Q1. 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?

Solution:

Given,
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, μ = M /l = 5/40 = 0.125 kg / m

We know,

Velocity of the transverse wave, $v = \sqrt{\frac{T}{\mu}}$

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

Therefore, the time taken by the transverse wave to reach the other side is 40 m/s.

Q2. 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})

Solution:

Given,

Height of the bridge, s = 300 m
Initial velocity of the stone, u = 0
Acceleration, a = g = 9.8 m/s^2
Speed of sound in air = 340 m/s

Let t be the time taken by the stone to hit the water's surface
We know,
$s = ut + ½ gt^2$
$300 = 0 + ½ \times 9.8 \times t^2$
therefore, t = 7.82 s

The time taken by the sound to reach the bridge, t'= 300/340 = 0.88 s

Therefore, from the moment the stone is released from the bridge, the sound of it splashing the water is heard after = t +t' = 7.82 s + 0.88 s = 8.7s

Q3. 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 the speed of a transverse wave on the wire equals the speed of sound in dry air at 20 °C = 343 m s^{-1}.

Solution:

Given,
Length of the steel wire, l = 12 m
Mass of the steel wire, m = 2.0 kg
Velocity of the transverse wave, v = 343 m/s

Mass per unit length, μ = M /l = 2.10/12 = 0.175 kg / m

We know,

Velocity of the transverse wave , v = $\sqrt{\frac{T}{\mu}}$

Therefore, T = v^2 μ

= 343^2 x 0.175 = 2.06 x 10^4 N

Q4. Using the formula v = $\sqrt{\frac{\gamma P}{\rho}}$ explain why the speed of sound in air

(a) does not depend upon pressure.
(b) increases with temperature and humidity.
(c) increases with humidity.

Solution:

Given,

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

We know,
PV = nRT (for n moles of ideal gas)
=> PV = RT (m/M)
Where, m is the total mass and M is molecular mass of the gas.
therefore, P = m (RT/M)

=> P = $\frac{\rho RT}{M}$

=> $\frac{P}{\rho} = \frac{RT}{M}$

(a) For a gas at a constant temperature, $\frac{P}{\rho}$

= constant
Thus, as P increases ρ and vice versa. This means that P/ρ ratio always remains constant meaning

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

= constant i.e., velocity of sound does not depend upon the pressure of the gas.

(b) Since, $\frac{P}{\rho} = \frac{RT}{M}$

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

We can see that v $\propto$ $\sqrt{T}$ i.e., speed of sound increases with temperature.

(c) When humidity increases, effective density of the air decrease. This means $v \propto \frac{1}{\sqrt{\rho}}$, thus velocity increases.

Q5. We know that the function y = f (x, t) represents a wave travelling in one direction, where x and t must appear in the combination x + vt or x– vt or i.e. y = f (x ± vt). Is the converse true? Can the following functions for y possibly represent a travelling wave:
(i) $(x – vt)^2$
(ii) log [(x + vt)/ x_0]
(iii) 1 / (x + vt)

Solution:

No, the converse is not true, because it is necessary for a wave function representing a travelling wave to have a finite value for all values of x and t.
As none of the above functions satisfy the above condition, thus, none represent a travelling wave.

Q6. 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}

Solution:

Given,
Frequency of the ultrasonic sound, v = 1000 kHz = 10^6 Hz
Speed of sound in air, v_A = 340 m/s
We know,

(i) The wavelength (λ_R) of the reflected sound is :
$\lambda_R = v_A / v$
= $340/10^6 = 3.4 \times 10^{-4}$ m

(ii) Speed of sound in water, v_W = 1486 m/s
Therefore, the wavelength (λ_T)of the transmitted sound is :

$\lambda_T = 1486 / 10^6$
$= 1.49 \times 10^{-3}$ m

Q7. An ultrasonic scanner operating at 4.2 MHz is used to locate tumours in tissues. If the speed of sound is 2 km /s in a certain tissue, calculate the wavelength of sound in this tissue.

Solution:

Given,
Speed of sound in the tissue, $v_T = 2$ km/s $= 2 \times 10^3$ m/s
Operating frequency of the scanner, $v = 4.2$ MHz $= 4.2 \times 10^6$ Hz

Therefore, the wavelength of sound:
$\lambda = v_T / v$
$= (2 \times 10^3)/ (4.2 \times 10^6)$
$= 4.76 \times 10^{-4}$ m

Q8. A transverse harmonic wave on a wire is expressed as:
y(x, t) =3 sin (36t +0.018x +π/4)
(i) Is it a stationary wave or a travelling one?
(ii) If it is a travelling wave, give the speed and direction of its propagation.
(iii) Find its frequency and amplitude.
(iv) Give the initial phase at the origin.
(v) Calculate the smallest distance between two adjacent crests in the wave.
[X and y are in cm and t in seconds. Assume the left to right direction as the positive direction of x]

Solution:

Given,
$y(x, t) = 3 \sin (36t + 0.018x + \pi/4)$ . . . . (1)

(i) We know, the equation of a progressive wave travelling from right to left is:
$y (x, t) = a \sin (\omega t + kx + \Phi)$ . . . . (2)

Comparing equation (1) to equation (2), we see that it represents a wave travelling from right to left and also we get:
$a = 3$ cm, $\omega = 36$ rad/s , $k = 0.018$ cm and $\phi = \pi/4$

(ii)Therefore, the speed of propagation , $v = \omega/k = 36/ 0.018 = 20$ m/s

(iii) Amplitude of the wave, $a = 3$ cm
Frequency of the wave $v = \omega / 2\pi$
$= 36 /2\pi = 5.7$ hz
(iv) Initial phase at the origin $= \pi/4$
(v) the smallest distance between two adjacent crests in the wave, $\lambda = 2\pi/ k = 2\pi / 0.018$
$= 349$ cm

Q9. For the wave in the above question (Q8), plot the displacement (y) versus (t) graphs for x = 0, 2 and 4 cm. (i) Give the shapes of these plots.

(ii) With respect to which aspects (amplitude, frequency or phase) does the oscillatory motion in a travelling wave differ from one point to another?

Solution:

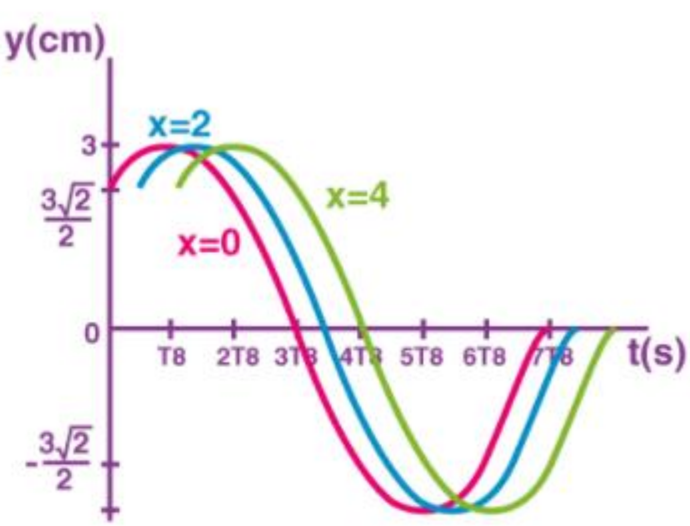
Given,
y(x, t) =3 sin (36t +0.018x + π/4) . . . . (1)

For x= 0, the equation becomes :
y(0, t) =3 sin (36t +0 + π/4) . . . . (2)
Also,
ω = 2 π/t = 36 rad/s
=> t = π/18 secs.

Plotting the displacement (y) vs. (t) graphs using different values of t listed below:

t	0	T/ 8	2T/ 8	3T/ 8	4T/ 8	5T/ 8	6T/ 8	7T/ 8	T
y	$\frac{3}{\sqrt{2}}$	3	$\frac{3}{\sqrt{2}}$	0	$\frac{-3}{\sqrt{2}}$	-3	$\frac{-3}{\sqrt{2}}$	0	$\frac{3}{\sqrt{2}}$

Similarly graphs are obtained for x = 0, x = 2 cm, and x = 4 cm. The oscillatory motion in the travelling wave is different from each other only in terms of phase. Amplitude and frequency are invariant for any change in x. The y-t plots of the three waves are shown in the given figure:



Q10. A travelling harmonic wave is given as: y (x, t) = 2.0 cos 2π (10t – 0.0080x + 0.35). What is the phase difference between the oscillatory motion of two points separated by a distance of:
(i) 8 m,
(ii) 1 m,
(iii) λ /2,

(iv) 6λ/4
[X and y are in cm and t is in secs].

Solution:

Given,
Equation for a travelling harmonic wave :
y (x, t) = 2.0 cos 2π (10t – 0.0080x + 0.35)
= 2.0 cos (20πt – 0.016πx + 0.70 π)
Where,
Propagation constant, k = 0.0160 π
Amplitude, a = 2 cm
Angular frequency, ω= 20 π rad/s

We know,
Phase difference Φ = kx = 2π/ λ

(i) For x = 8 m = 800 cm
Φ = 0.016 π × 800 = 12.8 π rad

(ii)For x = 1 m = 100 cm
Φ = 0.016 π × 100 = 1.6 π rad

(iii) For x =λ /2
Φ = (2π/ λ) x (λ/2)
= π rad

(iv) For x =6λ /4
Φ = (2π/ λ) x (6λ/4)
= 3 π rad

Q11. The transverse displacement of a wire (clamped at both its ends) is described as :

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

The mass of the wire is 6 x 10^{-2} kg and its length is 3m.
Provide answers to the following questions:
(i) Is the function describing a stationary wave or a travelling wave?
(ii) Interpret the wave as a superposition of two waves travelling in opposite directions. Find the speed, wavelength and frequency of each wave.
(iii) Calculate the wire's tension.
[X and y are in meters and t in secs]

Solution:

We know,
The standard equation of a stationary wave is described as:
y (x, t) = 2a sin kx cos ωt

Our given equation y (x, t) = $0.06sin(\frac{2\pi}{3}x)cos(120\pi t)$ is similar to the general equation .

(i) Thus, the given function describes a stationary wave.

(ii) We know, a wave travelling in the positive x-direction can be represented as :
$y_1 = a \sin(\omega t - kx)$
Also,
A wave travelling in the negative x-direction is represented as :
$y_2 = a \sin(\omega t + kx)$

Super- positioning these two waves gives us :
$y = y_1 + y_2$
$= a \sin(\omega t - kx) - a \sin(\omega t + kx)$
$= a\sin(\omega t)\cos(kx) - a\sin(kx)\cos(\omega t) - a\sin(\omega t)\cos(kx) - a\sin(kx)\cos(\omega t)$
$= -2a\sin(kx)\cos(\omega t)$

$= -2a\sin(\frac{2\pi}{\lambda}x)\cos(2\pi vt)$ .... (1)

The transverse displacement of the wires is described as :

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

Comparing equations (1) and (2) , we get :
$2\pi/\lambda = 2\pi/3$
Therefore, wavelength $\lambda = 3$m

Also, $2\pi v/\lambda = 120\pi$
Therefore, speed v = 180 m/s

And, Frequency = $v/\lambda = 180/3$
= 60 Hz

(iii)Given,
Velocity of the transverse wave, v = 180 m / s
The string's mass, $m = 6 \times 10^{-2}$ kg
String length, l = 3 m
Mass per unit length of the string, $\mu = m/l = (6 \times 10^{-2})/3$
$= 2 \times 10^{-2}$ kg/m
Let the tension in the wire be T
Therefore, $T = v^2 \mu$
$= 180^2 \times 2 \times 10^{-2}$
= 648 N.

Q12. Considering the wave described in the above question (Q11) answer the following questions;
(a) Are all the points in the wire oscillating at the same values of (i) frequency, (ii) phase, (iii) amplitude? Justify your answers.
(b) Calculate the amplitude of a point 0.4 m away from one end?

Solution:

(a) As the wire is clamped at both its ends, the ends behave as nodes and the whole wire vibrates in one segment. Thus,

(i) Except at the ends which have zero frequency, all the particles in the wire oscillate with the same frequency.
(ii) All the particles in the wire lie in one segment, thus they all have the same phase. Except for the nodes.
(iii) Amplitude, however, is different for different points.

(b) Given equation,

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

For x = 0.4m and t =0

Amplitude = displacement = $0.06sin(\frac{2\pi}{3}x)cos0$

= $0.06sin(\frac{2\pi}{3} \times 0.4)1$

= 0.044 m

Q13. Present below are functions of x and t to describe the displacement (longitudinal or transverse) of an elastic wave. Identify the ones describing (a) a stationary wave, (b) a travelling wave and (c) neither of the two :
(i) y = 3 sin(5x – 0.5t) + 4cos(5x – 0.5t)
(ii) y = cosxsint + cos2xsin2t.
(iii) y = 2 cos (3x) sin (10t)

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

Solution:

(i) This equation describes a travelling wave as the harmonic terms ωt and kx are in the combination of kx – ωt.
(ii) This equation describes a stationary wave because the harmonic terms ωt and kx appear separately in the equation. In fact, this equation describes the superposition of two stationary waves.
(iii) This equation describes a stationary wave because the harmonic terms ωt and kx appear separately.
(iv) This equation does not contain any harmonic term. Thus, it is neither a travelling wave nor a stationary wave.

Q14. A string clamped at both its ends is stretched out, it is then made to vibrate in its fundamental mode at a frequency of 45 Hz. The linear mass density of the string is 4.0×10^{-2} kg/m and its mass is 2×10^{-2} kg. Calculate:
(i) the velocity of a transverse wave on the string,
(ii) the tension in the string.

Solution:

Given,
Mass of the string, m = 2 x 10^{-2} kg
Linear density of the string = 4 x 10^{-2} kg
Frequency, v_F = 45 Hz

We know, length of the wire = m/µ
= (2 x 10^{-2})/ (4 x10^{-2}) = 0.5 m

We know, λ = 2l/n
Where, n = number of nodes in the wire.

For fundamental node, n =1
=> λ = 2l
= 2 x 0.5 = 1m

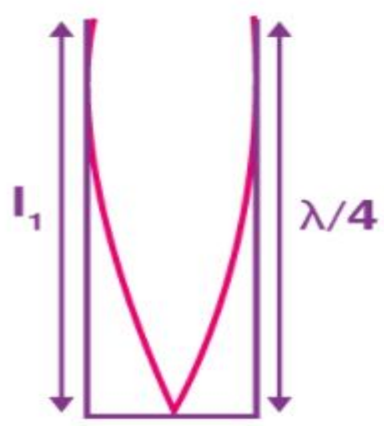
(i) Therefore, speed of the transverse wave, v = λ v_F
= 1 x 45 = 45 m/s
(ii) Tension in the string = µ v^2
= 4 x10^{-2} x 45 = 81 N

Q15. A 1m long pipe with a movable piston at one end and an opening at the other will be in resonance with a tuning fork vibrating at 340 Hz, if the length of the pipe is 79.3 cm or 25.5 cm. Calculate the speed of sound in air. Neglect the edge effects.

Solution:

Given,
Frequency of the turning fork, v_F = 340 Hz
Length of the pipe, l_1 = 0.255 m

As the given pipe is has a piston at one end, it will behave as a pipe with one end closed and the other end open, as depicted in the figure below:



This kind of system creates odd harmonics. We know, fundamental note in a closed pipe is written as:
l_1 = λ / 4

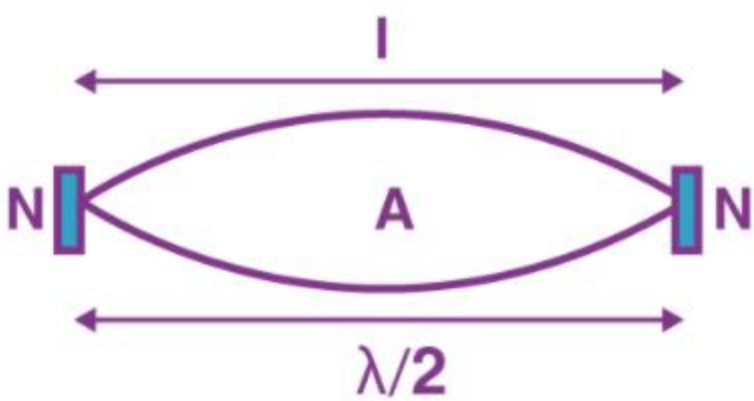
$0.255 \times 4 = \lambda = 1.02m$
Therefore speed of sound, $v = \lambda\, v_F$
$= 340 \times 1.02 = 346.8$ m/s

Q16. A steel bar of length 200 cm is nailed at its midpoint. The fundamental frequency of the longitudinal vibrations of the rod is 2.53 kHz. At what speed will the sound be able to travel through steel?

Solution:

Given,
Length , l = 200 cm = 2 m
Fundamental frequency of vibration, $v_F = 2.53$ kHz $= 2.53 \times 10^3$ Hz

The bar is then plucked at its midpoint, forming an antinode (A) at its centre, and nodes (N) at its two edges, as depicted in the figure below :



The distance between two successive nodes is $\lambda / 2$
=> $l = \lambda / 2$
Or, $\lambda = 2 \times 2 = 4m$

Thus, sound travels through steel at a speed of $v = v\lambda$
$v = 4 \times 2.53 \times 10^3$
$= 10.12$ km / s

Q17. One end of A 20 cm long tube is closed. Find the harmonic mode of the tube that will be resonantly excited by a source of frequency 430 Hz. If both the ends are open, can the same source still produce resonance in the tube? (Sound travels in air at 340 m /s).

Solution:

Given,
Length of the pipe, l = 20 cm = 0.2 m
Frequency of the source = n^{th}

the normal mode of frequency, v_N = 430 Hz
Speed of sound, v = 340 ms $^{-1}$

We know, that in a closed pipe the n^{th} normal mode of frequency v_N = (2n -1)v/4l
where n is an integer = 0, 1, 2, 3, 4, ...

430 = (2n – 1)(340/4 x0.2)
2n = 2.01
n ≈ 1
Thus, the given source resonantly excites the first mode of vibration frequency

Now, for a pipe open at both the ends, the n^{th} mode of vibration frequency:
V_R = nv/2l
n = V_R 2l/v
n = (2 x 0.2 x 430)/340 = 0.5
As the mode of vibration (n) has to be an integer, this source is not in resonance with the tube.

Q18. Guitar strings X and Y striking the note 'Ga' are a little out of tune and give beats at 6 Hz. When the string X is slightly loosened and the beat frequency becomes 3 Hz. Given that the original frequency of X is 324 Hz, find the frequency of Y.

Solution:

Given,
Frequency of X, f_X = 324 Hz
Frequency of Y = f_Y
Beat's frequency, n = 6 Hz
Also,

n = $|f_X \pm f_Y|$

6 = $324 \pm f_Y$

=> f_Y = 330 Hz or 318 Hz
As frequency drops with a decrease in tension in the string, thus f_Y cannot be 330 Hz
=> f_Y = 318 Hz

Q19. Explain how:
(i) A sound wave's pressure antinode is a displacement node and vice versa.
(ii) The Ganges river dolphin despite being blind, can manoeuvre and swim around obstacles and hunt down preys.
(iii) A guitar note and violin note are being played at the same frequency, however, we can still make out which instrument is producing which note
(iv) Both transverse and longitudinal wave can propagate through solids, but only longitudinal waves can move through gases.
(v) In a dispersive medium, the shape of a pulse propagating through it gets distorted.

Solution:

(i) An antinode is a point where pressure is the minimum and the amplitude of vibration is the maximum. On the other hand, a node is a point where pressure is the maximum and the amplitude of vibration is the minimum.
(ii) The Ganges river dolphin sends out click noises which return back as vibration informing the dolphin about the location and distances of objects in front of it. Thus, allowing it to manoeuvre and hunt down preys with minimum vision.
(iii) The guitar and the violin produce overtones of different strengths. Thus, one can differentiate between the notes coming from a guitar and a violin even if they are vibrating at the same frequencies.
(iv) Both solids and fluids have a bulk modulus of elasticity. Thus, they both allow longitudinal waves to propagate through them. However, unlike solids, gases do not have shear modulus. Thus, transverse waves cannot pass through gases.
(v) A pulse is a combination of waves of un-similar wavelengths. These waves move at different velocities in a dispersive medium. This causes the distortion in its shape.

Q20.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}.

Solution:

Frequency of the whistle = 400 Hz

Speed of sound in still air = 340 m/s

(i)

(a)Train approaches the platform at a speed, v_s = 10 m/s

Frequency of the whistle for a platform observer

$$f' = \frac{v}{v - v_s} \times f$$

$$f' = \frac{340}{340 - 10} \times 400 = 412 \text{ Hz}$$

(b) Train recedes from the platform at a speed, v_s = 10 m/s

Frequency of the whistle for a platform observer

$$f' = \frac{v}{v + v_s} \times f$$

$$f' = \frac{340}{340 + 10} \times 400 = 389 \text{ Hz}$$

(ii) The speed of the sound will not change. It will remain 340 m/s.

Q21. 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}

Solution:

Frequency of the whistle = 400 Hz

Speed of wind, v_w= 10 m/s

Speed of sound in still air,v= 340 m/s

Effective speed of the sound for an observer standing on the platform

$v' = v + v_w = 340 + 10 = 350$ m/s

There is no relative motion between the source and the observer, therefore the frequency of the sound heard by the observer will be the same.

Therefore, f = 400 Hz

Wavelength of the sound heard by the observer = speed of wave/frequency = 350/400 = 0.875 m

When the air is still and the observer runs towards the yard at a speed of 10 m s^{-1} then there is a relative motion between the observer the source with respect to the medium.

The medium is at rest. Therefore

v' = v = 340 m/s

The change in frequency, $f' = [(v + v_0)/ v] \times f$

= [(340 + 10)/340] x 400 = 411.76 Hz

Wavelength = 340/411.76 = 0.826 m

Obviously, the situations in the two cases are entirely different.

Q22. A travelling harmonic wave on a string is described by y(x, t) = 7.5 sin (0.0050x +12t + π/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?
(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.

Solution:

(a) The travelling harmonic wave is y(x, t) = 7.5 sin (0.0050x +12t + π/4)

At x = 1 cm and t = 1 s

y (1,1) = 7.5 sin (0.0050 (1) +12 (1) + π/4)

= 7.5 sin (12.0050 + π/4) ——-(1)

= 7.5 sin θ

θ = (12.0050 + π/4) x (180/3.14)

= 12.0050 + (3.14/4) = 12.79 x (180/3.14)

θ = 733.18^0

y (1,1) = 7.5 sin (733.18^0)

= 7.5 sin (90 x 8 + 13.18^0)

= 7.5 sin (13.18^0)

= 7.5 x 0.228

= 1.71

The velocity of oscillation,

$$v = \frac{d}{dt}y(x,t) = \frac{d}{dt}\left[7.5sin\left(0.0050x + 12t + \frac{\pi}{4}\right)\right]$$

$$= 7.5 \times 12cos(0.0050x + 12t + \frac{\pi}{4})$$

At x = 1 cm and t = 1 s

$$v = 90cos(12.005 + \frac{\pi}{4})$$

θ = (12.005 + π/4)

= (12.005 + π/4) x 180/π

= 12.79 x 180/3.14

θ = 12.79 x 57.32 = 733.18

v = 90 cos (733.18)

= 90 cos (720 + 13.18)

= 90 cos 13.18

= 90 x 0.97 cm/s

= 87.63 cm/s

The standard equation is given as

$$y(x,t) = tsin\left[\frac{\pi}{4}(vt + x) + \phi_0\right]$$

We get $y(x,t) = asin(kx + \omega t + \phi)$

here, $k = 2\pi/\lambda$

and $\omega = 2\pi v$

Comparing the given equation with the standard equation

a = 7.5 cm

ω = 12 rad/s

$\Rightarrow 2\pi f$ = 12 rad/s

Therefore, $f = 12/2\pi = 6/\pi$

k = 0.0050 cm^{-1}

$2\pi/\lambda$ = 0.0050 cm^{-1}

$\Rightarrow \lambda = 2\pi/0.0050 = 400\ \pi$

Velocity of the wave propagation, $v = f\lambda$

= $(6/\pi) \times 400\ \pi$ = 2400 cm/s

Velocity at x = 1 cm and t = 1s is not equal to the velocity of wave propagation

(b) Propagation constant, $k=2\pi/\lambda$

here λ is the wavelength

$\Rightarrow \lambda=2\pi/k=(2\times3.14)/0.0050$
=1256cm=12.56 m

All the points at distance $\pm\lambda$, $\pm2\lambda$, … from x =1 cm will have the same transverse displacement and velocity. As λ = 12.56 m, therefore the points ±12.56m, ± 25.12m, … and so on for x=1cm, will have the same displacement as the x=1cm points at t=2s,5s and 11s.

Q23. 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?

Solution:

(a) The speed of propagation is definite, it is equal to the speed of the sound in air. The wavelength and frequency will not be definite.

(b) The frequency of the note produced by a whistle is not 1/20 = 0.05 Hz. However, 0.05 Hz is the frequency of repetition of the short pip of the whistle.

Q24. One end of a long string of linear mass density 8.0×10^{-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 a function of x and t that describes the wave on the string.

Solution:

Linear mass density of the string, $\mu = 8.0 \times 10^{-3}$ kg m^{-1}

Frequency of the tuning fork = 256 Hz

Mass on the pan = 90 kg

Tension on the string, T = 90 x 9.8 = 882 N

Amplitude, A = 0.05 m

For a transverse wave, the velocity is given by the relation.

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

= 332 m/s

Angular frequency, $\omega = 2\pi f$

= 2 x 3.14 x 256 = 1608.5 rad/sec

Wavelength, $\lambda = v/f = 332/256 = 1.296$ m

Propagation constant, $k = 2\pi/\lambda = (2 \times 3.14)/ 1.296$

= 4.845 m^{-1}

The general equation of the wave is

$y(x,t) = A \sin(\omega t - kx)$

Substituting all the values we get

$y(x,t) = A \sin(1608.5t - 4.845x)$

x and y are in metre and t is in seconds.

Q25. 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}.

Solution:

Frequency of the SONAR system, f=40 kHz = 40 x 10^3 Hz

Speed of sound in water, v =1450m/s
Speed of the enemy submarine, v_0=360km/h= 360 x (5/18) = 100m/s

The SONAR is at rest and the energy submarine moves towards it. Therefore, the apparent frequency is given by the relation
$f' = [(v+v_0)/v]f$

$= [(1450 + 100)/1450] \times 40 \times 10^3$

$= 42.75 \times 10^3$

This frequency (f’) is reflected by the enemy submarine and it is observed by the SONAR. Therefore,
v_s = 360 km/s = 100m/s

$f'' = (v/(v - v_s)) \times f'$

$= (1450/(1450 - 100)) \times 42.75 \times 10^3$

$= (1450/1350) \times 42.75 \times 10^3$

$= 45.91 \times 10^3$

Q26.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 the S wave is about 4.0 km s^{-1}, and that of the 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 a straight line, at what distance does the earthquake occur?

Solution:

Let the speeds of S and P be v_1 and v_2 respectively. The time taken by the S and P waves to reach the position of the seismograph is t_1 and t_2 respectively

$l = v_1t_1 = v_2t_2$

The speed of S wave, v_1=4.0 km s^{-1}

The speed of P wave, v_2= 8.0 km s^{-1}

$4t_1 = 8t_2$

$t_1 = 2t_2$

The first P wave arrives 4 min before the S wave.

$t_1 - t_2 = 4$ min = 4 x 60 s = 240 s

$2t_2 - t_2 = 240$ s

$t_2 = 240$ s

$t_1 = 2t_2 = 2 \times 240 = 480$ s

Distance at which earthquake occur, $l = v_1t_1 = 4 \times 480 = 1920$ km

Q27. 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 the air. What frequency does the bat hear reflected off the wall?

Solution:

The sound emission frequency of the bat = 40 kHz

The velocity of the bat, $v_b = 0.03$ v

here v is the velocity of the sound in air

The apparent frequency of the sound hitting the wall

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

$$f' = \left(\frac{v}{v-0.03v}\right) \times 40$$

= 40/0.97 kHz

The frequency gets reflected by the wall and is received by the bat moving towards the wall.

$$f'' = \left(\frac{v+v_b}{v}\right) \times f'$$

$$f'' = \left(\frac{v+0.03v}{v}\right) \times \frac{40}{0.97}$$

= (1.03 x 40 /0.97) = 42.47 kHz

Q28. A man standing at a certain distance from an observer blows a horn of frequency 200 Hz in still air. (a) Find the horn's frequency for the observer when the man (i) runs towards him at 20 m/s (ii) runs away from him at 20 m /s.
(b) Find the speed of sound in both the cases.
[Speed of sound in still air is 340 m/ s]

Solution:

Given,
Frequency of the horn, v_H = 200 Hz
Velocity of the man, v_T = 20 m/ s
Velocity of sound, v = 340 m/ s

(a) We know,
(i) The apparent frequency of the horn as the man approaches the observer is:
$v' = v_H [v/(v - v_T)]$
= 200 [340 /(340 – 20)]
= 212.5 Hz
(ii) The apparent frequency of the horn as the man runs away from the observer is:
$v'' = v_H [v/(v + v_T)]$
= 200 [340 /(340 + 20)]
= 188.88 Hz
(b) The speed of sound is 340 m/s in both the cases. The apparent change in frequency is a result of the relative motions of the observer and the source.

Q29. A truck parked outside a petrol pump blows a horn of frequency 200 Hz in still air. The Wind then starts blowing towards the petrol pump at 20 m /s. Calculate the wavelength, speed, and frequency of the horn's sound for a man standing at the petrol pump. Is this situation completely identical to a situation when the observer moves towards the truck at 20 m /sand the air is still?

Solution:

For the standing observer:
Frequency, $v_H = 200$ Hz
Velocity of sound, $v = 340$ m/s
Speed of the wind, $v_W = 20$ m/s

The observer will hear the horn at 200 Hz itself because there is no relative motion between the observer and the truck.

Given that the wind blows in the observer's direction at 20 m/s.
Effective velocity of the sound, $v_E = 340 + 20 = 360$ m/s

The wavelength (λ) of the sound :
$\lambda = v_E / v_H = 360/200$
$\lambda = 1.8$ m

For the observer running towards the train :
Speed of the observer, $v_o = 20$ m/s

We know,
The apparent frequency of the sound as the observers move towards the truck is :
$v' = v_H [(v + v_o)/v]$
$= 200[(20 + 340)/340] = 211.764$ Hz

As the air is still the effective velocity of sound is still 340 m/s.
As the truck is stationary the wavelength remains 1.8 m.

Thus, the two cases are not completely identical.