

Chapter 15: Waves

NCERT Exemplar · Class 11 · Physics

Questions

Question 15.1

Water waves produced by a motorboat sailing in water are

- a) neither longitudinal nor transverse
- b) both longitudinal and transverse
- c) only longitudinal
- d) only transverse

Solution

The correct answer is b) both longitudinal and transverse

Question 15.2

Sound waves of wavelength λ travelling in a medium with a speed of v m/s enter into another medium where its speed is $2v$ m/s. The wavelength of sound waves in the second medium is

- a) λ
- b) $\lambda/2$
- c) 2λ
- d) 4λ

Solution

The correct answer is c) 2λ

Question 15.3

Speed of sound wave in air

- a) is independent of temperature

- b) increases with pressure
- c) increases with an increase in humidity
- d) decreases with an increase in humidity

Solution

The correct answer is c) increases with an increase in humidity

Question 15.4

Change in temperature of the medium changes

- a) frequency of sound waves
- b) amplitude of sound waves
- c) wavelength of sound waves
- d) loudness of sound waves

Solution

The correct answer is c) wavelength of sound waves

Question 15.5

With the propagation of longitudinal waves through a medium, the quantity transmitted is

- a) matter
- b) energy
- c) energy and matter
- d) energy, matter, and momentum

Solution

The correct answer is b) energy

Question 15.6

Which of the following statements are true for wave motion?

A.

mechanical transverse waves can propagate through all mediums

B.

longitudinal waves can propagate through solids only

C.

mechanical transverse waves can propagate through solids only

D.

longitudinal waves can propagate through a vacuum

Answer

Correct option: C

Solution

The correct answer is c) mechanical transverse waves can propagate through solids only

Question 15.7

A sound wave is passing through the air column in the form of compression and rarefaction. In consecutive compressions and rarefactions,

- a) density remains constant
- b) Boyle's law is obeyed
- c) bulk modulus of air oscillates
- d) there is no transfer of heat

Solution

The correct answer is d) there is no transfer of heat

Question 15.8

Equation of a plane progressive wave is given by $y = 0.6 \sin 2\pi(t-x/2)$. On reflection from a denser medium, its amplitude becomes $2/3$ of the amplitude of the incident wave

- a) $y = 0.6 \sin 2\pi(t+x/2)$

b) $y = -0.4 \sin 2\pi(t+x/2)$

c) $y = 0.4 \sin 2\pi(t+x/2)$

d) $y = -0.4 \sin 2\pi(t-x/2)$

Solution

The correct answer is b) $y = -0.4 \sin 2\pi(t+x/2)$

Question 15.9

A string of mass 2.5 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, the disturbance will reach the other end in

a) one second

b) 0.5 second

c) 2 seconds

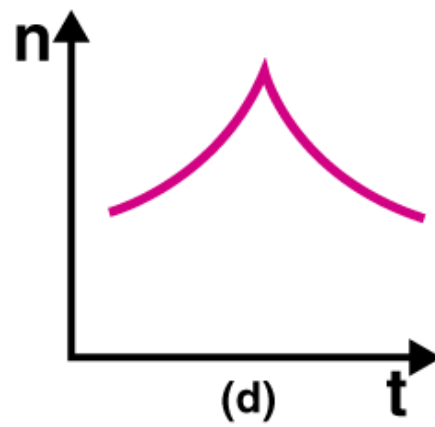
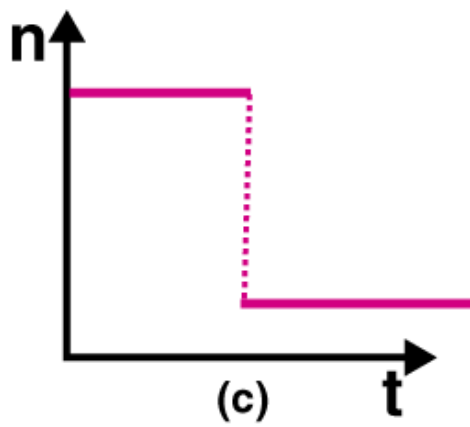
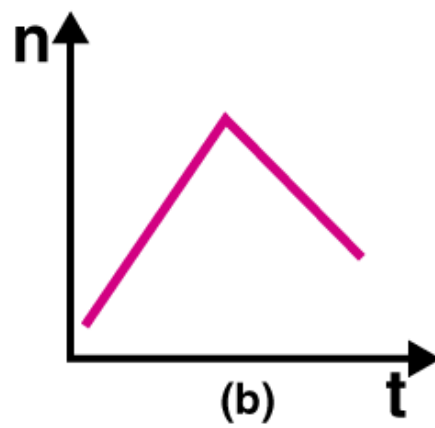
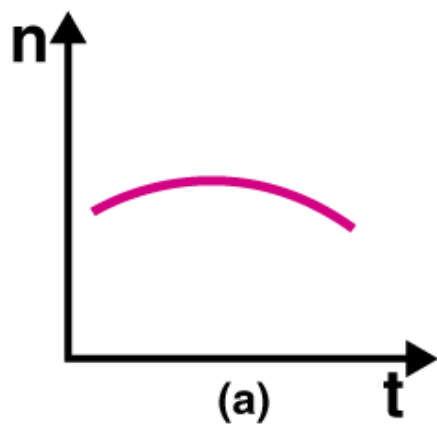
d) data given is insufficient

Solution

The correct answer is b) 0.5 second

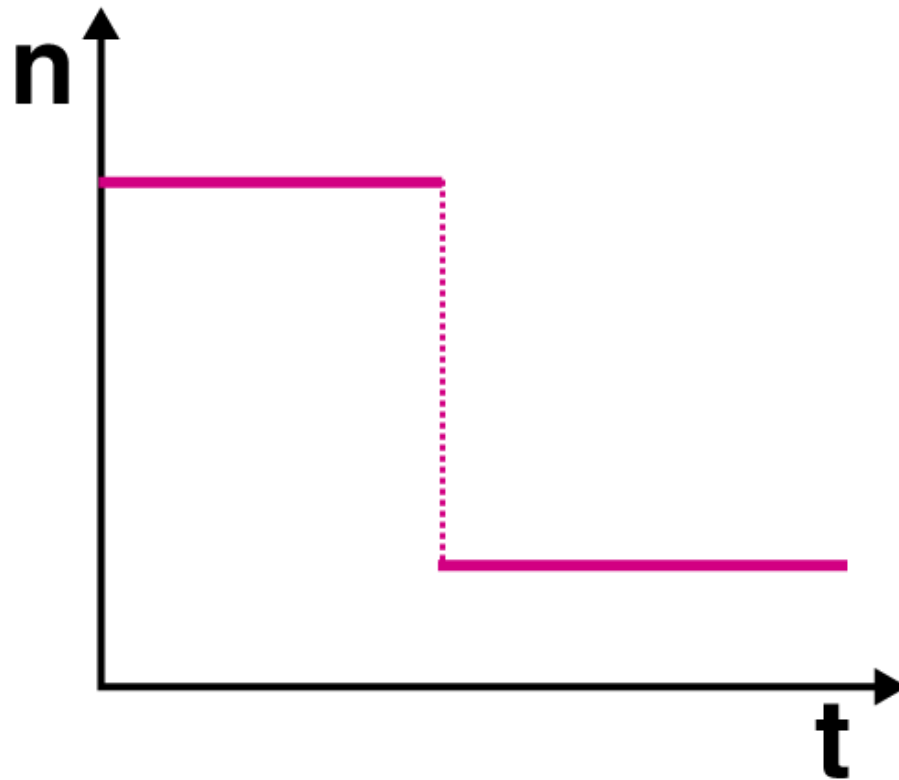
Question 15.10

A train whistling at constant frequency is moving towards a station at a constant speed V . The train goes past a stationary observer on the station. The frequency n' of the sound as heard by the observer is plotted as a function of time t . Identify the expected curve



Solution

The correct answer is c)



Multiple Choice Questions II

Question 15.11

A transverse harmonic wave on a string is described by $y(x,t) = 3.0 \sin(36t + 0.018x + \pi/4)$ where x and y are in cm and t is in s. The positive direction of x is from left to right

- a) the wave is travelling from right to left
- b) the speed of the wave is 20 m/s
- c) frequency of the wave is 5.7 Hz
- d) the least distance between two successive crests in the wave is 2.5 cm

Solution

The correct answers are

- a) the wave is travelling from right to left
- b) the speed of the wave is 20 m/s

c) frequency of the wave is 5.7 Hz

Question 15.12

The displacement of a string is given by $y(x,t) = 0.06 \sin(2\pi x/3) \cos(120\pi t)$ where x and y are in m and t in s. The length of the string is 1.5 m and its mass is 3.0×10^{-2} kg.

- a) it represents a progressive wave of frequency 60 Hz
- b) it represents a stationary wave of frequency 60 Hz
- c) it is the result of the superposition of two waves of wavelength 3 m, frequency 60 Hz each travelling with a speed of 180 m/s in the opposite direction
- d) amplitude of this wave is constant

Solution

The correct answers are

- b) it represents a stationary wave of frequency 60 Hz
 - c) it is the result of the superposition of two waves of wavelength 3 m, frequency 60 Hz each travelling with a speed of 180 m/s in the opposite direction
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Question 15.13

Speed of sound waves in a fluid depends upon

- a) directly on the density of the medium
- b) square of bulk modulus of the medium
- c) inversely on the square root of density
- d) directly on the square root of bulk modulus of the medium

Solution

The correct answers are

- c) inversely on the square root of density
 - d) directly on the square root of bulk modulus of the medium
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Question 15.14

During propagation of a plane progressive mechanical wave

- a) all the particles are vibrating in the same phase
- b) amplitude of all the particles is equal
- c) particles of the medium executes SHM
- d) wave velocity depends upon the nature of the medium

Solution

The correct answers are

- b) amplitude of all the particles is equal
- c) particles of the medium executes SHM
- d) wave velocity depends upon the nature of the medium

Question 15.15

The transverse displacement of a string is given by $y(x,t) = 0.06 \sin(2\pi x/3) \cos(120\pi t)$. All the points on the string between two consecutive nodes vibrate with

- a) same frequency
- b) same phase
- c) same energy
- d) different amplitude

Solution

The correct answers are

- a) same frequency
- b) same phase
- d) different amplitude

Question 15.16

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. Given that the speed of sound in still air is 340 m/s

- a) the frequency of sound as heard by an observer standing on the platform is 400 Hz
- b) the speed of sound for the observer standing on the platform is 350 m/s
- c) the frequency of sound as heard by the observer standing on the platform will increase
- d) the frequency of sound as heard by the observer standing on the platform will decrease

Solution

The correct answers are

- a) the frequency of sound as heard by an observer standing on the platform is 400 Hz
- b) the speed of sound for the observer standing on the platform is 350 m/s

Question 15.17

Which of the following statements is true for a stationary wave?

- e) there are some particles which are always at rest

A.

every particle has a fixed amplitude which is different from the amplitude of its nearest particle

B.

all the particles cross their mean position at the same time

C.

all the particles oscillate with the same amplitude

D.

there is no net transfer of energy across any plane

Solution

The correct answers are

- a) every particle has a fixed amplitude which is different from the amplitude of its nearest particle
- b) all the particles cross their mean position at the same time
- d) there is no net transfer of energy across any plane
- e) there are some particles which are always at rest

Very Short Answer

Question 15.18

A sonometer wire is vibrating in resonance with a tuning fork. Keeping the tension applied the same, the length of the wire is doubled. Under what conditions would the tuning fork still be at resonance with the wire?

Solution

The length of the wire used in a sonometer is twice when it vibrates. Therefore, if the tuning fork resonates at L , the sonometer resonates at $2L$. The following equation is used to express the frequency of the sonometer

$$f = \frac{n}{2L} \sqrt{\frac{T}{\mu}} = \frac{nv}{2L}$$

The velocity of the wave from the sonometer is constant. The resonance between the tuning fork and the wire will remain even after the change in the length of the wire.

Then,

$$n/L = \text{constant}$$

Which also means that,

$$n_1/L_1 = n_2/L_2$$

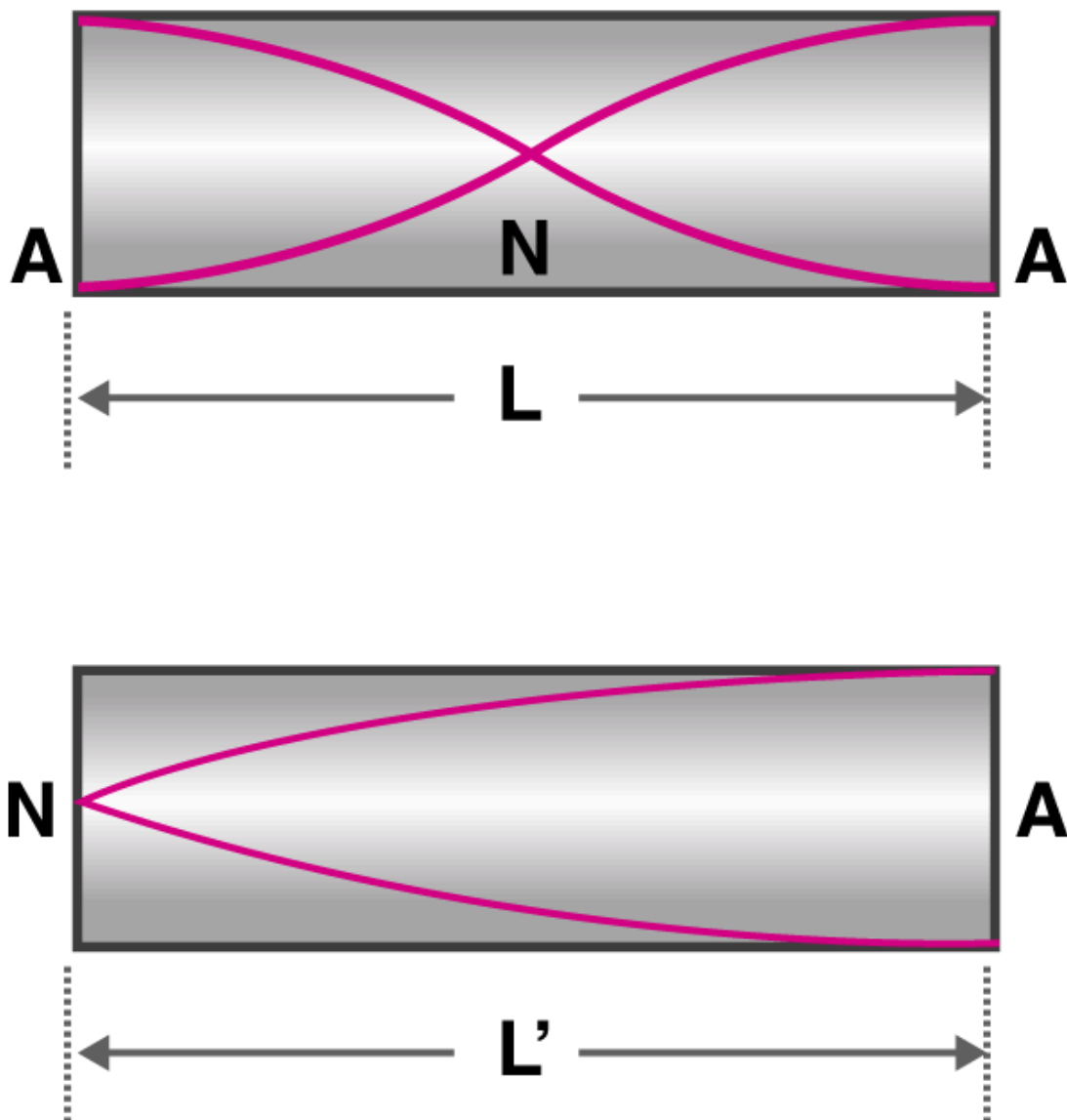
$$n_1/L_1 = n_2/2L_2$$

$$n_2 = 2n_1$$

Therefore, when the wire length is doubled, the resonance also gets doubled.

Question 15.19

An organ pipe of length L open at both ends is found to vibrate in its first harmonic when sounded with a tuning fork of 480 Hz. What should be the length of a pipe closed at one end, so that it also vibrates in its first harmonic with the same tuning fork?

Solution

From the harmonic is open, $L = \lambda/2$

$$\lambda = 2L$$

$$v/f_0 = 2L$$

$$(f_0)_{\text{open}} = v/2L$$

where v is the speed of the sound wave in the air.

When the harmonic is closed, $L' = \lambda/4$

$$\lambda = 4L'$$

$$(f_0)_{\text{closed}} = v/4L'$$

$$v/2L = v/4L'$$

$$L' = L/2$$

Question 15.20

A tuning fork A, marked 512 Hz, produces 5 beats per second, where sounded with another unmarked tuning fork B. If B is loaded with wax, the number of beats is again 5 per second. What is the frequency of the tuning fork B when not loaded?

Solution

When tuning fork B is loaded with the wax, the frequency of the tuning fork becomes less than its original frequency. When the tuning fork is marked 512 Hz, let's assume that the tuning fork B is marked to 517 Hz because it produces 5 beats per second and when it is loaded, the frequency is less than 512 Hz. So it can be said that when the tuning fork is not loaded, the frequency remains the same, that is, 517 Hz.

Question 15.21

The displacement of an elastic wave is given by the function $y = 3 \sin \omega t + 4 \cos \omega t$ where y is in cm and t is in second. Calculate the resultant amplitude.

Solution

Given,

$$y = 3 \sin \omega t + 4 \cos \omega t$$

Let's consider

$$3 = a \cos \phi$$

$$4 = a \sin \phi$$

Then

$$y = a \cos \phi \omega t + a \sin \phi \omega t$$

$$y = a \sin (\omega t + \phi)$$

$$\tan \phi = 4/3$$

$$\phi = \tan^{-1} 4/3$$

When the above equation is squared, we get

$$a^2 = 25$$

$$a = 5$$

Therefore, the new amplitude is 5 cm.

Question 15.22

A sitar wire is replaced by another wire of the same length and material but of three times the earlier radius. If the tension in the wire remains the same, by what factor will the frequency change?

Solution

The frequency of the stretched wire is given as:

$$v = \frac{n}{2L} \sqrt{\frac{T}{m}}$$

Given that,

No. of harmonic n , length L , and tension T are the same in both cases.

Therefore,

$$v \propto \frac{1}{\sqrt{m}} \Rightarrow \frac{v_1}{v_2} = \frac{\sqrt{m_2}}{\sqrt{m_1}}$$

Substituting the values of mass per unit length, we get

$$\frac{m_2}{m_1} = \frac{\pi r_2^2 \rho}{\pi r_1^2 \rho} = \frac{(3r)^2}{r^2} = \frac{9}{1}$$

Solving the above the equation, we get $v_2 = 1/3 v_1$

Therefore, the frequency of the sitar is reduced by 1/2 of its actual value.

Question 15.23

At what temperatures will the speed of sound in the air be 3 times its value at 0°C?

Solution

We know that,

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

Given that,

$$v_T = 3v_0$$

$$\frac{3v_0}{v_0} = \sqrt{\frac{T}{273 + 0}} \Rightarrow \sqrt{T} = 3\sqrt{273}$$

$$T = 2457 - 273 = 2184^\circ\text{C}$$

Question 15.24

When two waves of almost equal frequencies, n_1 and n_2 , reach at a point simultaneously, what is the time interval between successive maxima?

Solution

It is given that the two frequencies are almost equal, that is $n_1 = n_2$.

For the formation of the beats, the frequencies must be $n_2 > n_1$.

The no. of frequencies per second in maxima = $n = n_2 - n_1$

Therefore, the time period of the maxima = $1/n = 1/n_2 - n_1$ second.

Short Answers

Question 15.25

A steel wire has a length of 12 m and a mass of 2.10 kg. What will be the speed of a transverse wave on this wire when a tension of 2.06×10^4 N is applied?

Solution

Length, $l = 12$ m

Total mass, $M = 2.10$ kg

$$m = M/l = 2.1/12$$

Tension, $T = 2.06 \times 10^4$ N

Therefore, v is given as

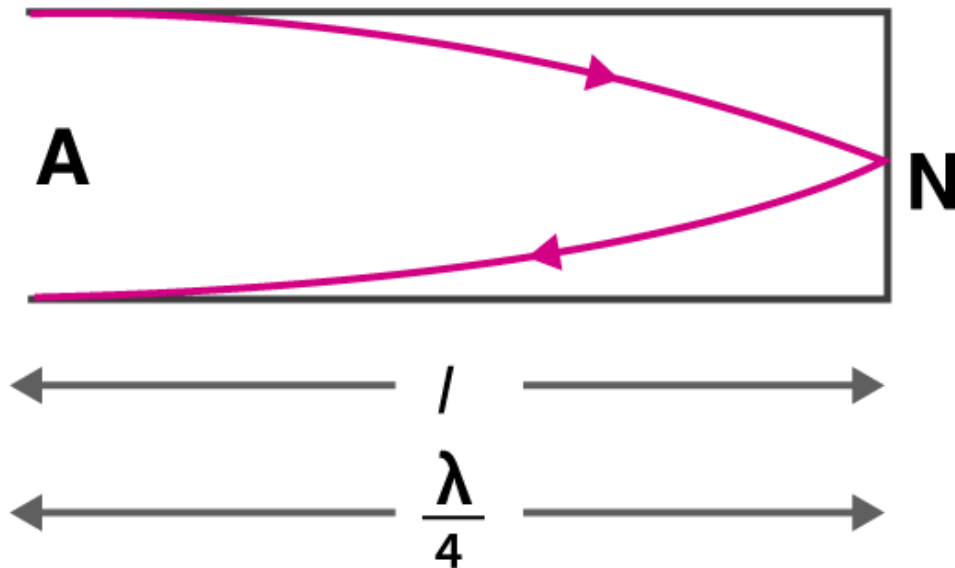
$$v = \sqrt{\frac{T}{m}} = \frac{2.06 \times 10^4 \times 12}{2.10} = 3.43 \times 10^2$$

$$v = 343.0 \text{ m/s}$$

Question 15.26

A pipe of 20 cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a source of 1237.5 Hz?

Solution



Given,

Length, $l = 20 \text{ cm} = 0.2 \text{ m}$

$v = 1237.5 \text{ Hz}$

Assuming that velocity of sound in air = 330 m/s

$$l = \lambda/4$$

$$\lambda = 4l$$

We know that,

$$v_1 = v / \lambda = v / 4l$$

$$v_1 = 412.5 \text{ Hz}$$

$$v/v_1 = 1237.5/412.5 = 3/1$$

Therefore, the third harmonic will have 1237.5 Hz frequency.

Question 15.27

A train standing at the outer signal of a railway station blows a whistle of frequency 400 Hz still air. The train begins to move at a speed of 10 m/s towards the platform. What is the frequency of the sound for an observer standing on the platform?

Solution

$$v_0 = 400 \text{ Hz}$$

$$v_z = 10 \text{ m/s}$$

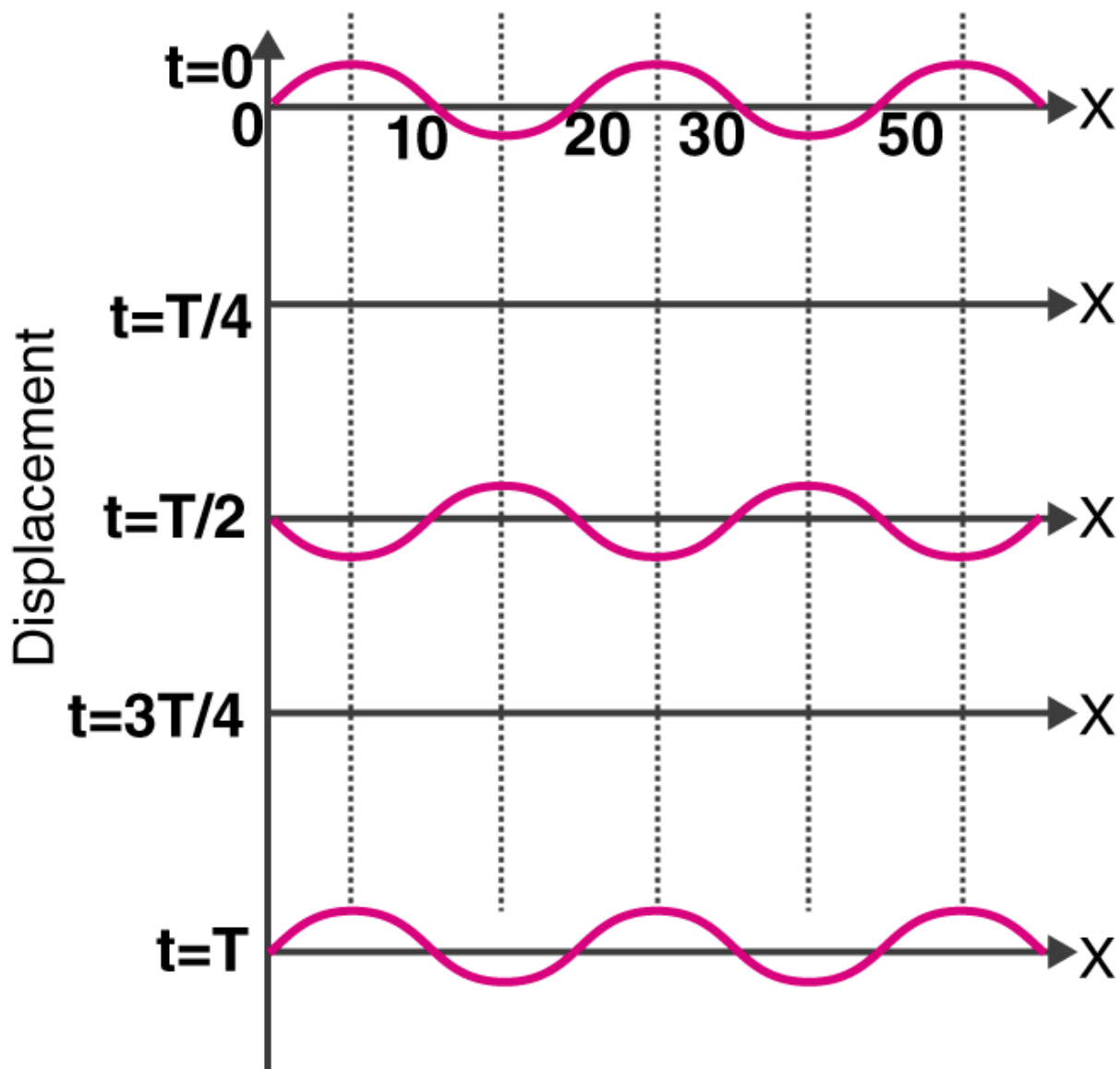
The velocity of sound in air, $v_a = 330 \text{ m/s}$

v' is the frequency heard by the observer standing on the platform

$$v' = (330)(400)/320 = 412.5 \text{ Hz}$$

Question 15.28

The wave pattern on a stretched string is shown in the figure. Interpret what kind of wave this is and find its wavelength.



Solution

When particles at $t = T/4$ and $3T/4$ are at rest on a stationary wave which is at its mean position.

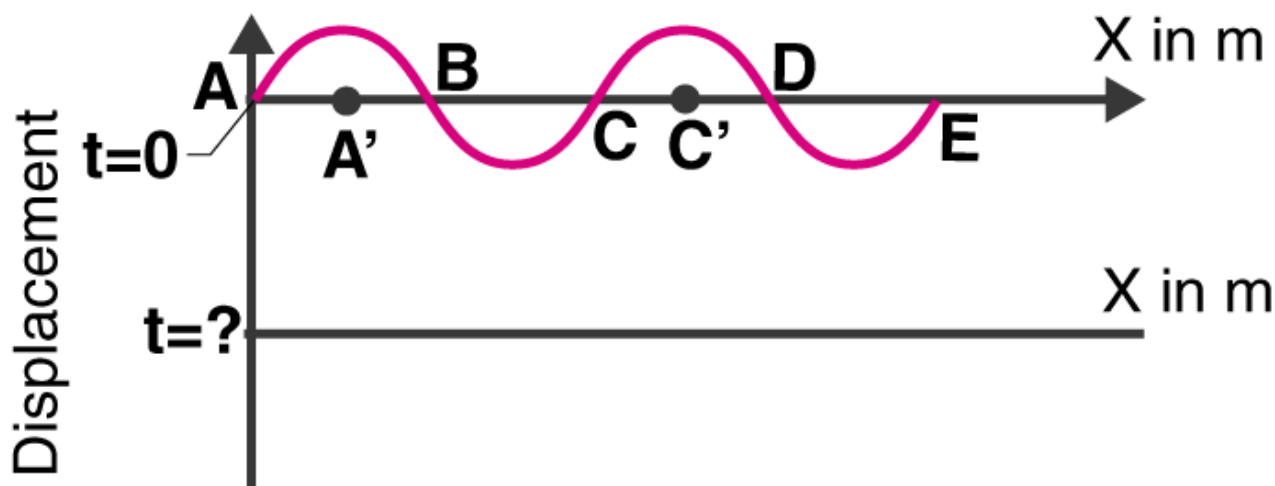
The nodes in the graph when the wave is at $x = 10, 20, 30, 40$ cm have a distance with the successive node is $\lambda/2$.

$$\lambda/2 = 30 - 20 = 20$$

$$\lambda = 20 \text{ cm}$$

Question 15.29

The pattern of standing waves formed on a stretched string at two instants of time is shown in the figure. The velocity of two waves superimposing to form stationary waves is 360 m/s, and their frequencies are 256 Hz.



- calculate the time at which the second curve is plotted
- mark nodes and antinodes on the curve
- calculate the distance between A' and C'

Solution

The frequency of the wave, $\nu = 256 \text{ Hz}$

$$T = 1/\nu = 1/256 \text{ sec} = 0.00390$$

$$T = 3.9 \times 10^{-3} \text{ sec}$$

- When the particle's mean position changes after $T/4$, the time is calculated as

$$t = T/4 = (3.9 \times 10^{-3})/4 = 0.975 \times 10^{-3} \text{ sec}$$

$$t = 9.8 \times 10^{-4} \text{ sec}$$

- Nodes: A, B, C, D, E

Antinode: A', C'

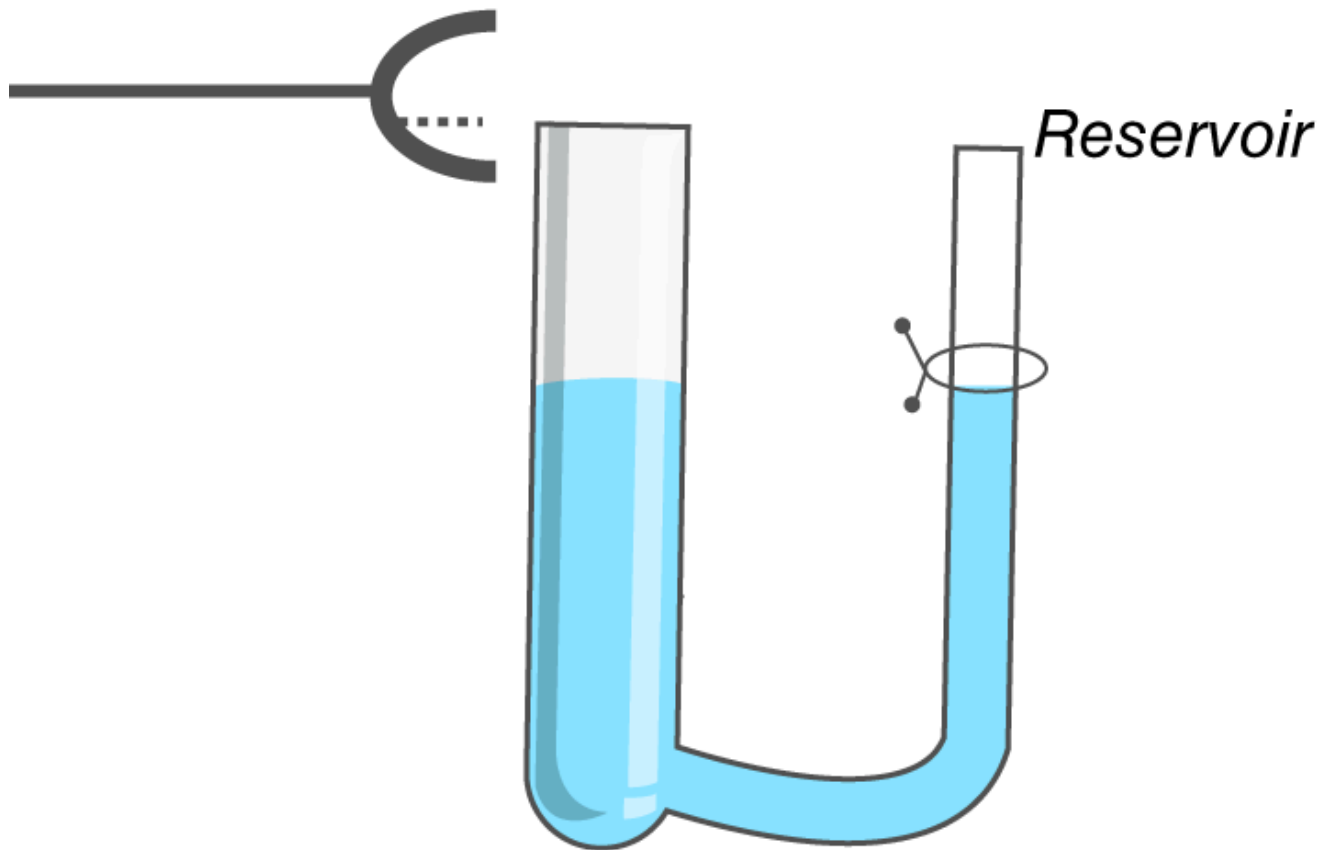
- The distance between A' and C' is

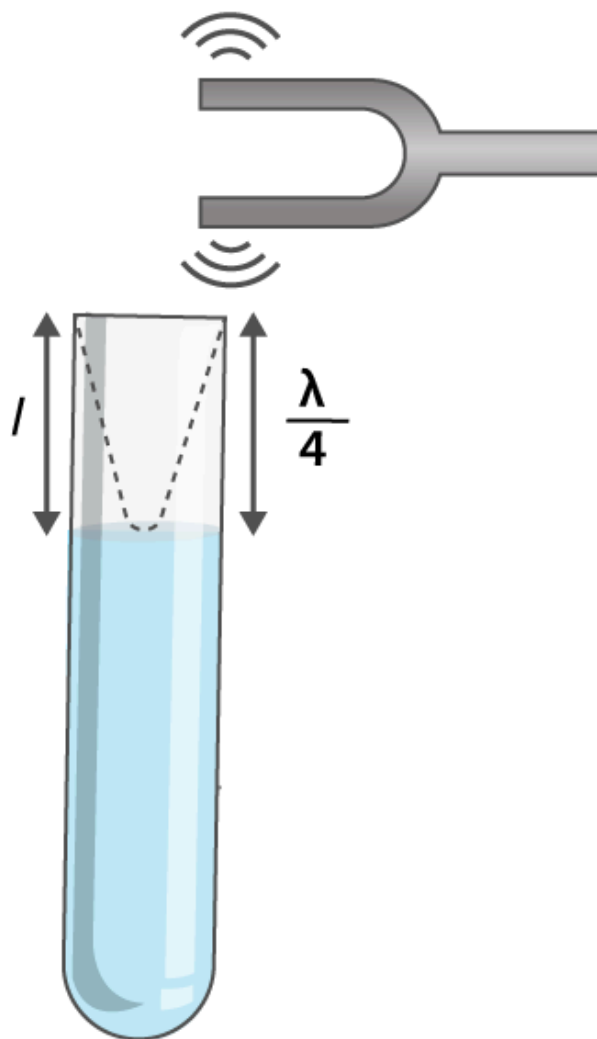
$$\lambda = v/f = 360/256 = 1.41 \text{ m}$$

Question 15.30

A tuning fork vibrating with a frequency of 512 Hz is kept close to the open end of a tube filled with water. The water level in the tube is gradually lowered. When the water level is 17 cm below the open end, the maximum intensity of sound is heard. If the room temperature is 20°C, calculate

- speed of sound in air at room temperature
- speed of sound in air at 0°C
- if the water in the tube is replaced with mercury, will there be any difference in your observations?



Solution

Given,

The frequency of the tuning fork, $f = 512 \text{ Hz}$

a) When the first maxima is considered, the length in the air column is, $l = \lambda/4$

$$\lambda = 4l$$

Speed of sound, $v = f \lambda = 348.16 \text{ m/s}$

b) We know that,

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

$$\frac{v}{v_0} = \sqrt{\frac{273 + 20}{273 + 0}} = \sqrt{\frac{293}{273}} \Rightarrow v_0 = 338 \text{ m/s}$$

Question 15.31

Show that when a string fixed at its two ends vibrates in 1 loop, 2 loops, 3 loops, and 4 loops, the frequencies are in the ratio 1:2:3:4.

Solution

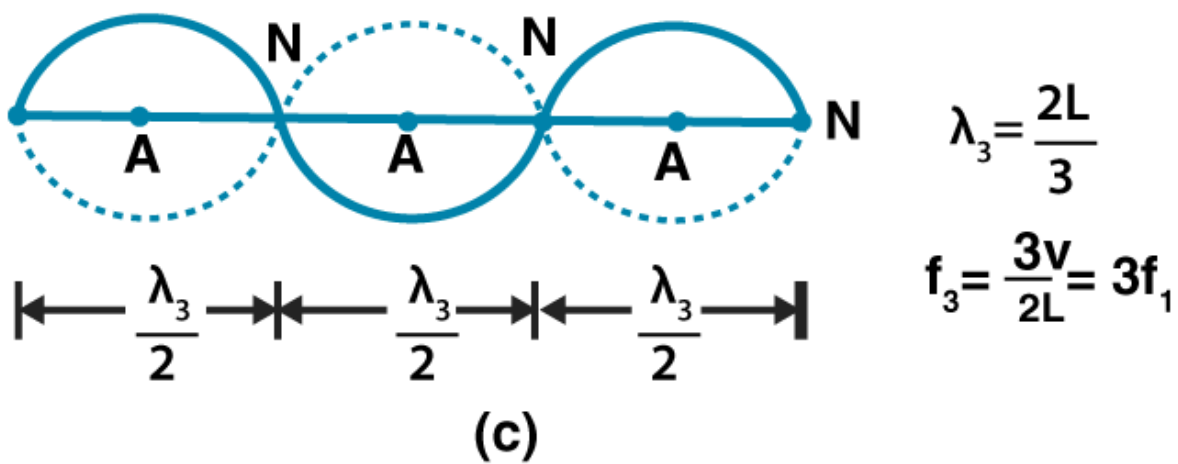
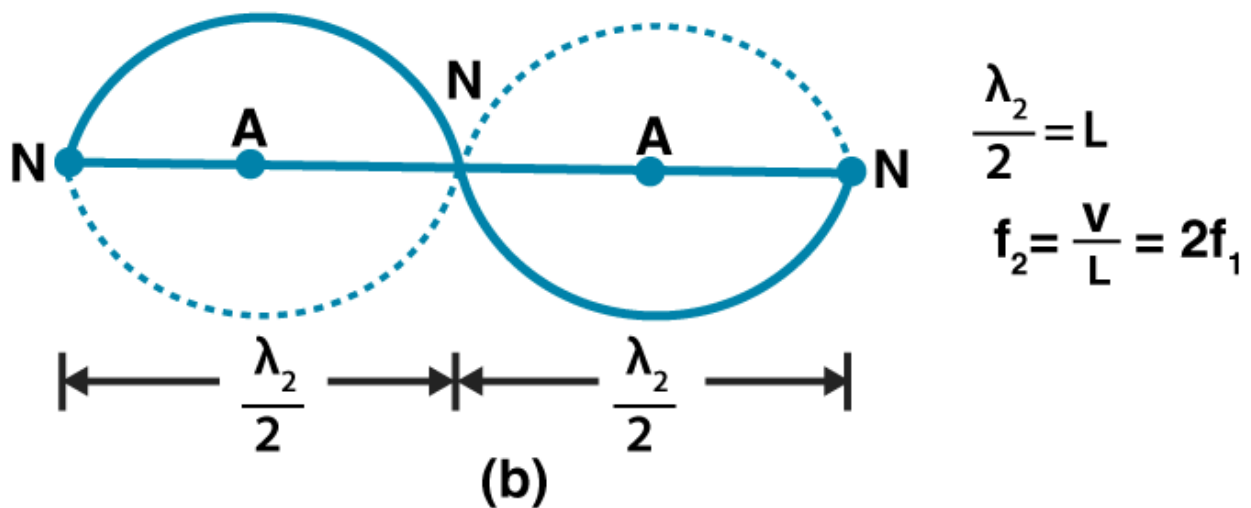
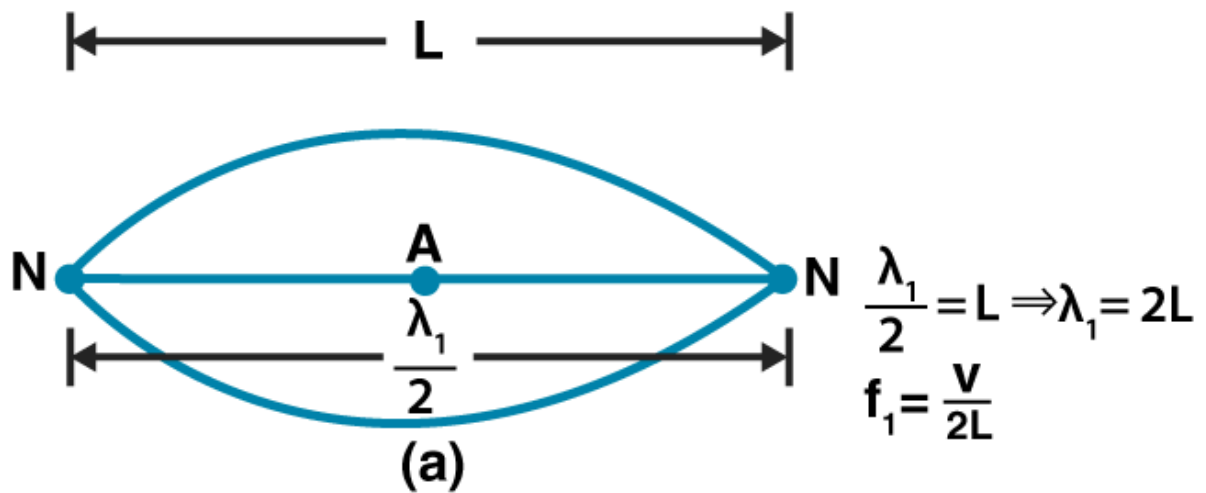
When $n = 1$, $f_1 = v/2L$, which is known as the fundamental frequency.

When $n = 2$, $f_2 = 2(v/2L)$, which is known as the first overtone.

When $n = 3$, $f_3 = 3(v/2L)$, which is known as the second overtone.

When $n = 4$, $f_4 = 4(v/2L)$, which is known as the third overtone.

In all cases, the tone is equal to the fundamental frequency.

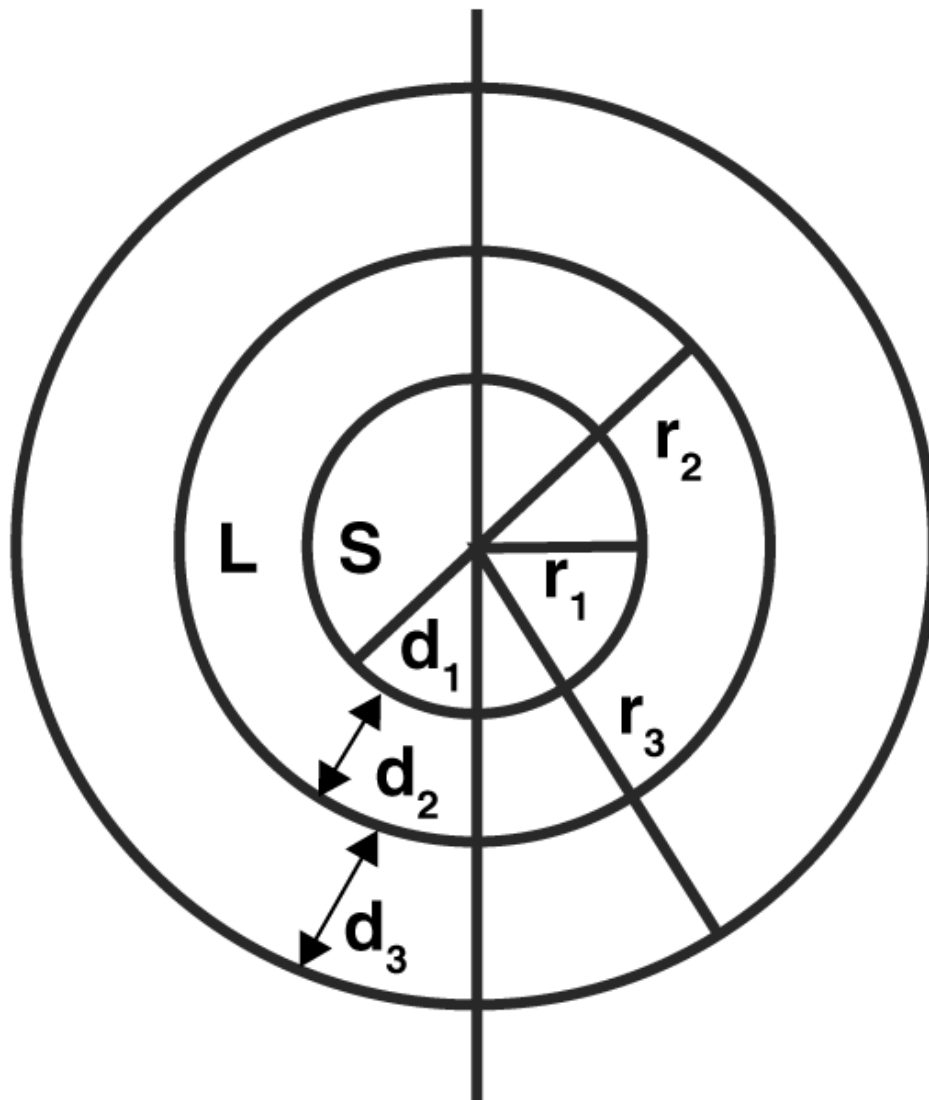


Long Answers

Question 15.32

The earth has a radius of 6400 km. The inner core of the 1000 km radius is solid. Outside it, there is a region from 1000 km to a radius of 3500 km which is in a molten state. Then again, from 3500 km to 6400 km, the earth is solid. Only longitudinal (P) waves can travel inside a liquid. Assume that the P wave has a speed of 8 km/s in solid parts and of 5 km/s in liquid parts of the earth. An earthquake occurs at someplace close to the surface of the earth. Calculate the time after which it will be recorded in a seismometer at a diametrically opposite point on the earth if the wave travels along diameter.

Solution



Given,

$$r_1 = 1000 \text{ km}$$

$$r_2 = 3500 \text{ km}$$

$$r_3 = 6400 \text{ km}$$

$$d_1 = 1000 \text{ km}$$

$$d_2 = 3500 - 1000 = 2500 \text{ km}$$

$$d_3 = 6400 - 3500 = 2900 \text{ km}$$

The solid distance is given as:

$$2(d_1 + d_3) = 2(1000 + 2900)$$

Time taken by the wave during the production of an earthquake is

$$(3900)(2)/8 \text{ sec}$$

$$\text{Liquid distance} = 2d_2 = (2)(2500)$$

Time taken by the seismic wave in the liquid part is

$$(2)(2500)/5$$

Therefore, total time taken = time taken by the wave during the production of an earthquake + time taken by the seismic wave in the liquid part

$$= 32 \text{ minutes } 55 \text{ seconds}$$

Question 15.33

If c is r.m.s speed of molecules in a gas and v is the speed of sound waves in the gas, show that c/v is constant and independent of temperature for all diatomic gases.

Solution

We know the following is the equation for molecules:

$$c = \sqrt{\frac{3P}{\rho}}$$

$$c = \sqrt{\frac{3RT}{M}}$$

$$p/\rho = PT/M$$

Where, M is the molar mass of the gas

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

c/v is given as:

$$\frac{c}{v} = \frac{\sqrt{\frac{3RT}{M}}}{\sqrt{\frac{\gamma RT}{M}}} = \sqrt{\frac{3}{\gamma}}$$

Therefore,

$$\frac{c}{v} = \sqrt{\frac{3}{\frac{7}{5}}} = \sqrt{\frac{15}{7}} = \text{constant}$$

Question 15.34

Given below are some functions of x and t to represent the displacement of an elastic wave.

a) $y = 5 \cos (4x) \sin (20t)$

b) $y = 4 \sin (5x-t/2) + 3 \cos (5x-t/2)$

c) $y = 10 \cos [(252-250)\pi t] \cos [(252+250) \pi t]$

d) $y = 100 \cos (100 \pi t + 0.5x)$

State which of these represent

a) a travelling wave along -x direction

b) a stationary wave

c) beats

d) a travelling wave along +x direction

Give reasons for your answers

Solution

a) When a wave travels in (-x) direction, it must have +kx, which is given as:

d) $y = 100 \cos (100 \pi t + 0.5x)$

b) When a stationary wave is there, then,

a) $y = 5 \cos (4x) \sin (20t)$

c) When beats are involved

c) $y = 10 \cos [(252-250)\pi t] \cos [(252+250) \pi t]$

d) a travelling wave along +x direction is

b) $y = 4 \sin (5x-t/2) + 3 \cos (5x-t/2)$

Question 15.35

In the given progressive waves $y = 5 \sin (100 \pi t - 0.4 \pi x)$ where y and x are in m, t is in s. What is the

a) amplitude

b) wavelength

c) frequency

d) wave velocity

e) particle velocity amplitude

Solution

Given,

The wave is travelling in +x direction

The equation is

$y = 5 \sin (100 \pi t - 0.4 \pi x)$

- a) amplitude, $a = 5 \text{ m}$
- b) wavelength, $\lambda = 2\pi / k = 5 \text{ m}$
- c) frequency, $\nu = 50 \text{ Hz}$
- d) wave velocity, $v = 250 \text{ m/s}$
- e) particle velocity amplitude $= 500 \pi \text{ m/s}$

Question 15.36

For the harmonic travelling wave $y = 2 \cos 2 \pi(10t - 0.0080x + 3.5)$ where x and y are in cm and t is second. What is the phase difference between the oscillatory motion at two points separated by a distance of

- a) 4 m
- b) 0.5 m
- c) $\lambda/2$
- d) $3 \lambda/4$
- e) what is the phase difference between the oscillation of a particle located at $x = 100 \text{ cm}$ at $t = T$ and $t = 5s$?

Solution

Given,

$$y = 2 \cos 2 \pi(10t - 0.0080x + 3.5)$$

$$a = 2$$

$$\omega = 20 \pi$$

$$k = 0.016 \pi$$

$$\phi = 7 \pi$$

- a) path difference, $p = 4 \text{ m} = 400 \text{ cm}$

Substituting the values, we get phase difference $= 6.4 \pi \text{ rad}$

- b) path difference, $p = 0.5 \text{ m} = 50 \text{ cm}$

Substituting the values, we get phase difference $= 0.8 \pi \text{ rad}$

c) path difference, $p = \lambda/2$

Substituting the values, we get phase difference = π rad

d) path difference, $p = 3\lambda/4$

Substituting the values, we get phase difference = 98π rad

Different Types of Waves

1. Microwaves
2. Infrared radiation
3. Gamma rays
4. X-rays
5. Radio waves
6. Ultraviolet radiation

Important Concepts Covered in Class 11 Physics Chapter 15 Waves

1. Transverse and longitudinal waves
 2. Displacement relation in a progressive wave
 3. The speed of a travelling wave
 4. The principle of superposition of waves
 5. Reflection of waves
 6. Beats
 7. Doppler effect.
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