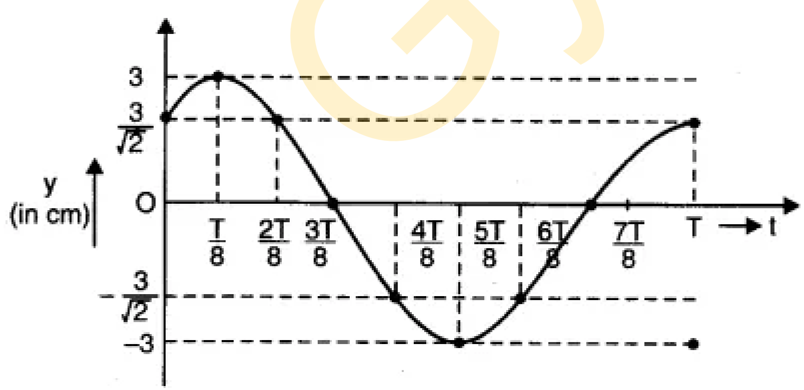
The time period of oscillation is T

$$T = \frac{\pi}{18}\ s$$

To make the y versus t graph we tabulate values of y(t) at different values of t as follows

t	0	$\frac{T}{8}$	$\frac{T}{4}$	$\frac{3T}{8}$	$\frac{T}{2}$	$\frac{5T}{8}$	$\frac{3T}{4}$	$\frac{7T}{8}$	T
$y(t)$	$\frac{3}{\sqrt{2}}$	3	$\frac{3}{\sqrt{2}}$	0	$\frac{-3}{\sqrt{2}}$	-3	$\frac{-3}{\sqrt{2}}$	0	$\frac{3}{\sqrt{2}}$

The graph of y versus t is as follows



For other values of x, we will get a similar graph. Its time period and amplitude would remain the same, it just will be shifted by different amounts for different values of x.

Q.15.10 (a) For the travelling harmonic wave

$y(x,t) = 2.0\ \cos 2\pi(10t - 0.0080\ x + 0.35)$

where x and y are in cm and t in s. Calculate the phase difference between oscillatory motion of two points separated by a distance of $(a)\ 4\ m$

Answer:

The phase difference between two points separated by a distance of Δx is given by

$\Delta\phi = k\Delta x$

$y(x,t) = 2.0\ \cos 2\pi(10t - 0.0080\ x + 0.35)$

$k = 2\pi \times 0.008\ cm^{-1}$

Phase difference for two points separated by a distance of 4 m would be

$\Delta\phi = 2\pi \times 0.0080 \times 4 \times 100$
$\Delta\phi = 6.4\pi\ rad$

Q.15.10 (b) For the travelling harmonic wave

$y(x,t) = 2.0\ \cos 2\pi(10t - 0.0080\ x + 0.35)$

where x and y are in cm and t in s. Calculate the phase difference between oscillatory motion of two points separated by a distance of

$(b)\ 0.5\ m$

Answer:

The phase difference between two points separated by a distance of Δx is given by

$\Delta\phi = k\Delta x$

$$y(x,t) = 2.0\ \cos 2\pi(10t - 0.0080\ x + 0.35)$$

$$k = 2\pi \times 0.008\ cm^{-1}$$

Phase difference for two points separated by a distance of 0.5 m would be

$$\Delta\phi = 2\pi \times 0.0080 \times 0.8 \times 100$$
$$\Delta\phi = 0.8\pi\ rad$$

Q.15.10 (c) For the travelling harmonic wave

$$y(x,t) = 2.0\ \cos 2\pi(10t - 0.0080\ x + 0.35)$$

where x and y are in cm and t in s. Calculate the phase difference between oscillatory motion of two points separated by a distance of $(c)\lambda/2$

Answer:

The phase difference between two points separated by a distance of Δx is given by

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$

Phase difference for two points separated by a distance of $\frac{\lambda}{2}$ would be

$$\Delta\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{2}$$
$$\Delta\phi = \pi\ rad$$

Q.15.10 (d) For the travelling harmonic wave

$$y(x,t) = 2.0\ \cos 2\pi(10t - 0.0080\ x + 0.35)$$

where x and y are in cm and t in s. Calculate the phase difference between oscillatory motion of two points separated by a distance of $(d)3\lambda/4$

Answer:

The phase difference between two points separated by a distance of Δx is given by

$$\Delta\phi = \frac{2\pi}{\lambda}\Delta x$$

Phase difference for two points separated by a distance of $\frac{3\lambda}{4}$ would be

$$\Delta\phi = \frac{2\pi}{\lambda} \times \frac{3\lambda}{4}$$

$$\Delta\phi = \frac{3\pi}{2}\ rad$$

Q.15.11 The transverse displacement of a string (clamped at its both ends) is given by

$$y(x,t) = 0.06\ \sin(\frac{2\pi}{3}x)\cos(120\ \pi t)$$

where x and y are in m and t in s. The length of the string is 1.5 m and its mass is $3.0 \times 10^{-2}\ kg$.

Answer the following :

(a) Does the function represent a travelling wave or a stationary wave?

Answer:

The given function is of the following form

$$y(x,t) = 2Asin\ (kx)\,cos(\omega t)$$

which is the general equation representing a stationary wave and therefore the given function represents a stationary wave.

Q.15.11 (b) The transverse displacement of a string (clamped at its both ends) is given by $y(x,t) = 0.06\ \sin(\frac{2\pi}{3}x)\cos(120\ \pi t)$

where x and y are in m and t in s. The length of the string is 1.5 m and its mass is $3.0 \times 10^{-2}\ kg$.

Answer the following :

(b) Interpret the wave as a superposition of two waves travelling in opposite directions. What is the wavelength, frequency, and speed of each wave?

Answer:

We know that when two waves of the same amplitude, frequency and wavelength travelling in opposite directions get superimposed we get a stationary wave.

$y_1 = asin(kx - \omega t)$

$y_2 = asink(\omega t + kx)$

Comparing the given function with the above equations we get

$$k = \frac{2\pi}{3}$$
$$\lambda = \frac{2\pi}{k}$$
$$\lambda = 3\ m$$

$$\omega = 120\pi$$
$$\nu = \frac{\omega}{2\pi}$$
$$\nu = 60\ Hz$$

$$v = \nu\lambda$$
$$v = 60 \times 3 = 180\ m\ s^{-1}$$

Q.15.11 (c) The transverse displacement of a string (clamped at its both ends) is given by $y(x,t) = 0.06\ \sin(\frac{2\pi}{3}x)\cos(120\ \pi t)$

where x and y are in m and t in s. The length of the string is 1.5 m and its mass is $3.0 \times 10^{-2}\ kg$.

Answer the following :

(c) Determine the tension in the string

Answer:

The mass per unit length of the string is

$$\mu = \frac{M}{l}$$
$$\mu = \frac{3 \times 10^{-2}}{1.5}$$
$$\mu = 0.02\ kg\ m^{-1}$$

Speed of a transverse wave is given by

$$v = \sqrt{\frac{T}{\mu}}$$
$$T = \mu v^2$$
$$T = 0.02 \times (180)^2$$
$$T = 648\ N$$

15.12) For the wave on a string described in Exercise 15.11, do all the points on the string oscillate with the same (a) frequency, (b) phase, (c) amplitude? Explain your answers. (ii) What is the amplitude of a point 0.375 m away from one end?

Answer:

(i) (a) All the points vibrate with the same frequency of 60 Hz.

(b) They all have the same phase as it depends upon time.

(c) At different points, the amplitude is different and is equal to A(x) given by

$$A(x) = 0.06 sin(\frac{2\pi}{3}x)$$

(ii)

Q.15.13 Given below are some functions of x and t to represent the displacement (transverse or longitudinal) of an elastic wave. State which of these represent (i) a travelling wave, (ii) a stationary wave or (iii) none at all:

$(a)\ y = 2\ \cos(3x)\sin(10t)$

$(b)\ y = 2\sqrt{x - vt}$

$(c) y = 3\sin(5x - 0.5t) + 4\ \cos(5x - 0.5t)$

$(d)\ y = \cos x\ \ \sin t + \cos 2x\ \ \sin\ 2t$

Answer:

(a) It represents a stationary wave.

(b) The given function does not represent a wave as we can see at certain values of x and t the function would not be defined.

(c) It represents a travelling wave.

(d) It represents a stationary wave. It is a superposition of two stationary waves which ultimately results in another stationary wave.

Q.15.14 A wire stretched between two rigid supports vibrates in its fundamental mode with a frequency of $45\ Hz$. The mass of the wire is $3.5 \times 10^{-2}\ kg$ and its linear mass density is $4.0 \times 10^{-2}\ kg\ m^{-1}$. What is **(a)** the speed of a transverse wave on the string?

Answer:

Length of the string is l given by

$$l = \frac{M}{\mu}$$
$$l = \frac{3.5 \times 10^{-2}}{4 \times 10^{-2}}$$
$$l = 0.875m$$

Since the wire is vibrating in the fundamental mode

$$l = \frac{\lambda}{2}$$
$$\lambda = 2l$$
$$\lambda = 2 \times 0.875$$
$$\lambda = 1.75m$$

Speed of the string (v) is

$$v = \nu l$$
$$v = 45 \times 1.75$$
$$v = 78.75\ ms^{-1}$$

Q.15.14 (b) A wire stretched between two rigid supports vibrates in its fundamental mode with a frequency of $45\ Hz$. The mass of the wire is $3.5 \times 10^{-2}\ kg$ and its linear mass density is $4.0 \times 10^{-2}\ kg\ m^{-1}$. What is **(b)** the tension in the string?

Answer:

Tension in the string is given by

$$T = \mu v^2$$
$$T = 4 \times 10^{-2} \times (78.75)^2$$
$$T = 248.0625\ N$$

Q.15.15 A metre-long tube open at one end, with a movable piston at the other end, shows resonance with a fixed frequency source (a tuning fork of frequency $340\ Hz$) when the tube length is $25.5\ cm$ or $79.3\ cm$. Estimate the speed of sound in air at the temperature of the experiment. The edge effects may be neglected.

Answer:

The pipe behaves as a pipe open at one end and closed at one end. Such a pipe would produce odd harmonics i.e.

$$\nu = (2n-1)\frac{v}{4l_n}$$

Two consecutive modes of vibration are given in the question

For l_1 = 25.5 cm

$$\nu = (2n-1)\frac{v}{4l_1}$$

For l_2 = 79.3 cm

$$\nu = (2(n+1)-1)\frac{v}{4l_2}$$
$$\nu = (2n+1)\frac{v}{4l_2}$$

Since at both these modes the system resonates with the same frequency we have

(our approximation is correct since the edge effects may be neglected)

$$\nu = \frac{v}{4l_1}$$
$$v = 340 \times 4 \times 0.255$$
$$v = 346.8\ ms^{-1}$$

Q.15.16 A steel rod $100\ cm$ long is clamped at its middle. The fundamental frequency of longitudinal vibrations of the rod are given to be $2.53\ kHz$. What is the speed of sound in steel?

Answer:

When the rod is clamped at the middle at is vibrating in the fundamental mode, a node is formed at the middle of the rod and antinodes at the end. i.e.

$$\frac{L}{2} = \frac{\lambda}{4}$$
$$\lambda = 2L$$
$$\lambda = 0.2m$$

where L is the length of the rod.

Speed of sound in steel is

$$v = \nu\lambda$$
$$v = 2.53 \times 10^3 \times 0.2$$
$$v = 5060ms^{-1}$$

Q.15.17 A pipe $20\ cm$ long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a source? Will the same source be in resonance with the pipe if both ends are open? (speed of sound in air is $340\ m\ s^{-1}$).

Answer:

Let the n^{th} harmonic mode of the pipe get resonantly excited by a 430 Hz source.

$$\frac{(2n-1)v}{4l} = \nu$$
$$2n - 1 = \frac{430 \times 4 \times 0.2}{340}$$
$$n = 1$$

The pipe resonates with a 430 Hz source in the fundamental mode when one end is open.

Let the m th harmonic mode of the pipe get resonantly excited by a 430 Hz source when both ends are open.

$$\lambda = \frac{2l}{m}$$
$$m = \frac{2l\nu}{v}$$
$$m = \frac{2 \times 0.2 \times 430}{340}$$
$$m = 0.5$$

Since m is coming out to be less than 1 the same source **will not be in resonance** with the pipe if both ends are open.

Q.15.18 Two sitar strings A and B playing the note 'Ga' are slightly out of tune and produce beats of frequency $6\ Hz$. The tension in the string A is slightly reduced and the beat frequency is found to reduce to $3\ Hz$. If the original frequency of A is $324\ Hz$, what is the frequency of B?

Answer:

$$\nu_A = 324Hz$$
$$Beat\ frequency(b) = 6Hz$$
$$\nu_B = \nu_A \pm b$$
$$\nu_B = 318Hz$$
$$or$$
$$\nu_B = 330Hz$$

Since frequency increases with an increase in Tension, the frequency of string A must have decreased. Therefore $\nu_B = 318 Hz$.(If it were 330 Hz the beat frequency would have increased with decrease in Tension in string A)

Q.15.19 Explain why (or how) :

(a) in a sound wave, a displacement node is a pressure antinode and vice versa,

Answer:

In the propagation of a sound wave the pressure increases at points where displacement decreases, Therefore maximum pressure at points of minimum displace and vice-versa i.e. a displacement node is a pressure antinode and vice versa.

Q.15.19 Explain why (or how) :

(b) bats can ascertain distances, directions, nature, and sizes of the obstacles without any "eyes",

Answer:

Bats emit ultrasonic waves and when these waves strike the obstacles and get reflected back to the bats they ascertain distances, directions, nature, and sizes of the obstacles without any "eyes".

Q.15.19 Explain why (or how) :

(c) a violin note and sitar note may have the same frequency, yet we can distinguish between the two notes,

Answer:

We can distinguish between the two notes with the same frequency as the harmonics they emit are different.

Q.15.19 (d) Explain why (or how) :

(d) solids can support both longitudinal and transverse waves, but only longitudinal waves can propagate in gases,

Answer:

Transverse waves produce shear, gases don't have shear modulus and cannot sustain shear and therefore can only propagate longitudinal waves. Solids have both shear and bulk modulus of elasticity and can propagate both transverse and longitudinal waves.

Q.15.19 (e) Explain why (or how): the shape of a pulse gets distorted during propagation in a dispersive medium.

Answer:

As we know a pulse contains waves of different wavelengths, these waves travel at different speeds in a dispersive medium and thus the shape of the pulse gets distorted.

Q.15.20 A train, standing at the outer signal of a railway station blows a whistle of frequency $400\ Hz$ in still air. (i) What is the frequency of the whistle for a platform observer when the train (a) approaches the platform with a speed of $10\ m\ s^{-1}$, (b) recedes from the platform with a speed of $10\ m\ s^{-1}$? (ii) What is the speed of sound in each case ? The speed of sound in still air can be taken as $340\ m\ s^{-1}$.

Answer:

$$\nu_o = \left(\frac{v \pm v_o}{v \pm v_s}\right) \nu$$

where ν_o is the frequency as observed by the observer, ν is the frequency of the source, v is the speed of the wave, v_o is the speed of the observer and v_s is the speed of the source.

(i) (a) When the source is moving towards the observer and the observer is stationary.

$$\nu_o = \left(\frac{v}{v - v_s}\right)\nu$$
$$\nu_o = \frac{340}{340 - 10} \times 400$$
$$\nu_o = 412 Hz$$

(b)

$$\nu_o = \left(\frac{v}{v + v_s}\right)\nu$$
$$\nu_o = \frac{340}{340 + 10} \times 400$$
$$\nu_o = 389 Hz$$

(ii) The speed of the sound does not change as it is independent of the speed of observer and source and remains equal to 340 ms^{-1}.

Q.15.21 A train, standing in a station-yard, blows a whistle of frequency $400\ Hz$ in still air. The wind starts blowing in the direction from the yard to the station with a speed of $10\ m\ s^{-1}$. What are the frequency, wavelength, and speed of sound for an observer standing on the station's platform? Is the situation exactly identical to the case when the air is still and the observer runs towards the yard at a speed of $10\ m\ s^{-1}$? The speed of sound in still air can be taken as $340\ m\ s^{-1}$

Answer:

Speed of the wind v_w = 10 m s^{-1}

Speed of sound in still air v_a = 340 m s^{-1}

Effective speed with which the wave reaches the observer = v = $v_w + v_a$ = 10 + 340= 350 m s^{-1}

There is no relative motion between the observer and the source and therefore the frequency heard by the observer would not change.

The wavelength of the sound as heard by the observer is

$$\lambda = \frac{v}{\nu}$$
$$\lambda = \frac{350}{400}$$
$$\lambda = 0.875m$$

The above situation is not identical to the case when the air is still and the observer runs towards the yard as then there will be relative motion between the observer and the source and the frequency observed by the observer would change.

$$\nu_o = \left(\frac{v \pm v_o}{v \pm v_s}\right)\nu$$

The frequency as heard by the observer is

$$\nu_o = \frac{340 + 10}{340} \times 400$$
$$\nu_o = 411.76Hz$$

$$\lambda = \frac{340}{400}$$
$$\lambda = 0.85m$$

Q.15.22 (a) A travelling harmonic wave on a string is described by

$$y(x,t) = 7.5\ \sin(0.0050\ x + 12t + \pi/4)$$

(a) what are the displacement and velocity of oscillation of a point at $x = 1\ cm$, and $t = 1\ s$? Is this velocity equal to the velocity of wave propagation?

Answer:

$y(x,t) = 7.5\ \sin(0.0050\,x + 12t + \pi/4)$

The displacement of oscillation of a point at x = 1 cm and t = 1 s is

The general expression for the velocity of oscillation is

$$v_y(1,1) = 90cos(0.0050 \times 1 + 121 + \frac{\pi}{4})$$
$$= 90cos(12.79)$$
$$= 90cos(733.18^o)$$
$$= 87.63\ cm\ s^{-1}$$

$y(x,t) = 7.5\ \sin(0.0050\,x + 12t + \pi/4)$

k=0.005 cm $^{-1}$

$\omega = 12rad/s$

The velocity of propagation of the wave is

The velocity of oscillation of point at x = 1 cm and t = 1 cm is not equal to the propagation of the wave.

NCERT solutions for class 11 physics chapter 15 waves additional exercise

Q.15.22 A travelling harmonic wave on a string is described by

$$y(x,t) = 7.5\ \sin(0.0050\, x + 12t + \pi/4)$$

(b) Locate the points of the string which have the same transverse displacements and velocity as the $x = 1\ cm$ point at $t = 2\ s$, 5 s and 11 s.

Answer:

The wavelength of the given wave is

$$\lambda = \frac{2\pi}{k}$$
$$\lambda = \frac{2\pi}{0.005cm^{-1}}$$
$$\lambda = 1256cm$$
$$\lambda = 12.56m$$

The points with the same displacements and velocity at the same instant of time are separated by distances $n\lambda$.

The points of the string which have the same transverse displacements and velocity as the $x = 1\ cm$point at $t = 2\ s$, 5 s and 11 s would be at a distance of

$\pm\lambda, \pm 2\lambda, \pm 3\lambda...$ from x = 1cm.

$$\lambda = 12.56m$$

Therefore all points at distances $\pm 12.56m, \pm 25.12m, \pm 37.68m$ from the point x=1cm would have the same transverse displacements and velocity as the $x = 1\ cm$ point at $t = 2\ s$, 5 s and 11 s.

Q.15.23 A narrow sound pulse (for example, a short pip by a whistle) is sent across a medium. (a) Does the pulse have a definite (i) frequency, (ii) wavelength, (iii) speed of propagation? (b) If the pulse rate is 1 after every $20\ s$, (that is the whistle is blown for a split of second after every $20\ s$), is the frequency of the note produced by the whistle equal to $1/20$ or $0.05\ Hz$?

Answer:

(a) The pulse does not have a definite frequency or wavelength however the wave has definite speed given the medium is non-dispersive.

(b) The frequency of the note produced by the whistle is not 0.05 Hz. It only implies the frequency of repetition of the pip of the whistle is 0.05 Hz,

Q.15.24 One end of a long string of linear mass density $8.0 \times 10^{-3} kg\ m^{-1}$ is connected to an electrically driven tuning fork of frequency $256\ Hz$. The other end passes over a pulley and is tied to a pan containing a mass of $90\ kg$. The pulley end absorbs all the incoming energy so that reflected waves at this end have negligible amplitude. At $t = 0$, the left end (fork end) of the string $x = 0$ has zero transverse displacement $(y = 0)$ and is moving along positive y-direction. The amplitude of the wave is $5.0\ cm$. Write down the transverse displacement y as function of x and t that describes the wave on the string.

Answer:

$$y(x,t) = Asin(\omega t \pm kx + \phi)$$

A=0.05 m

Tension in the string is T=mg

$$T = 90 \times 9.8$$
$$T = 882N$$

The speed of the wave in the string is v

$$v = \sqrt{\frac{T}{\mu}}$$
$$v = \sqrt{\frac{882}{8 \times 10^{-3}}}$$
$$v = 332ms^{-1}$$

Angular frequency of the wave is

$$\omega = 2\pi\nu$$
$$\omega = 2\pi \times 256$$
$$\omega = 1608.5rad/s$$

$$k = \frac{2\pi}{\lambda}$$
$$k = \frac{2\pi\nu}{v}$$
$$k = 4.84m^{-1}$$

Since at t=0, the left end (fork end) of the string x=0 has zero transverse displacements (y=0) and is moving along the positive y-direction, the initial phase is zero. $(\phi = 0\ rad)$

Taking the left to the right direction as positive we have

$$y(x,t) = 0.05sin(1608.5t - 4.84x)$$

Here t is in seconds and x and y are in metres.

Q.15.25 A SONAR system fixed in a submarine operates at a frequency $40.0\ kHz$. An enemy submarine moves towards the SONAR with a speed of $360\ km\ h^{-1}$. What is the frequency of sound reflected by the submarine? Take the speed of sound in water to be $1450\ m\ s^{-1}$.

Answer:

Frequency of SONAR (ν) =40 kHz

Speed of enemy submarine v_o=360 km h^{-1} = 100 m s^{-1}

$$\nu_o = (\frac{v + v_o}{v})\nu$$
$$= \frac{1450 + 100}{1450} \times 40 \times 10^3$$
$$= 42.76\ kHz$$

This is the frequency which would be observed and reflected by the enemy submarine but won't appear the same to the SONAR(source) as again there is relative motion between the source(enemy submarine) and the observer(SONAR)

The frequency which would be received by the SONAR is

Q.15.26 Earthquakes generate sound waves inside the earth. Unlike a gas, the earth can experience both transverse (S) and longitudinal (P) sound waves. Typically the speed of S wave is about $4.0\ km\ s^{-1}$, and that of P wave is $8.0\ km\ s^{-1}$. A seismograph records P and S waves from an earthquake. The first P wave arrives 4 min before the first S wave. Assuming the waves travel in straight line, at what distance does the earthquake occur?

Answer:

Let us assume the earthquake occurs at a distance s.

The origin of the earthquake is at a distance of 1960 km.

Q.15.27 A bat is flitting about in a cave, navigating via ultrasonic beeps. Assume that the sound emission frequency of the bat is $40\ kHz$. During one fast swoop directly toward a flat wall surface, the bat is moving at 0.03 times the speed of sound in air. What frequency does the bat hear reflected off the wall ?

Answer:

Apparent frequency striking the wall and getting reflected is

The frequency emitted by the bats is $\nu = 40kHz$

Speed of sound is v

Speed of bat is 0.03v

$$\nu' = (\frac{v}{v - v_s})\nu$$
$$= \frac{v}{v - 0.03v} \times 40kHz$$
$$= 41.237kHz$$

Frequency of sound as heard by the bat

$$\nu'' = (\frac{v + v_o}{v})\nu'$$
$$= \frac{v + 0.03v}{v} \times \nu'$$
$$= 1.03 \times 41.237kHz$$
$$= 42.474kHz$$