SHORT QUESTIONS

8.1 What feature do longitudinal waves have in common with transverse waves?

Ans. The following features are common in transverse wave and longitudinal waves:

(i) Both are mechanical waves.

(ii) Both waves transfer energy from one point to another point but not matter.

(iii) Both produce disturbance in the medium through which they travel.

(iv) The relation $v = f\lambda$ holds for both the waves here v is speed of wave, "f", frequency and λ is wavelength.

8.2 The five possible waveforms obtained, when the output from a microphone is fed into the y-input of cathode ray oscilloscope, with the time base on, are shown in Fig. 8.23. These waveform are obtained under the same adjustment of the cathode ray oscilloscope controls, indicate the waveform:

(a) which trace represents the loudest note?

(b) which trace represents the highest frequency?

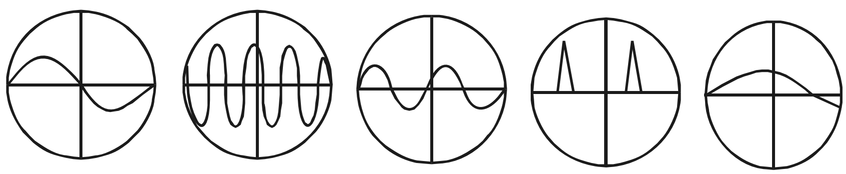


Fig. 8.23

Ans. (a) The trace (B) represents the loudest sound because the loudness of sound depends upon the amplitude of vibration.

(b) The trace (B) represents the highest frequency because the number of waves per second are maximum.

8.3 Is it possible for two identical waves traveling in the same direction along a string to give rise to a stationary wave?

Ans. No, the stationary waves are not produced when the two identical waves are travelling the same direction. Because in order to produce stationary waves, two identical waves should travel in opposite direction.

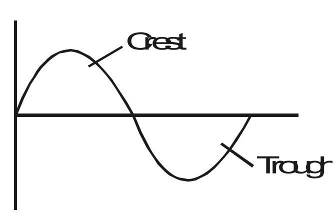
8.4 A wave is produced along a stretched string but some of its particle permanently shows zero displacement. What types of wave is it?

Ans. It will be a stationary wave because in stationary wave, some points will remain permanently at rest i.e., zero displacement called node.

8.5 Explain the terms crest, through, node, and anti-node.

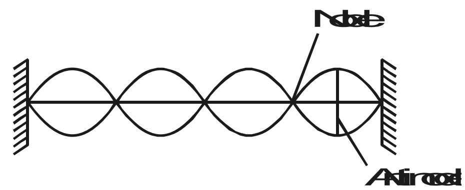
Ans. **Crest:** The upper portion of the transverse wave from the mean position is called crest.

Trough: The lower portion of the transverse wave from the mean position is called trough.



Node: The point at which the displacement of the stationary wave is zero is called node.

Anti-node: The point at which the displacement of the stationary wave is maximum is called anti-node.



8.6 Why does sound travel faster in solid than in gases?

Ans. As we know that the speed of sound is given by the expression

$$v = \sqrt{\frac{E}{\rho}}$$

From this equation we see that speed of sound is directly proportional to square root of modulus of elasticity. As the elasticity of medium is greater for solid as compared to gases and density is also greater for solids. So the effect of elasticity is greater than density thus the sound travels faster in solids than in gases.

8.7 How are beats useful in tuning musical instruments?

Ans. In musical instruments, various notes can be produced by changing the length of air column. To get a particular note, a standard instrument is taken and is sounded together with musical instrument which is to be tuned. The number of beats produced per second are recorded. The frequency of the instrument to be tuned is so adjusted that it gives no beat with standard instrument. So the musical instrument is tuned to a particular frequency with the help of phenomenon of beats.

8.8 When two notes of frequency f_1 and f_2 are sounded together, beats are formed. If $f_1 > f_2$, what will be frequency of beats?

(i) $f_1 + f_2$ **(ii)** $\frac{1}{2}(f_1 + f_2)$ **(iii)** $f_1 - f_2$ **(iv)** $\frac{1}{2}(f_2 - f_1)$

Ans. The number of beats produced in one second is equal to the difference in the frequencies of two notes. So:

Number of beats per second $= f_1 - f_2$

Hence the correct answer is (iii).

8.9 As a result of a distant explosion, an observer senses a ground tremor and then hears the explosion. Explain the time difference.

Ans. We know that sound waves travel faster through solid as compared to gases. So the time difference is due to that waves produced by explosions reach through solid ground much faster than the f sound waves travelling through air.

8.10 Explain why sound travels faster in warm air than in cold air.

Ans. We know that the expression for speed of sound in air is

$$v = \sqrt{\frac{rP}{\rho}}$$

From this equation we see that speed of sound is inversely proportional to $\sqrt{\rho}$. Which means that if density of air is greater, speed of sound will be small and vice versa. As warm air has smaller density than that of cold air therefore sound travel faster in warm air than in cold air.

8.11 How should a sound source move with respect to an observer so that frequency of its sound does not change?

Ans. If both sound waves and observer are moving in same direction with same velocity then their relative velocity is equal to zero. So the frequency of its sound does not change.

PROBLEMS WITH SOLUTIONS

PROBLEM 8.1

The wavelength of the signals from a radio transmitter is 1500 m and the frequency is 200 KHz. What is the wavelength for a transmitter operating at 1000 KHz and with what speed the radio waves travel?

Data

Wavelength of signals = λ_1 = 1500 m

Frequency of signals = f_1 = 200 KHz

= 200×1000 Hz

= 2×10^5 Hz

Frequency for transmitter = f_2 = 1000 KHz

= 1000×1000 Hz

= 10^6 Hz

To Find

Wavelength for transmitter = λ_2 = ?

Speed of radio waves = v = ?

SOLUTION

By formula

$$v = f\lambda$$

For speed of radio waves

$$v = f_1\lambda_1$$

$$= 2 \times 10^5 \times 1500$$

$$= 3000 \times 10^5$$

$$= 3 \times 10^8 \text{ m/s}$$

And for wavelength

$$v = f_2\lambda_2$$

$$\lambda_2 = \frac{v}{f_2}$$

$$= \frac{3 \times 10^8}{10^6}$$

$$= 3 \times 10^{8-6}$$

$$= 3 \times 10^2$$

$$\lambda_2 = 300 \text{ m}$$

Result

Wavelength for transmitter = λ_2 = 300 m

Speed of radio waves = v = 3×10^8 m/s

PROBLEM 8.2

Two speakers are arranged as shown in Fig. 8.24. The distance between them is 3 m and they emit a constant tone of 344 Hz. A microphone P is moved along a line parallel to and 4.00 m from the line connecting the two speakers. It is found that tone of maximum loudness is heard and displayed on the CRO when microphone is on the centre of the line and directly opposite each speaker. Calculate the speed of sound.

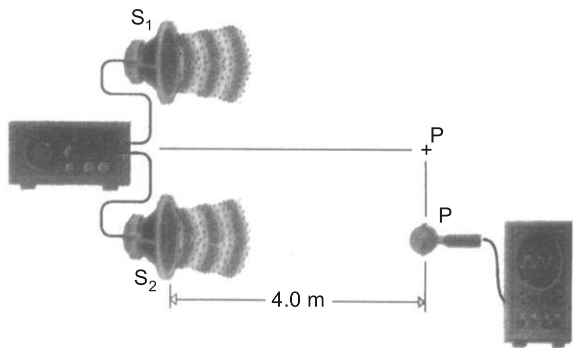


Fig. 8.24

Data

Distance between speakers = d = 3.0 m

Frequency of sound = f = 344 Hz

Distance between microphone and speakers = L = 4.0 m

To Find

Speed of sound = v = ?

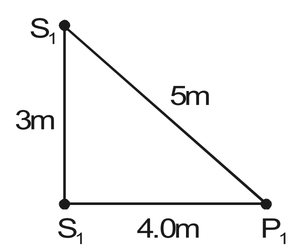
SOLUTION

By formula

$$v = f\lambda$$

Where λ = Path difference

$= S_1P_1 - S_2P_1$



Consider the $\Delta S_1P_1S_2$ is right angle triangle then

$$(S_1P_1)^2 = (S_1S_2)^2 + (S_2P_1)^2$$

$$= (3)^2 + (4)^2$$

$$(S_1P_1)^2 = 9 + 16$$

$$S_1P_1 = \sqrt{25}$$

$$= 5$$

So $\lambda = S_1P_1 - S_2P_1$

$= 5 - 4$

$\lambda = 1 \text{ m}$

Then $v = f\lambda$

$= 1 \times 344$

$v = 344 \text{ m/s}$

Result

Speed of sound = $v = 344 \text{ m/s}$

PROBLEM 8.3

A stationary wave is established in a string which is 120 cm long and fixed at both ends. The string vibrates in four segments, at a frequency of 120 Hz. Determine its wavelength and the fundamental frequency?

Data

Length of string = l = 120 cm

= 1.20 m

Number of segments = N = 4

Frequency of four segments = f_4 = 120 Hz

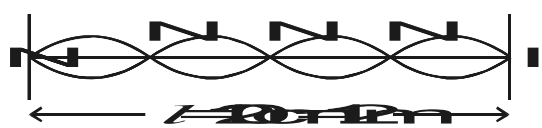
To Find

Fundamental frequency = f_1 = ?

Wavelength = λ = ?

SOLUTION

For the wavelength



$$l = 4 \times \frac{\lambda}{2}$$

$$\lambda = \frac{2l}{4} = \frac{2 \times 1.2}{4}$$

$$\lambda = 0.6 \text{ m}$$

and for fundamental frequency

$$f_4 = 4f_1$$

$$\boxed{f_1 = \frac{f_4}{4}}$$

$$f_1 = \frac{120}{4}$$

$$f_1 = 30 \text{ Hz}$$

Result

Fundamental frequency = f_1 = 30 Hz

Wavelength = λ = 0.6 m

PROBLEM 8.4

The frequency of the note emitted by a stretched string is 300 Hz. What will be the frequency of this note when

(a) the length of the wave is reduced by one-third without changing the tension.

(b) the tension is increased by one-third without changing the length of the wire.

Data

Frequency of the note = f = 300 Hz

To Find

(a) Frequency = f_1 = ? (When the length of the wave reduced by one-third)

(b) Frequency = f_2 = ? (When the tension is increased by one-third)

SOLUTION

(a) Suppose the length of wave = λ

One-third of that length = $\frac{1}{3}\lambda$

After reducing the length = $\lambda - \frac{1}{3}\lambda$

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

So according to relation

$$\lambda f = \frac{2}{3}\lambda f_1$$

$$\frac{2}{3}f_1 = f$$

$$f_1 = \frac{3}{2}f$$

$$f_1 = \frac{3}{2}\times 300$$

$$f_1 = 450\text{ Hz}$$

(b) As we know that

$$f_2 = \frac{1}{2l}\sqrt{\frac{F}{m}}$$

Suppose the tension = F

One-third of that tension = $\frac{1}{3}F$

After increasing the tension, the new tension becomes $= F' = F + \frac{1}{3}F$

$$= \frac{4}{3}F$$

Therefore the frequency at that tension is

$$f_2 = \frac{1}{2l}\sqrt{\frac{F'}{m}}$$

$$f_2 = \frac{1}{2l}\sqrt{\frac{\frac{4}{3}F}{m}}$$

$$f_2 = \frac{1}{2l}\sqrt{\frac{F}{m}} \times \sqrt{\frac{4}{3}}$$

Therefore; $f_2 = f \times \sqrt{\frac{4}{3}}$

$$f_2 = 300 \times 1.15$$

$$= 346.4 \text{ Hz}$$

Result

(a) Frequency when length of the wave is reduced $= f_1 = 450$ Hz

(b) Frequency when tension is increased $= f_2 = 346$ Hz

PROBLEM 8.5

An organ pipe has a length of 50 cm. Find the frequency of its fundamental note and the next harmonic when it is

(a) open at both ends.

(b) closed at one end.

(Speed of sound = 350 ms^{-1})

Data

Length of organ pipe $= l = 50$ cm

$= 0.5$ m

Speed of sound $= v = 350$ m/s

To Find

(a) Frequency $= f_1 = ?$
Frequency $= f_2 = ?$ (When open at both ends)

(b) Frequency $= f_1 = ?$
Frequency $= f_3 = ?$ (When closed at one end)

SOLUTION

(a) When pipe is opened at both ends

$$v = f\lambda$$

$$f_1 = \frac{v}{\lambda}$$

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

$$\lambda = 2l = 2 \times 0.5 = 1.0$$

So $f_1 = \frac{350}{1.0} = 350 \text{ Hz}$

Next harmonic frequency $= f_2 = 2f_1 = 2 \times 350 = 700 \text{ Hz}$

(b) When pipe is closed at one-end

$f_1 = \frac{v}{\lambda}$ But $l = \frac{\lambda}{4}$

$$\lambda = 4l = 4 \times 0.5 = 2.0$$

So $f_1 = \frac{350}{2.0} = 175 \text{ Hz}$

For next harmonic $= f_3 = 175 \times 3 = 525 \text{ Hz}$

Result

(a) Frequency $= f_1 = 350$ Hz

Next harmonic frequency $= f_2 = 700$ Hz (When pipe is opened at both ends)

(b) Frequency $= f_2 = 175$ Hz

Next harmonic frequency $= f_3 = 525$ Hz (When pipe is closed at one end)

PROBLEM 8.6

A church organ consists of pipes, each open at one end of different lengths. The minimum length is 30 mm and the longest is 4m. Calculate the frequency range of the fundamental notes.

(Speed of sound = 340 ms^{-1})

Data

Minimum length of pipe $= l_1 = 30$ mm

$= 30 \times 10^{-3}$ m

$= 0.03$ m

Maximum length of pipe $= l_2 = 4$ m

Speed of sound $= v = 340$ m/s

To Find

Frequency for minimum length $= f_1 = ?$

Frequency for maximum length $= f_2 = ?$

SOLUTION

By formula

$$f_1 = \frac{v}{4l_1} \quad \text{(When the pipes are opened at one-end)}$$

For minimum length Since $\lambda = 4l_1$

$$f_1 = \frac{340}{4(0.03)}$$

$$= \frac{340}{0.12}$$

$$f_1 = 2833 \text{ Hz}$$

For maximum length

$$f_2 = \frac{v}{4l_2}$$

$$= \frac{340}{4 \times 4} = \frac{340}{16} = 21.2 \text{ Hz}$$

Result

Frequency for minimum length $= f_1 = 2833$ Hz

Frequency for maximum length $= f_2 = 21$ Hz

PROBLEM 8.7

Two tuning forks exhibit beats at a beat frequency of 3 Hz. The frequency of one fork is 256 Hz. Its frequency is then lowered slightly by adding a bit of wax to one of its prong. The two forks then exhibit a beat frequency of 1 Hz. Determine the frequency of the second tuning fork.

Data

Number of beats per second before loadings $= n = 3$

Number of beats after loading $= n = 1$

Frequency of 1st tuning fork $= f_A = 256$ Hz

To Find

Frequency of 2nd tuning fork $= f_B = ?$

SOLUTION

By formula

$$f_A - f_B = \pm n$$

$$f_B = f_A \pm n$$

$$= 256 \pm 3$$

$$f_A = 256 + 3 \quad \text{or} \quad f_B = 256 - 3$$

$$f_B = 259 \text{ Hz} \quad \text{or} \quad f_B = 253 \text{ Hz}$$

As after loading number of beats reduces so.

Result

Frequency of 2nd tuning fork $= f_B = 253$ Hz

PROBLEM 8.8

Two cars P and Q are traveling along a motorway in the same direction. The leading car P travels at a steady speed of 12 ms^{-1}; the other car Q, traveling at a steady speed of 20 ms^{-1}, sound its horn to emit a steady note which P's driver estimates, has a frequency of 830 Hz. What frequency does Q's own driver hear?

(Speed of sound = 340 ms^{-1})

Data

Speed of car P = 12 m/s

Speed of car Q = 20 m/s

Relative speed $= u_s = 20 - 12$

$= 8$ m/s

Speed of sound $= v = 340$ m/s

Apparent frequency $= f_A = 830$ Hz

To Find

Frequency heard by Q's driver $= f = ?$

SOLUTION

By using formula, when the source moves towards the observer

$$f_A = \left(\frac{v}{v - u_s}\right) f$$

$$\boxed{f = \frac{(v - u_s)\, f_A}{v}}$$

$$= \frac{340 - 8}{340} \times 830$$

$$= \frac{332 \times 830}{340}$$

$$f = 810 \text{ Hz}$$

Result

Frequency heard by Q's driver = f = 810 Hz

PROBLEM 8.9

A train sounds its horn before it sets off from the station and an observer waiting on the plateform estimates its frequency at 1200 Hz. The train then moves off and accelerates steadily. Fifty seconds after departure, the driver sounds the horn again and the plateform observer estimates the frequency at 1140 Hz. Calculate the train speed 50 s after departure. How far from the station is the train after 50 s?

(Speed of sound = 340 ms^{-1})

Data

Fundamental frequency	=	f	=	1200 Hz
Apparent frequency	=	f_A	=	1140 Hz
Speed of sound	=	v	=	340 m/s
Time taken	=	t	=	50 sec.

To Find

Speed of train	=	u_s	=	?
Distance covered by train	=	S	=	?

SOLUTION

By formula, when the source moves away from the observer

$$f_A = \frac{v}{v + u_s} f$$

$$v + u_s = \frac{v}{f_A} f$$

$$\boxed{u_s = \frac{vf}{f_A} - v}$$

$$u_s = \frac{340 \times 1200}{1140} - 340$$

$$= 357.894 - 340$$

$$u_s = 17.894 \text{ m/s}$$

For the distance covered by the train

$$S = u_{ave} \times t$$

$$u_{ave} = \frac{0 + 17.9}{2} = \frac{17.9}{2} = 8.95 \text{ m/s}$$

So, $S = 8.95 \times 50$

$= 448 \text{ m}$

Result

Speed of train $= u_s = 17.89$ m/s

Distance covered by train $= S = 448$ m

PROBLEM 8.10

The absorption spectrum of faint galaxy is measured and the wavelength of one of the lines identified as the Calcium α line is found to be 478 nm. The same line has a wavelength of 397 nm when measured in a laboratory.

(a) Is the galaxy moving towards or away from the Earth?

(b) Calculated the speed of the galaxy relative to Earth.

(Speed of light = 3.0×10^8 ms^{-1})

Data

Apparent wavelength $= \lambda_A = 478$ nm

$= 478 \times 10^{-9}$ m

Fundamental wavelength $= \lambda = 397$ nm

$= 397 \times 10^{-9}$ m

Speed of light $= C = 3 \times 10^8$ m/s

To Find

(a) Is the galaxy moving towards or away from the earth?

(b) Speed of galaxy relative to earth $= u_s = ?$

SOLUTION

(a) As we know that

$$f = \frac{C}{\lambda}$$

For apparent wavelength

$$f_A = \frac{C}{\lambda_A}$$

$$= \frac{3 \times 10^8}{478 \times 10^{-9}}$$

$$= 6.27 \times 10^{8+9-3}$$

$$= 6.27 \times 10^{14} \text{ Hz}$$

For fundamental wavelength

$$f = \frac{C}{\lambda}$$

$$= \frac{3 \times 10^8}{397 \times 10^{-9}}$$

$$= 7.55 \times 10^{14} \text{ Hz}$$

So $f_A < f$

The galaxy is moving away from the earth.

(b) For the speed of galaxy, when the galaxy is moving away from the earth

$$f_A = \frac{v}{v + u_s} f$$

$$v + u_s = \frac{v_f}{f_A}$$

$$\boxed{u_s = \frac{v_f}{f_A} - v}$$

$$= \frac{3 \times 10^8 \times 7.55 \times 10^{14}}{6.27 \times 10^{14}} - 3 \times 10^8$$

$$u_s = 3.612 \times 10^8 - 3 \times 10^8$$

$$= 0.612 \times 10^8$$

$$= 6.12 \times 10^7 \text{ m/s}$$

Result

(a) Galaxy is moving away from the earth.

(b) Speed of galaxy $= u_s = 6.12 \times 10^7$ m/s