NCERT Solutions for Class-XI Physics

Chapter-15

NCERT Physics Class 11

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?

1. Mass of the string, M = 2.50 kg

Tension in the string, T = 200 N

Length of the string, l = 20.0 m

Mass per unit length, $\mu = \frac{M}{l} = \frac{2.50}{20} = 0.125 kgm^{-1}$

The velocity (v) of the transverse wave in the string is given by the relation:

$$v = \sqrt{\frac{T}{\mu}}$$

$$= \sqrt{\frac{200}{0.125}} = \sqrt{1600} = 40 m/s$$

∴ Time taken by the disturbance to reach the other end, $t = \frac{l}{v} = \frac{20}{40} = 0.50 s$

2. A stone dropped from the top of a tower of height 300 m high 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})

2. It is provided that,

Tower height, s = 300m

Stone's initial velocity, u = 0

Acceleration, 2 a g 9.8 ms− = =

Sound speed in air = 340 m/ s

The time that stone takes to strike the water in the pond can be estimated using the motion's second equation, as:

$$s = ut_1 + \frac{1}{2} g y_1^2$$

$$\Rightarrow 300 = 0 + \frac{1}{2} \times 9.8 \times t_1^2$$

We get,

$$t_1 = \sqrt{\frac{300 \times 2}{9.8}} = 7.82 s$$

Time taken by the sound to reach the tower top, $t_2 = \frac{300}{340} = 0.88 s$

Therefore, the time after which the sound of splash is heard, t = t + t2

$$\Rightarrow t = 7.82 + 0.88 = 8.7 s$$

The time after which the sound of splash is heard is 8.7s.

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 °C = 343 m s^{-1}

3. Length of the steel wire, l = 12 m
Mass of the steel wire, m = 2.10 kg
Velocity of the transverse wave, v = 343 m/s
Mass per unit length, $\mu = \frac{\mu}{l} = \frac{2.10}{12} = 0.175 \text{kg m}^{-1}$
For tension T, velocity of the transverse wave can be obtained using the relation:

$$v = \sqrt{\frac{T}{\mu}}$$

$$\therefore T = v^2\mu$$

$= (343)^2 \times 0.175 = 20588.575 \approx 2.06 \times 10^4$ N

4. Use the formula $v = \sqrt{\frac{\gamma P}{\rho}}$ to explain why the speed of sound in air is independent of pressure, increases with temperature, increases with humidity.

4. Take the relation:

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad \text{....(i)}$$

Where
Density, $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V}$
M = Molecular weight of the gas
V = Volume of the gas
Hence, equation (i) reduces to:

$$v = \sqrt{\frac{\gamma PV}{M}} \quad \text{...(ii)}$$

Now from the ideal gas equation for n = 1:
PV = RT
For constant T, PV = Constant
Since both M and γ are constants, v = Constant
Hence, at a constant temperature, the speed of sound in a gaseous medium is independent of the change in the pressure of the gas.
Take the relation:

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad \text{.....(i)}$$

For one mole of an ideal gas, the gas equation can be written as:
PV = RT

$$P = \frac{RT}{V} \quad \text{...(ii)}$$

Substituting equation (ii) in equation (i), we get:

$$v = \sqrt{\frac{\gamma RT}{V\rho}} = \sqrt{\frac{\gamma RT}{M}} \qquad \text{...(iv)}$$

Where,

Mass, $M = \rho V$ is a constant

γ and R are also constants

We conclude from equation (iv) that $v \propto \sqrt{T}$

Hence, the speed of sound in a gas is directly proportional to the square root of the temperature of the gaseous medium, i.e., the speed of the sound increases with an increase in the temperature of the gaseous medium and vice versa.

Let v_m and v_d be the speeds of sound in moist air and dry air respectively.

Let ρ_m and ρ_d be the densities of moist air and dry air respectively.

Take the relation:

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

Hence, the speed of sound in moist air is:

$$v_m = \sqrt{\frac{\gamma P}{\rho_m}} \qquad \text{.....(i)}$$

And the speed of sound in dry air is:

$$v_d = \sqrt{\frac{\gamma P}{\rho_d}} \qquad \text{…(ii)}$$

On dividing equation (i) and (ii), we get:

$$\frac{v_m}{d_d} = \sqrt{\frac{\gamma P}{\rho_m} \times \frac{\rho_d}{\gamma}} = \sqrt{\frac{\rho_d}{\rho_m}}$$

However, the presence of water vapour reduces the density of air, i.e.,

$\rho_d < \rho_m$

$\therefore v_m > v_d$

Hence, the speed of sound in moist air is greater than it is in dry air. Thus, in a gaseous medium, the speed of sound increases with humidity.

5. 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 ± v t). Is the converse true? Examine if the following functions for y can possibly represent a travelling wave:

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

(b) $\log\left[\frac{x + vt}{x_0}\right]$

(c) $\frac{1}{(x + vt)}$

5. (a) $\frac{1}{(x + vt)}$

No

For x = 0 and t = 0, the function $(x + vt)^2$ becomes 0.

Hence, for x = 0 and t = 0, the function represents a point.

(b) $\log\left[\dfrac{x+vt}{x_0}\right]$

Yes

For x = 0 and t = 0, the function $\log\left(\dfrac{x+vt}{x_0}\right) = \log 0 = \infty$

Since the function does not converge to a finite value for x = 0 and t = 0, it does not represent a travelling wave.

(c) $\dfrac{1}{(x+vt)}$

No.

For x = 0 and t = 0, the function

$\dfrac{1}{x+vt} = \dfrac{1}{0} = \infty$

Since the function does not converge to a finite value for x = 0 and t = 0, it does not represent a travelling wave.

The converse is not true. The requirement for a wave function of a travelling wave is that for all x and t values, wave function should have a finite value. Therefore, none can represent a travelling wave.

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}.

6. Frequency of the ultrasonic sound, v = 1000 kHz = 10^6 Hz

Speed of sound in air, va = 340 m/s

The wavelength (λr) of the reflected sound is given by the by the relation:

$\lambda_r = \dfrac{v}{v}$

$= \dfrac{340}{10^6} = 3.4 \times 10^{-4}\,m$

Frequency of the ultrasonic sound, v = 1000 kHz = 10^6 Hz

Speed of sound in water, v_w = 1486 m/s

The wavelength of the transmitted sound is given as:

$\lambda_1 = \dfrac{1486}{10^6} = 1.49 \times 10^{-3}\,m$

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.

7. It is provided that,

Sound speed in the tissue, v = 1.7 Kms^{-1} = 1.7 × 10^3 ms^{-1}.

Scanner's operating frequency, v = 4.24 MHz = 4.2 × 10^6 HZ

The wavelength of sound wave in the tissue is given by:

$\lambda = \dfrac{v}{v} = \dfrac{1.7 \times 10^3}{4.2 \times 10^6} = 4.1 \times 10^{-4}\,m$

The wavelength of sound in the tissue is 4.1 × 10^{-4} m.

8. A transverse harmonic wave on a string is described by

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

Where x and y are in cm and t in s. The positive direction of x is from left to right.
Is this a travelling wave or a stationary wave?
If it is travelling, what are the speed and direction of its propagation?
What are its amplitude and frequency?
What is the initial phase at the origin?
What is the least distance between two successive crests in the wave?

8. Yes ; Speed = 20 m/s, Direction = Right to left
3 cm; 5.73 Hz

$\frac{\pi}{4}$

3.49 m

Explanation:

The equation of a progressive wave travelling from right to left is given by the displacement function:

Y(x, t) = a sin (ωt + kx + Φ) ….(i) The given

Equation is:

$$y\left(x,t\right) = 3.0\sin\left(36t + 0.018x + \frac{\pi}{4}\right) \quad ....(ii)$$

On comparing both the equations, we find that equation (ii) represents a travelling wave, propagating from right to left.

Now, using equations (i) and (ii), we can write:

ω = 36 rad/s and k = 0.018 m^{-1} We know

That:

$$v = \frac{\omega}{2\pi} \text{ and } \lambda = \frac{2\pi}{k}$$

Also, v = vλ

$$\therefore v = \left(\frac{\omega}{2\pi}\right) \times \left(\frac{2\pi}{\kappa}\right) = \frac{\omega}{k}$$

$$= \frac{36}{0.018} = 2000 \text{ cm/s} = 20 \text{ m/s}$$

Hence, the speed of the given travelling wave is 20 m/s.

Amplitude of the given wave, a = 3 cm Frequency of the given wave:

$$v = \frac{\omega}{2\pi} = \frac{36}{2 \times 3.14} = 5.73\text{Hz}$$

On comparing equations (i) and (ii), we find that the initial phase angle, $\phi = \frac{\pi}{4}$

The distance between two successive crests or troughs is equal to the wavelength of the wave. Wavelength is given by the relation:

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

$$\therefore \lambda = \frac{2\pi}{k} = \frac{2 \times 3.14}{0.018} = 348.89 \text{ cm} = 3.49 \text{ m}$$

9. For the wave described in Exercise, 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?

9. All the waves have different phase.

The given transverse harmonic wave is:

$$Y(x, t) = 3.0 \sin\left(36t + 0.018x + \frac{\pi}{4}\right) \quad \text{....(i)}$$

For x = 0, the equation reduces to:

$$y(0,t) = 3.0\sin\left(36t + \frac{\pi}{4}\right)$$

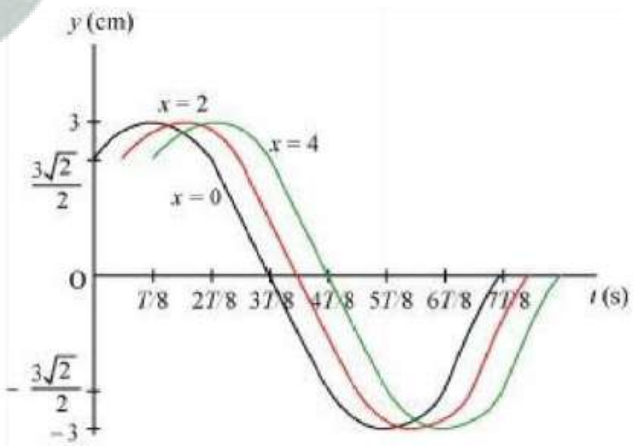
Also, $\omega = \frac{2\pi}{T} = 36 rad/s^{-1}$

$$\therefore T = \frac{\pi}{8}s$$

Now, plotting y vs. t graphs using the different values of t, as listed in the given table.

T(s)	0	$\frac{T}{8}$	$\frac{2T}{8}$	$\frac{3T}{8}$	$\frac{4T}{8}$	$\frac{5T}{8}$	$\frac{6T}{8}$	$\frac{7T}{8}$
Y(cm)	$\frac{3\sqrt{2}}{2}$	3	$\frac{3\sqrt{2}}{2}$	0	$\frac{3\sqrt{2}}{2}$	–3	$\frac{-3\sqrt{2}}{2}$	0

For x = 0, x = 2, and x = 4, the phase of the three waves will get changed. This is because amplitude and frequency are invariant for any change in x. The y-t plots of the three waves are shown in the given figure.



10. For the travelling harmonic wave y (x, t) = 2.0 cos
2π (10t – 0.0080x + 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 4 m, 0.5 m,
$\frac{\lambda}{2}, \frac{3\lambda}{4}$

10. Equation for a travelling harmonic wave is given as:

y(x, t) = 2.0 cos 2π (10t – 0.0080x + 0.35)

= 2.0 cos (20πt – 0.016 πx + 0.70 π)

Where,

Propagation constant, k = 0.0160 π

Amplitude, a = 2 cm

Angular frequency, ω = 20 π rad/s

Phase difference is given by the relation:

$$\phi = kx = \frac{2\pi}{\lambda}$$

For x = 4m = 400 cm

Φ = 0.016 π × 400 = 6.4 π rad

For 0.5 m = 50 cm

Φ = 0.016 π × 50 = 0.8 πrad

For $x = \frac{\lambda}{2}$

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

For $x = \frac{3\lambda}{4}$

$$\phi = \frac{2\pi}{\lambda} \times \frac{3\lambda}{4} = 1.5\pi \text{ rad}$$

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

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.

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

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

Determine the tension in the string.

11. The general equation representing a stationary wave is given by the displacement function:

y (x, t) = 2a sin kx cos ωt

This equation is similar to the given equation:

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

Hence, the given function represents a stationary wave.

A wave travelling along the positive x-direction is given as:

$$y_1 a \sin(\omega t - kx)$$

The wave travelling along the negative x-direction is given as:

$$y_2 = a \sin(\omega t + kx)$$

The superposition of these two waves yields:

$$y = y_1 + y_2 = a\sin(\omega t - kx) - a\sin(\omega t + kx)$$

$$= a\sin(\omega t)\cos(kx) - a\sin(kx)\cos(\omega t) - a\sin(\omega t)\cos(kx) - a\sin(kx)\cos(\omega t)$$

$$= -2a\sin(kx)\cos(\omega t)$$

$$= -2a\sin\left(\frac{2\pi}{\lambda}x\right)\cos(2\pi vt) \qquad \text{....(i)}$$

The transverse displacement of the string is given as:

$$y(x,t) = 0.06\sin\left(\frac{2\pi}{3}x\right)\cos(120\pi t) \qquad \text{.....(ii)}$$

Comparing equation (i) and (ii), we have:

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

∴ Wavelength, $\lambda = 3$ m

It is given that:

$120\pi = 2\pi v$

Frequency, v = 60 Hz

Wave speed, $v = v\lambda$

= 60 × 3 = 180 m/s

The velocity of a transverse wave travelling in a string is given by the relation:

$$v = \sqrt{\frac{T}{\mu}} \qquad \text{....(i)}$$

Where,

Velocity of the transverse wave, v = 180 m/s

Mass of the string, $m = 3.0 \times 10^{-2}$ kg

Length of the string, $m = 3.0 \times 10^{-2}$ kg

Length of the string, l = 1.5 m

Mass per unit length of the string, $\mu = \frac{m}{l}$

$$= \frac{3.0}{1.5} \times 10^{-2}$$

= 2 × 10–2 kg m–1

Tension in the string = T

From equation (i), tension can be obtained as:

T = v2μ

$= (180)^2 \times 2 \times 10^{-2}$

= 648 N

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?

12. (i)

(a)

Yes, all the points on the string vibrate with the same frequency, except at the nodes which are having zero frequency.

(b) Yes, all the points in any oscillating loop have the same phase, except at the nodes.

(c) No, all the points in any oscillating loop have different vibrating amplitudes.

(ii) The given equating is:

$$y(x,t) = 0.06\sin\left(\frac{2\pi}{3}x\right)\cos(12\pi t)$$

For x = 0.375 m and t = 0

Amplitude = 0.06 sin $\left(\frac{2\pi}{3}x\right)$cos

$$\Rightarrow a = 0.06\sin\left(\frac{2\pi}{3}\times 0.375\right)\times 1$$

$$\Rightarrow a = 0.6\sin(0.25\pi) = 0.06\sin\left(\frac{\pi}{4}\right)$$

$$\Rightarrow a = 0.06\times\frac{1}{\sqrt{2}} = 0.042\text{m}$$

The value of amplitude is 0.042m.

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 traveling wave, (ii) a stationary wave or (iii) none at all:

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

$$y = 2\sqrt{x - vt}$$

$$y = 3\sin(5x - 0.5t) + 4\cos(5x - 05t)\,y = \cos x$$

sin t + cos 2x sin 2t

13. The given equation represents a stationary wave because the harmonic terms kx and ωt appear separately in the equation.

The given equation does not contain any harmonic term. Therefore, it does not represent either a travelling wave or a stationary wave.

The given equation represents a travelling wave as the harmonic terms kx and ωt are in the combination of kx – ωt.

The given equation represents a stationary wave because the harmonic terms kx and ωt appear separately in the equation. This equation actually represents the superposition of two stationary waves.

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 3.5×10^{-2} kg and its linear mass density is 4.0×10^{-2} kg m^{-1}. What is (a) the speed of a transverse wave on the string, and (b) the tension in the string?

14. (a)

Provided that,

Mass of the wire, m = 3.5×10^{-2} kg

Linear mass density, $\mu = \frac{m}{1} = 4.0\times 10^{-2}$ kgm^{-1}

Frequency of vibration, v = 45Hz

Length of the wire, $l = \frac{m}{\mu} = \frac{3.5 \times 10^{-2}}{4.0 \times 10^{-2}} = 0.875\text{m}$

The wavelength of the stationary wave (λ) is given by:

$\lambda = \frac{2l}{n}$ where, n = number of nodes

For fundamental node, n = 1:

$\lambda = 2l$

$\lambda = 2 \times 0.875 = 1.75$

transverse wave in the string is given as:

$v = \nu\lambda = 45 \times 1.75 = 78.75\ \text{ms}^{-1}$.

The speed of transverse wave is $78.75\ \text{ms}^{-1}$.

(b) the tension in the string?

The tension produced in the string is given by the relation:

$T = v^2\mu$

$\Rightarrow T = (78.75)^2 \times 4.0 \times 10^{-2} = 248.06\text{N}$

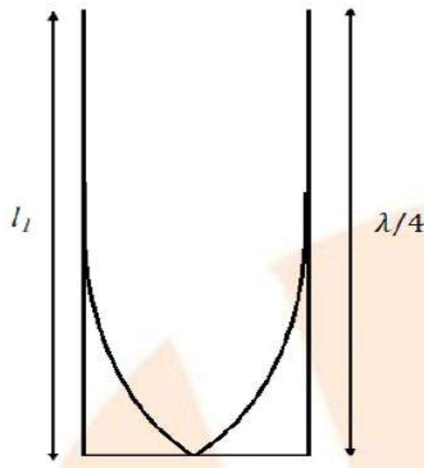
The tension in the string is 248.06N.

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.

15. Ans: It is provided that,

Frequency of the turning fork, $\nu = 340$ Hz

Since the given pipe is attached with a movable piston at one end, it will behave as a pipe with one end closed and the other end open, as shown in the given figure.



Such a system gives odd harmonics. The relation of fundamental note in a closed pipe is given by:

$l_1 = \frac{\lambda}{4}$

Where, length of the pipe l1 = 25.5cm = 0.255m

$\Rightarrow \lambda = 4l1 = 4 \times 0.255 = 1.02$ m

The relation of sound speed is given by:

$v = \nu\lambda = 340 \times 1.02 = 346.8\ \text{ms}^{-1}$

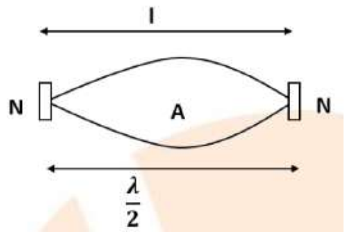
16. A steel rod 100 cm long is clamped at its middle. The fundamental frequency of longitudinal vibrations of the rod is given to be 2.53 kHz. What is the speed of sound in steel?

16. We have,

Length of the steel rod, l = 100 cm = 1 m

Fundamental frequency of vibration, v = 2.53kHZ = 2.53×10^3Hz

An antinode (A) is formed at its centre, and nodes (N) are formed at its two ends when the rod is plucked at its middle, as shown in the given figure.



The distance between two successive nodes is $\frac{\lambda}{2}$

$\therefore l = \frac{\lambda}{2}$

$\lambda = 2l = 2 \times 1 = 2m$

The sound speed in steel is given by:

$v = v\lambda$

$\Rightarrow v = 2.53 \times 103 \times 2$

$\Rightarrow v = 5.06 \times 10^3\ ms^{-1}$

$\Rightarrow v = 5.06\ kms^{-1}$

The speed of sound in steel is 5.06 kms^{-1}.

17. A pipe 20 cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a 430 Hz source? Will the same source be in resonance with the pipe if both ends are open? (Speed of sound in air is 1 340 ms^{-1}).

17. First (Fundamental); No

Length of the pipe, l = 20 cm = 0.2 m

Source frequency = n^{th} normal mode of frequency, $v_n = 430$ Hz

Speed of sound, v = 340 m/s

In a closed pipe, the n^{th} normal mode of frequency is given by the relation:

$v_n = (2n-1)\frac{v}{4l}$; n is an integer = 0,1,2,3,..

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

$2n - 1 = \frac{430 \times 4 \times 0.2}{340} = 1.01$

$2n = 2.01$

$n \sim 1$

Hence, the first mode of vibration frequency is resonantly excited by the given source.

In a pipe open at both ends, the n^{th} mode of vibration frequency is given by the relation:

$$v_n = \frac{nv}{2l}$$

$$n = \frac{2lv_n}{v}$$

$$= \frac{2 \times 0.2 \times 430}{340} = 0.5$$

Since the number of the mode of vibration (n) has to be an integer, the given source does not produce a resonant vibration in an open pipe.

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?

18. Frequency of string A, F_A = 324 Hz

Frequency of string B = f_B

Beat's frequency, n = 6Hz

Beat's frequency is given as:

$$n = | f_A \pm f_B |$$

$6 = 324 \pm f_B$

fB = 330 Hz or 315 Hz

Frequency decreases with a decrease in the tension in a string. This is because frequency is directly proportional to the square root of tension. It is given as:

$$v \propto \sqrt{T}$$

Hence, the beat frequency cannot be 330 Hz

$$\therefore f_B = 318\text{Hz}$$

19. Explain why (or how):

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

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

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

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

(e) The shape of a pulse gets distorted during propagation in a dispersive medium.

19. A node is a point where the amplitude of vibration is the minimum and pressure is the maximum. On the other hand, an antinode is a point where the amplitude of vibration is the maximum and pressure is the minimum.

Therefore, a displacement node is nothing but a pressure antinode, and vice versa.

Bats emit very high-frequency ultrasonic sound waves. These waves get reflected back toward them by obstacles. A bat receives a reflected wave (frequency) and estimates the distance, direction, nature, and size of an obstacle with the help of its brain senses.

The overtones produced by a sitar and a violin, and the strengths of these overtones, are different.

Hence, one can distinguish between the notes produced by a sitar and a violin even if they have the same frequency of vibration. Solids have shear modulus. They can sustain shearing stress. Since fluids do not have any definite shape, they yield to shearing stress. The propagation of a transverse wave is such that it produces shearing stress in a medium. The propagation of such a wave is possible only in solids, and not in gases.

Both solids and fluids have their respective bulk moduli. They can sustain compressive stress.

Hence, longitudinal waves can propagate through solids and fluids.

A pulse is actually is a combination of waves having different wavelengths. These waves travel in a dispersive medium with different velocities, depending on the nature of the medium. This results in the distortion of the shape of a wave pulse.

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}.

20. (i) What is the frequency of the whistle for a platform observer when the train

(a) approaches the platform with a speed of 10 ms^{-1},

Frequency of the whistle, v = 400 Hz

Speed of the train, $v_t = 10$ m/s

Speed of sound, v = 340 m/s

The whistle's apparent frequency (v') as the train approaches the platform is given by:

$$v' = \left(\frac{v}{v - v_T}\right)v$$

$$\Rightarrow v'\left(\frac{340}{340-10}\right)\times 400 = 412.12\text{Hz}$$

b.

The apparent frequency (v") of the whistle as the train recedes from the platform is given by the relation:

$$v'' = \left(\frac{v}{v + v_{Tr}}\right)$$

$$= \left(\frac{340}{340-10}\right)\times 400 = 412.12\text{Hz}$$

The apparent frequency of the whistle is 388.57Hz .

(ii) The apparent change in sound frequency is caused by the relative motions of the source and the observer. These relative motions generate no effect on the sound speed. Therefore, the sound speed in the air in both cases remains the same, i.e., 340 m/ s.

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 at 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}.

21. For the stationary observer: 400 Hz; 0.875 m; 350 m/s

For the running observer: Not exactly identical

For the stationary observer:

Frequency of the sound produced by the whistle, $\nu = 400$ Hz

Speed of sound = 340 m/s

Velocity of the wind, v = 10 m/s

As there is no relative motion between the source and the observer, the frequency of the sound heard by the observer will be the same as that produced by the source, i.e., 400 Hz.

The wind is blowing toward the observer. Hence, the effective speed of the sound increases by 10 units, i.e.,

Effective speed of the sound, ve = 340 + 10 = 350 m/s

The wavelength (λ) of the sound heard by the observer is given by the relation:

$$\lambda = \frac{v_e}{v} - = \frac{350}{400} = 0.875\text{m}$$

For the running observer:

Velocity of the observer, $v_o = 10$ m/s

The observer is moving toward the source. As a result of the relative motions of the source and the observer, there is a change in frequency (v')

This is given by the relation:

$$v' = \left(\frac{v + v_0}{v}\right)v$$

This is given by the relation:

$$v'\left(\frac{v + v_0}{v}\right)v = \left(\frac{340 + 10}{340}\right) \times 400 = 411.76\text{Hz}]$$

Since the air is still, the effective speed of sound = 340 + 0 = 340 m/s

The source is at rest. Hence, the wavelength of the sound will not change, i.e., λ remains 0.875 m. Hence, the given two situations are not exactly identical.