14

Sound Waves

A sound wave is pressure wave given by $p = p_0 \sin(\omega t - kx)$. It is longitudinal in nature and consists of alternate compressions and rarefactions. To human ear only the frequency range 20-20000 Hz is audible. These limits are subjective and may vary slightly from person to person

If $y = y_0 \sin(\omega t - kx)$ is displacement wave, then change in volume

$$dV = A dy = \frac{A dy}{dx} \, dx = A y_0(-k) \cos(\omega t - kx) \, dx.$$

Volumetric strain

$$\frac{dV}{V} = \frac{A y_0 \left(-\frac{\omega}{v} \right) \cos(\omega t - kx) dx}{A dx} \quad \begin{cases} \because \frac{\omega}{k} = v \\ \therefore k = \frac{\omega}{v} \end{cases}$$

$$p = -\frac{B \partial V}{V} = \frac{B.y_0 \omega}{v} \cos(\omega t - kx)$$

where B is bulk modulus.

Also note that there exists a phase shift of 90° between displacement and pressure wave

General formula $v = \sqrt{\dfrac{E}{\rho}}$ where E is elastic constant

Speed of the Sound Wave

Newton's formula $v = \sqrt{\dfrac{P}{\rho}}$

Newton considered the change to be isothermal.

Laplace's correction Laplace considered adiabatic change and derived

$$v = \sqrt{\frac{\gamma P}{\rho}} \text{ (It gives correct results)} \qquad \text{where}$$

$$\gamma = \frac{C_P}{C_V}$$

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

and B is bulk modulus where M is molecular mass of the gas.

In solids we may write

$$v = \sqrt{\frac{Y}{\rho}} \text{ were } Y \text{ is Young's modulus}$$

For transverse waves in solids (bulk material)

$$v = \sqrt{\frac{B + \eta/3}{\rho}} \text{ where } \eta \text{ is shear modulus.}$$

Effect of Temperature

$$v = \sqrt{T} \text{ where } T \text{ is temperature in Kelvin.}$$

$$\frac{v}{v_0} = \sqrt{\frac{T}{273}} = \sqrt{1 + \frac{t}{273}}$$

where t is temperature in celsius (°C)

when temperature rises by 1°C velocity of sound increases by 0.61 ms^{-1}.

Intensity $I = 2\pi^2 \rho y_0^2 f^2 v$

$$I = \frac{2\pi^2 B y_0^2 f^2}{v} = \frac{P_0^2 v}{2B} = \frac{P_0^2}{2\rho v}$$

Intensity $I \propto \dfrac{1}{r^2}$ (for an isotropic source)

$I \propto \dfrac{1}{r}$ (for cylindrical source)

where r is the distance between the source and observer.

Effect of Pressure   Velocity of sound is not affected by pressure.

Effect of density $v \propto \dfrac{1}{\sqrt{\rho}}$ where ρ is density.

With increase in humidity the density of air decreases and, hence, speed of sound increases.

Appearance of sound in human air is characterised by three parameters — pitch, loudness and quality.

Pitch   is related to frequency. Higher the pitch sweeter is the sound. Children and Ladies speak at higher pitch as compared to men, therfore, their sound appears sweeter. Higher the frequency higher is the pitch

Loudness   is correlated with sound level. Human ear can hear a minimum intensity

$I_0 = 10^{-12}$ W/m^2

whispering $10 \rightarrow$ dB

normal talk $\rightarrow$ 60dB

sound level in dB $SL = 10 \log_{10}\left(\dfrac{I}{I_0}\right)$

Even at 80 dB (heard continuously for sometime) headache begins. At 130 dB person may become temporarily insane.

Quality   No source of sound generates a single frequency. For example, even a tuning fork marked 288 Hz will not produce only fundamental frequency of 288 Hz but also produces along with it, integral multiple of frequencies like $2 \times 288 = 576$ Hz, $3 \times 288 = 864$ Hz and so on and so forth. The difference in sound of a **tabla** and **mridung** being played at same frequencies is due to number of harmonics produced and their amplitudes.

Remember that speech ends upto 3 kHz. Rest frequency range upto 20 kHz are only higher harmonics and are used in music. The higher harmonics are particularly pleasant to the ear. A noise has frequencies that do not bear any well-defined relationship among themselves.

Interference of sound waves   If $P_1 = P_{01}\sin(\omega t - kx)$ and $P_2 = P_{02}\sin(\omega t - kx + \delta)$ interfere we assume the sources are coherent (say two tuning forks of same frequency) then

$$P = P_1 + P_2 = P_0 \sin(\omega t - kx + \phi)$$

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$$P_0 = \sqrt{p_{01}^2 + p_{02}^2 + 2p_{01}p_{02}\cos\delta} \qquad \text{and}$$

$$\tan\phi = \frac{p_{02}\sin\delta}{p_{01} + p_{02}\cos\delta}$$

If phase difference $\delta = k\Delta x = 0$ or $2n\pi$ then, intensity will be maximum and constructive interference results. Path difference in such cases is an intergral multiple of wavelength.

If phase difference $\delta = k\Delta x = (2n+1)\pi$ then, intensity will be minimum and destructive interference results. In such cases path difference $\Delta x = (2n+1)\dfrac{\lambda}{2}$

$$\frac{I_{max}}{I_{min}} = \frac{(p_{01} + p_{02})^2}{(p_{01} - p_{02})^2} = \frac{(y_{01} + y_{02})^2}{(y_{01} - y_{02})^2}$$

Quinke's tube is used to demonstrate interference of sound.

If path difference is Δx then phase difference

$$\delta = k\Delta x = \frac{2\pi\Delta x}{\lambda}.$$

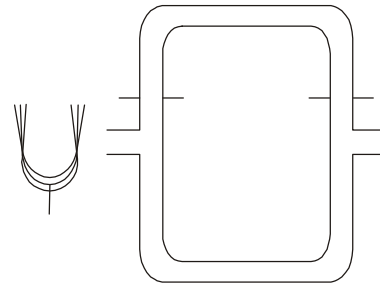Reflection of sound wave can cause: (a) echo (b) longitudinal standing waves.

Fig. 14.1   Interference in quinke tube

Echo is produced when the reflected wave (sound) is heard again by the producer or by others also.

Echo is produced when a minimum distance between the source and the reflector is 16.6 m as demonstrated in the Fig. 14.2. Distance covered by sound to reach the producer is
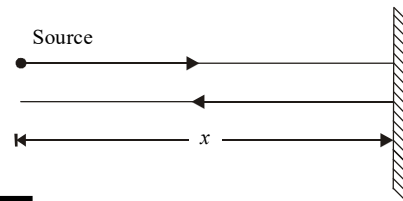

Fig. 14.2   Echo production

$$2x = vt$$

$$x = \frac{vt}{2} = \frac{332}{2} \times \frac{1}{10} = 16.6 \text{ m} \sqcup 55 \text{ ft.}$$

We take $t = \dfrac{1}{10}$ s because this is the minimum time between two syllables being heard clearly.

Echo can be heard in a smaller room provided it is empty and windows and doors are closed.

To find the distance in echo production use $x = \dfrac{vt}{2}$.

Standing Waves

(a) Standing waves in closed pipes are with reference to diplacement waves. For pressure waves position of nodes and antinodes will interchange. Same is true for Fig. 14.4, that is, open pipes.
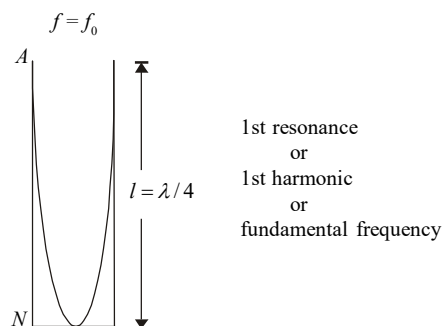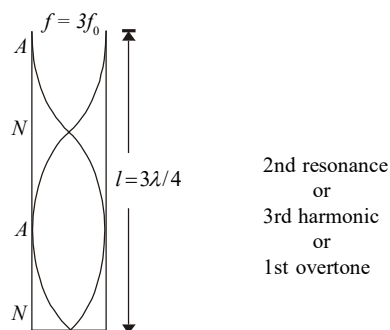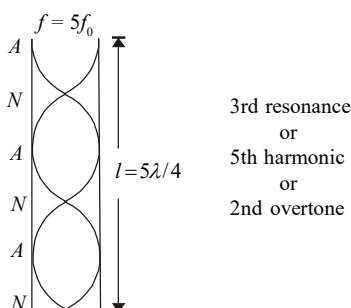

Fig. 14.3 (a)

$f = f_0$

$l = \lambda/4$

1st resonance
or
1st harmonic
or
fundamental frequency

Fig. 14.3 (b)

$f = 3f_0$

$l = 3\lambda/4$

2nd resonance
or
3rd harmonic
or
1st overtone

Fig. 14.3 (c)

$f = 5f_0$

$l = 5\lambda/4$

3rd resonance
or
5th harmonic
or
2nd overtone

In closed pipes resonance occurs at

$$l = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, ..., \text{ that is, at odd multiple of}$$

$\lambda/4$.

Only odd integral multiples of fundamental frequencies f_0, $3f_0$, $5f_0$ and so on are allowed.

Note that at the open end an antinode occurs and at closed end a node occurs.

(b) Open pipes

Fig. 14.4 (a)

$f = f_0$

$l = \lambda/2$

fundamental frequency
or
1st resonance
or
1st harmonic

Fig. 14.4 (b)

$f = 2f_0$

$l = \lambda$

2nd resonance
or
2nd harmonic
or
1st overtone

Fig. 14.4 (c)

$f = 3f_0$

$l = 3\lambda/2$

3rd resonance
or
3rd harmonic
or
2nd overtone
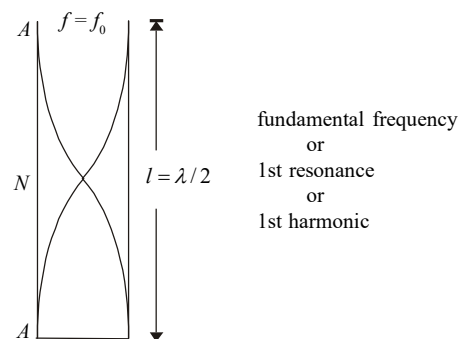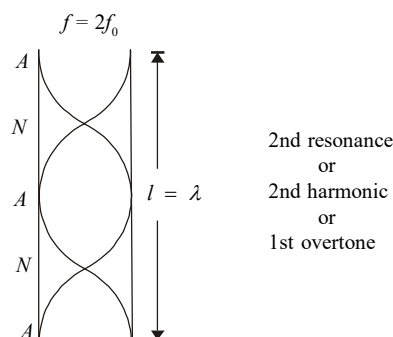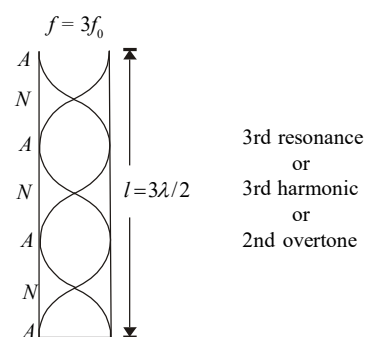
In open pipes resonance occurs at

$$l = \frac{\lambda}{2}, \lambda, \frac{3\lambda}{2}, ..., \text{ that is, all integral multiples}$$

of $\lambda/2$.

All integral multiple of fundamental frequencies f_0, $2f_0$, $3f_0$ .... are allowed or all harmonics are allowed

End correction $l_1 + 0.3\,d = \lambda/4$ for 1 st resonance.

where, d is diameter of the pipe

$$l_2 + 0.3\,d = \frac{3\lambda}{4}$$

$$(l_2 - l_1) = \frac{\lambda}{2}$$

$$v = 2(l_2 - l_1)f \; (=f\lambda).$$

In Kundt's Tube heaps of lycopodium powder/sand are collected at nodes

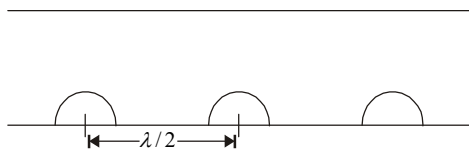$\therefore$ separation between two heaps is equal to $\dfrac{\lambda}{2}$.

Fig. 14.5 Kundt's tube method

Beats Periodic increase and fall in the intensity of sound is called beats. Beats are produced when two sources of sound of nearly same frequency are sounded together. Beat frequency

$$n = |f_2 - f_1|$$
$$n \leq 10 \text{ Hz}$$

Beats can also be produced by superposition of tones. We illustrate it by an example. Assume two sources of sound of frequencies 200 Hz and 404 Hz are sounded together [as $f_2 - f_1 \gg 10$ no beat should have been heard] Then 4 beats/s are heard. It is because of the fact that

$404 - 2(200) = 4$ beats/s are produced.

That is, fundamental frequency of 404 Hz superposes with 2nd harmonic of 200 Hz wave to produce 4 beats/s

Note: Beat is interference in the time regime while generally known interference is superposition in distance or space regime.

Refraction of Sound

As solids are most elastic and gases are least elastic
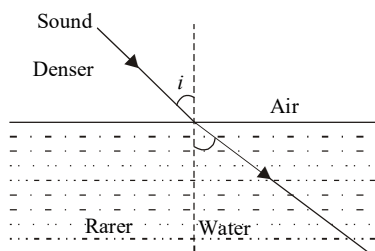
or $E_{solid} > E_{liquid} > E_{gas}$

Fig. 14.6 (a) Refraction of sound

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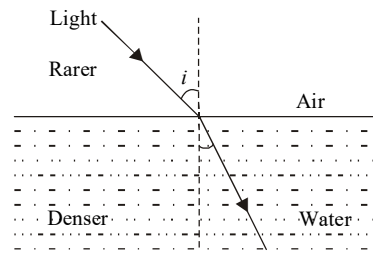**Fig. 14.6 (b)** Refraction of light

Therefore, velocities are maximum in solids.

$v_{solid} > v_{liquid} > v_{gas}.$

There could be few exceptions. For example, in vulcanized rubber velocity of sound is less than that of gases. In alcohol also velocity of sound is less than that of gases. Velocity of sound is virtually independent of frequency variations.

For light, water is denser as the speed of light decreases. In case of sound water is rarer as speed of sound increases as illustratid in Fig. 14.6

However, $\dfrac{\sin i}{\sin r} = \dfrac{v_1}{v_2}$ is valid even for sound.

Diffraction Bending of waves from an obstacle or an opening is called diffraction. Diffraction is a characteristic property of wave motion. All types of waves are diffracted. Wave nature of even electrons was demonstrated by Davisson and Germer by diffraction of electrons. Diffraction of sound is more pronounced as the wavelength is large. Therefore, it can be diffracted from any material object.

Doppler Effect When there is relative motion between the source and the listener the apparent frequency changes. This change in apparent frequency because of relative motion is called Doppler effect.
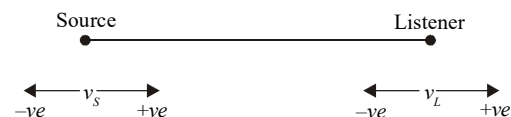
Fig. 14.7 Doppler effect

Let v be the velocity of sound, v_S velocity of the source, v_L velocity of the listener then

$$f_{app} = \frac{v - v_L}{v - v_S}\, f$$

where f_{app} is the apparent frequency heard by the listener and frequency f is the frequency of the source.

The above formula is written keeping in view the positive and negative sign to be assigned for v_S and v_L as shown in Fig. 14.7.

If any of the two is at rest that particular velocity becomes zero in the above formula. Thus, this formula may be applied to all cases.

If the source or listener moves with a velocity greater than velocity of sound then Doppler effect cannot be applied.

When the source of sound goes past the observer (stationary) the change in frequency is

$$\Delta f = \frac{2vv_S f}{v^2 - v_S^2}$$

If the observer goes past a stationary source then change in frequency

$$\Delta f = \frac{2v_L}{v_S} f.$$

Doppler effect in light is $\dfrac{\Delta \lambda}{\lambda} = \dfrac{\Delta f}{f} = \dfrac{v}{c}$

Reverberation time $T = \dfrac{0.17V}{A}$

where V is total volume and $A = \sum a_i s_i$ where a_i is absorption coefficient for surface area s_i.

SHORT CUTS AND POINTS TO NOTE

1. $\dfrac{v_{sound}}{v_{rms}\left(\text{of a gas}\right)} = \sqrt{\dfrac{\gamma}{3}}$ where $\gamma = \dfrac{C_p}{C_v}$.

2. Speed of sound

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

where M is molecular mass of the gas and ρ is density of the gas.

In solids $v = \sqrt{\dfrac{Y}{\rho}}$ if rod or string or long rail where Y is Young's modulus.

$v = \sqrt{\dfrac{B}{\rho}}$ in bulk of material. Where B is bulk modulus.

$v = \sqrt{\dfrac{B + \eta/3}{\rho}}$ in bulk of material for transverse mechanical waves where η is shear modulus.

3. $v = \dfrac{\omega}{k} = f\lambda.$

4. There is a phase shift of 90° between pressure and displacement wave.

5. $p = p_0 \sin(\omega t - kx)$ is the pressure wave or sound wave.

$p_0 = \dfrac{B y_0 \omega}{v}$ where, B is bulk modulus. y_0 is amplitude of displacement wave.

6. Effect of temperature $v \propto \sqrt{T}$

or $\dfrac{v}{v_0} = \sqrt{\dfrac{T(\text{K})}{273}} = \sqrt{1 + \dfrac{t^0 \text{C}}{273}}$

$v_0 = 330 \text{ ms}^{-1}$ at 0^0C

7. Velocity of sound in a medium is independent of wavelength or frequency. Freuency of a tuning fork in falling plate method is $f = m\sqrt{\dfrac{g}{d_2 - d_1}}$

where m is complete number of waves used and d_2 and d_1 are consecutive distance for m number of waves. In stroboscopic method $f = mp$ where m is number of holes on the plate and p is angular frequency in revolution per second.
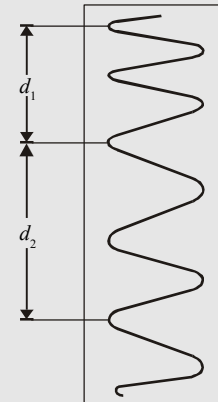
Fig. 14.8 Velocity of sound by falling plate method

8. Velocity of sound is independent of pressure. But it varies with density $v \propto \dfrac{1}{\sqrt{\rho}}$. Velocity of sound is maximum in rainy season.

9. Intensity of sound $I = 2\pi^2 \rho y_0^2 f^2 v$

$$I = 2\pi^2 \rho y_0^2 f^2 v = \frac{2\pi^2 B y_0^2 f^2}{v} = \frac{p_0^2 v}{2B} = \frac{p_0^2}{2\rho v}.$$

10. Pitch is related to frequency. Higher the pitch, higher is the frequency. Children and ladies speak at higher pitch compared to men. Higher frequency or higher pitch sound is more sweet.

11. Loudness is correlated with sound level. Minimum intensity that is audible to human ear is 10^{-12} Wm^{-2}

Sound level in dB $SL = 10 \log_{10}\left(\dfrac{I}{I_0}\right).$

$10 \log \dfrac{I_2}{I_0} = 10 \log \dfrac{I_1}{I_0} - 10 \log \dfrac{I_1}{I_2}$

80 dB sound level can cause headache if heard continuously for some time.

Sound level ≥ 130 dB may make a person temporarily insane. Maximum tolerable sound is 120 dB. Normal talking level is 60 dB.

12. Quality of sound is related to number of harmonics produced and their amplitude by a source. It is due to quality of sound that we can recognize a person by his/her voice. Even an instrument being played can be judged.

13. Interference of sound in time frame (regime) produces beats, that is, if two sources having frequencies nearly equal superpose then periodic increase and fall in the intensity of sound is heard. This is called beats.

Beat frequency $n = |f_1 - f_2| \le 10$ if they are to be heard.

If a tuning fork is vaned or filed its frequency slightly increases and if a tuning fork is loaded or waxed its frequency slightly decreases. More than 10 beats/s cannot be heard.

Tuning fork frequency $f = \dfrac{1}{2l}\sqrt{\dfrac{T}{\mu}}$.

14. Superposition of wave in space (x) is termed as interference and gives intensity of sound varying with distance. Sound intensity is maximum if phase shift is an integral multiple of 2π or path difference is $n\lambda$. Intensity is minimum when phase difference is $(2n + 1)\pi$ or path difference is $(2n + 1)\dfrac{\lambda}{2}$.

$$\dfrac{I_{max}}{I_{min}} = \left(\dfrac{p_{01} + p_{02}}{p_{01} - p_{02}}\right)^2 = \left(\dfrac{y_{01} + y_{02}}{y_{01} - y_{02}}\right)^2$$

15. Quinke's tube is used to study interference of sound.

16. Reflection of sound from a general obstacle may result in an echo. For echo to be produced separation between source and obstacle should be 16.6 m or 55 ft. Though echo can be produced because of multiple reflection in a closed and empty room. Felts, cushion and curtains and so on are absorbers of sound. A window (or opening) is the best absorber of sound. Human beings also absorb sound

17. Reflection of sound wave in organ pipes produce standing waves. A flute may be used both as closed and an open pipe. If all the holes are closed it acts like closed pipe. By closing different holes, we can vary the length of the pipe and hence frequency varies. In closed pipes resonance occurs at

$$l = \dfrac{\lambda}{4}, \dfrac{3\lambda}{4}, \dfrac{5\lambda}{4}, ... \text{ or } l = (2n - 1)\,\lambda/4$$

where $n = 1, 2, 3, ...$

Only odd integral multiple of frequencies are allowed in closed pipes, i.e., $f_0, 3f_0, 5f_0,....$ are allowed

18. In open pipes all integral multiple of fundamental frequency are allowed, i.e., $f_0, 2f_0, 3f_0, ...$ are allowed. Resonance occurs when

$$l = \dfrac{\lambda}{2}, \lambda, \dfrac{3\lambda}{2}, ..., \text{ that is, } l = \dfrac{n\lambda}{2}\ (n = 1, 2, 3,...)$$

19. End correction is required in resonance tube experiment.

$$l_1 + 0.3\,d = \dfrac{\lambda}{4}\ \text{ for first resonance.}$$

and $l_2 + 0.3\,d = \dfrac{3\lambda}{4}$ for second resonance.

$v = 2f(l_2 - l_1)$.

20. Separation between two consecutive nodes or antinodes is $\dfrac{\lambda}{2}$ and separation between a node and an antinode is $\dfrac{\lambda}{4}$.

21. Refraction of sound occurs when sound wave travels from one medium to another. Normally velocity of sound follows the trend

$v_{solid} > v_{liquid} > v_{gas}$.

For light, glass or water is denser than air But for sound, glass or water is rarer than air as velocity of sound is more in these materials.

$$\mu = \dfrac{\sin i}{\sin r} = \dfrac{v_1}{v_2}, \text{ that is, Snell's law is valid.}$$

22. Diffraction of sound is more pronounced than light because wavelength of sound is large. The diffraction occurs from any obstacle or a hole. Diffraction is a specific characteristic of wave

23. Doppler effect is the apparent change in frequency of sound appearing to the listener because of motion between source and listener.

$$f_{app} = \left(\dfrac{v - v_L}{v - v_S}\right) f \text{ can be applied}$$

If wind of velocity v_w blows in the direction of sound then change v to $v + v_w$ or $v - v_w$ depending upon wind is blowing in same or opposite direction. If wind is in the direction of sound then.

$$f_{app} = \dfrac{(v + v_w - v_L)f}{(v + v_w - v_s)} .$$

24. If the source or listener move with a speed greater than the speed of sound then Doppler effect cannot be applied.

25. Music is formed only with vowels. Octave (1 : 2) majortone (8 : 9), minortone (9 : 10) and semitone (15 : 16).

26. Mach number = $\dfrac{\text{Velocity of a body}}{\text{Velocity of sound}} = \dfrac{v_{body}}{330}$

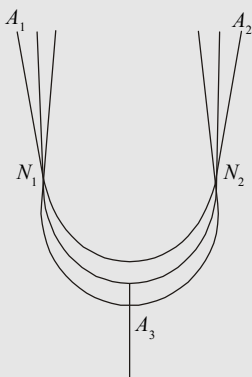27. Number of nodes = $2n$ and number of antinodes = $2n + 1$ when a tuning fork vibrates in nth harmonic.

Fig. 14.9

CAUTION

1. Not applying end correction in resonant pipes.

$\Rightarrow$ Apply an end correction equal to $0.3\,d$ where d is diameter of the pipe using

$\lambda/4 = l_1 + 0.3\,d$ and $\dfrac{3\lambda}{4} = l_2 + 0.3\,d$ use $\dfrac{\lambda}{2} = l_2 - l_1$.

2. Confusing formulae for open and closed pipes.

$\Rightarrow$ In closed pipes only odd integral multiple of fundamental frequency are allowed.

length of the pipe $l = \dfrac{\lambda}{4}, \dfrac{3\lambda}{4}, \dfrac{5\lambda}{4}, \dots$

for 1st, 2nd, 3rd, harmonic.

In open pipes all harmonics are allowed and length of the pipe is

$l = \dfrac{\lambda}{2}, \lambda, \dfrac{3\lambda}{2}, \dots$

3. Considering that a vibrating source always produces sound.

$\Rightarrow$ Sound frequency lies between 20 and 20000 Hz. Frequencies less than 20 Hz are called infrasonic and are not audible to human ear. Frequencies > 20 kHz are inaudible and termed as ultrasonic. Bodies/waves having velocity > 330 ms^{-1} (velocity of second) are termed as supersonic.

4. Considering intensity of sound and loudness as identical terms.

$\Rightarrow$ Loudness is related to level of sound. It is measured in dB.

Sound level $SL = 10 \log_e \dfrac{I}{I_0}$

where $I_0 = 10^{-12}$ Wm^{-2} is the minimum intensity audible to human ear. Pressure variation upto 10^{-10} Nm^{-2} can be detected.

5. Considering that a source/musical instrument of same frequency will have same number of harmonics.

$\Rightarrow$ Number of harmonics and their amplitudes are different and form quality of sound.

6. Assuming that frequency, wavelength and velocity all change when a wave passes from one medium to another.

$\Rightarrow$ Frequency does not vary. Also note that unlike light waves, sound waves with different wavelengths pass through a medium with same velocity.

7. Considering that doppler effect can always be applied if there is a relative motion between source and listener.

$\Rightarrow$ You cannot apply Doppler effect if the velocity of source/listener is larger than speed of sound.

8. Comfusing between wave number and velocity amplitude and acceleration amplitude.

$\Rightarrow$ Wave number or propagation constant

$k = \dfrac{2\pi}{\lambda}$.

Velocity amplitude $v_0 = \dfrac{2\pi y_0}{\lambda} = k y_0$

Acceleration amplitude

$a_0 = \dfrac{2\pi^2 y_0}{T^2} = \dfrac{\omega^2 y_0}{2}$ where $T \to$ time period

9. Considering that there is no exception in the rule $v_{solid} > v_{liquid} > v_{gas}$.

$\Rightarrow$ In vulcanised rubber the velocity of sound $<$ velocity of sound in hydrogen. In alcohol also velocity of sound $<$ velocity of sound in hydrogen.

10. Not remembering value of γ for monoatomic, diatomic or polyatomic gases

$\Rightarrow$ Values of $\gamma = \dfrac{5}{3}$ for monoatomic, $\gamma = 1.4$ for diatomic and $\gamma = \dfrac{4}{3}$ for polyatomic gases.

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

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11. Confusing how to use the formula

$$v = \sqrt{\frac{\gamma RT}{M}} = \sqrt{\frac{\gamma P}{\rho}} \text{ in a mixture of gases.}$$

$\Rightarrow$ Use $\gamma_{av} = \dfrac{n_1\gamma_1 + n_2\gamma_2}{n_1 + n_2}$;

$M_{av} = \dfrac{n_1 M_1 + n_2 M_2}{n_1 + n_2}$ where n_1 and n_2 are number of moles of gas 1 and gas 2 respectively.

12. Considering that mediums which are denser for light are also denser for sound waves from refractive index point of view.

$\Rightarrow$ Velocity of sound waves $v_{solid} > v_{liquid} > v_{gas}$. Therefore, gases appear to have higher refractive index than liquids or solids.

However, $\dfrac{v_1}{v_2} = \dfrac{\sin i}{\sin r} = \mu$ is valid.

SOLVED PROBLEMS

1. Sound signal is sent through a composite tube as shown in the Fig. 14.10. The radius of the semicircle is r. Speed of sound in air is v. The source of sound is capable to generate frequencies in the range f_1 to f_2 $(f_2 > f_1)$. If n is an integer then frequency for maximum intensity is given by
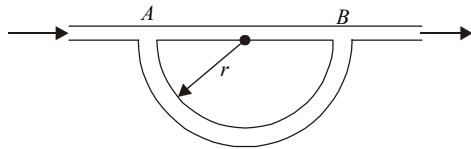

Fig. 14.10

(a) $\dfrac{nv}{r}$

(b) $\dfrac{nv}{r(\pi - 2)}$

(c) $\dfrac{nv}{\pi r}$

(d) $\dfrac{nv}{(r - 2)\pi}$

Solution (b) path difference $\pi r - 2r = n\lambda$

or $r(\pi - 2) = \dfrac{nv}{f}$ thus $f = \dfrac{nv}{r(\pi - 2)}$.

2. Two tuning forks when sounded together produce 6 beats/s. The first fork has the frequency 3% higher than a standard one and the second has the frequency 2% less than the standard fork. The frequencies for the forks are

(a) 126.3, 120.3 Hz   (b) 162.7, 156.7 Hz

(c) 136.2, 130.2 Hz   (d) 123.6, 117.6 Hz

Solution (d) $\left(f + \dfrac{3f}{100}\right) - \left(f - \dfrac{2f}{100}\right) = 6$

$\Rightarrow$ $5f = 600$ or $f = 120$ Hz

$f + \dfrac{3f}{100} = 123.6$ Hz,

$f - \dfrac{2f}{100} = 120 - \dfrac{2 \times 120}{100} = 117.6$ Hz.

3. The dimensions of an auditorium is $100 \times 40 \times 10$ m³. It has 1000 m² curtains of absorption coefficient 0.2 m⁻² 2000 m² of carpets of absorption coefficient 0.7 m⁻². If 1000 men of absorption coefficient 0.9 per person are sitting in the hall, then reverberation time is

(a) 2.7 s   (b) 7.2 s

(c) 3.5 s   (d) 3.7 s

Solution (a) $T = \dfrac{0.17V}{A} = \dfrac{0.17V}{\sum a_i s_i}$

$= \dfrac{0.17(100 \times 40 \times 10)}{0.2(1000) + 0.7(2000) + 0.9(1000)}$

$= \dfrac{0.17 \times 4000 \times 10}{2500} = 2.72$ s

4. A and B are two wave trains shown in the Fig. 14.11, the ratio of intensity of A to B is

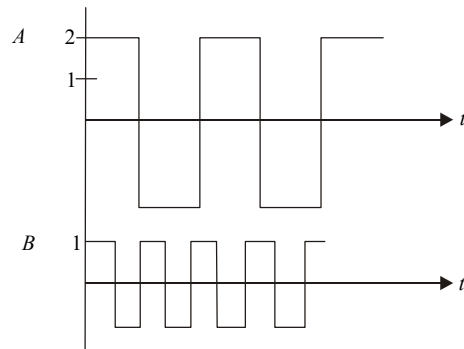**Fig. 14.11**

(a) 1   (b) 2

(c) 4   (d) 8

Solution (a) $I \propto x_0^2$ and $I \propto f^2$

In A $x_{0A} = 2x_0$ and $f_{0A} = f_0$

In B $x_{0B} = x_0$ and $f_{0B} = 2f_0$ $\therefore$ $\dfrac{I_A}{I_B} = 1$.

5. The fundamental frequency of a closed organ pipe is same as the first overtone frequency of the open pipe.

The length of open pipe is 50 cm. The length of closed pipe is

(a) 25 cm (b) 100 cm
(c) 200 cm (d) 125 cm

Solution (d) $f_{0(open)} = \dfrac{330}{2l} = 330$ Hz

$f_1 = 2 \times 330 = 660$ Hz

$f_{0(closed)} = \dfrac{330}{4l} = 660$

or $8l = 1$ m, that is, $l = 12.5$ cm.

6. Sound waves from a tuning fork F reach a point P by two separate routes FAP and FBP. FBP is 12 cm larger than FAP. There is silence at P. If the separation becomes 24 cm, the sound becomes maximum at P and at 36 cm there is again silence and so on. The least frequency of tuning fork is

(a) 1357 Hz (b) 1735 Hz
(c) 1375 Hz (d) 1400 Hz

Solution (c) $\dfrac{\lambda}{2} = 12$ cm or $\lambda = 24$ cm

$f = \dfrac{330}{0.24} = 1375$ Hz.

7. A sound source emits sound waves in a uniform medium. If energy density is E and maximum speed of the particles of the medium is v_{max}. The plot between E and v_{max} is best represented by
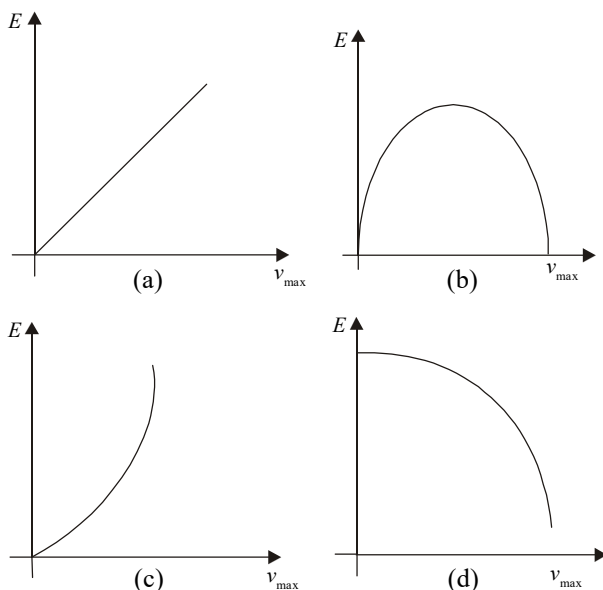
Fig. 14.12

Solution (c) Energy density $= \dfrac{I}{v} = 2\pi^2 \rho f^2 x_0^2$

$v_{max} = \omega x_0 = 2\pi f x_0$

that is, $E \propto v_{max}^2$.

8. A sound source rotates anticlock wise with an angular velocity ω. Radius of the circle is R. A person is at P. The maximum frequency is heard when position of the source is at
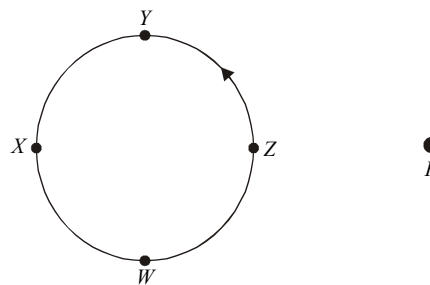
Fig. 14.13 (a)

(a) Y (b) X
(c) Z (d) W

Solution (d) Note from Fig. 14.13(b) that velocity at W is towards the listener. Hence according to Doppler's effect maximum frequency is heard at W.
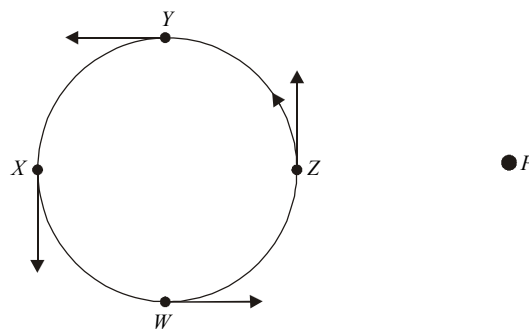
Fig. 14.13 (b)

9. The intensity level 1 m away from a source is 60 dB. Threshold intensity of hearing is 10^{-12}Wm^{-2}. If there is no loss of sound power in air then intensity level at 2000 cm from the source is

(a) 45 dB (b) 34 dB
(c) 35 dB (d) 64 dB

Solution (b) $I \propto \dfrac{1}{r^2}$ and $\Delta I = I_1 - I_2$

$10 \log \dfrac{I_2}{I_0} = 10 \log \dfrac{I_1}{I_0} - 10 \log \dfrac{I_1}{I_2}$

and $10 \log \dfrac{I_1}{I_2} = 10 \log 400 = 26.02$ dB

$\therefore$ intensity level at 2000 cm away is

$60 - 26 = 34$ dB

10. Three tuning forks of frequency 400 Hz, 401 Hz and 402 Hz are sounded simultaneously. The number of beats heard per second are

(a) 1 (b) 2
(c) 3 (d) none of these

[IIT 1992]

Solution (a) See from Fig. 14.14 that 2 Hz and 1 Hz are sounded together giving 1 beats/s.
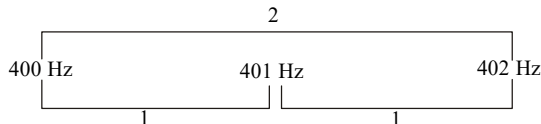
Fig. 14.14

11. Two open pipes of length 50 cm and 51 cm produce 6 beats when sounded together, find the speed of sound.

   (a) $330\,ms^{-1}$
   (b) $316\,ms^{-1}$
   (c) $306\,ms^{-1}$
   (d) $360\,ms^{-1}$

Solution (c) $f_1 - f_2 = 6$ or $\dfrac{v}{2l_1} - \dfrac{v}{2l_2} = 6$

$$\frac{v}{2(0.5)} - \frac{v}{2(0.51)} = 6 \text{ or } v = 306\,ms^{-1}.$$

12. If fundamental frequency of an open pipe is f_0. Its fundamental frequency when it is half-filled with water is

   (a) f_0
   (b) $\dfrac{\lambda}{4}$
   (c) $2f_0$
   (d) none of these

   [CBSE 1998]

Solution (a) See the situation shown in the Fig. 14.15(b). When the pipe is half-filled with water it becomes a closed pipe and the length.

(a)   (b)
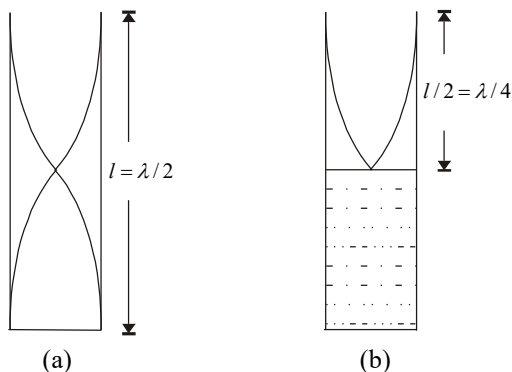
Fig. 14.15

$$\frac{l}{2} = \frac{\lambda}{4} \text{ or } \lambda = 2l$$

same wavelength existed in open pipe. Therefore, frequency remains unchanged as $f = \dfrac{v}{\lambda}$.

13. In the experiment for determination of the speed of sound in air using resonance tube method. The length of air column that resonates with fundamental mode

with a tuning fork is 0.1 m. When its length is changed to 0.35 m it resonates in first over tone. The end correction is

   (a) 0.012 m
   (b) 0.025 m
   (c) 0.05 m
   (d) 0.0024 m

Solution (b) $l_1 + 0.3\,d = \dfrac{\lambda}{4}$, $l_2 + 0.3\,d = \dfrac{3\lambda}{4}$;

$$\frac{\lambda}{2} = l_2 - l_1 = 0.25 \text{ m or } \frac{\lambda}{4} = 0.125 \text{ m}$$

$$0.3\,d = \frac{\lambda}{4} - l_1 = 0.025 \text{ m}$$

14. An observer moves towards a stationary source of sound with one-fifth of the speed of sound. The wavelength and frequency of the source emitted are λ and f respectively. The apparent frequency and wavelength recorded by the observer are

   (a) $0.85f, 0.8\,\lambda$
   (b) $1.2f, 1.2\,\lambda$
   (c) $1.2f, \lambda$
   (d) $f, 1.2\lambda$

   [CBSE 2003]

Solution (c) $f_{app} = \dfrac{v + v/5}{v}\, f = 1.2\,f$ wavelength remains unchanged.

15. An air column closed at one end and open at the other end resonates with a tuning fork when 45 and 99 cm of length. The wavelength of the sound in air column is

   (a) 36 cm
   (b) 54 cm
   (c) 108 cm
   (d) 180 cm

Solution (c) $\dfrac{\lambda}{2} = 99 - 45 = 54$ cm

or $\lambda = 108$ cm

   [DPMT 2002]

16. The frequency of a tuning fork is 384 Hz and velocity of sound in air is $352\,ms^{-1}$. How far sound has travelled when fork completes 36 vibration?

   (a) 33 m
   (b) 16.5 m
   (c) 11 m
   (d) 22 m

   [DPMT 2002]

Solution (a) $x = v.t = 352 \times \dfrac{36}{384} = 33$ m.

17. A sound source is falling under gravity. At some time $t = 0$ the detector lies vertically below source at a height H as shown in Fig. 14.16. If v is velocity of sound and f_0 is frequency of the source then the apparent frequency recorded after $t = 2$ second is

Fig. 14.16

(a) f_0

(b) $f_0 \dfrac{(v+2g)}{v}$

(c) $f_0 \dfrac{(v+2g)}{v}$

(d) $f_0 \left(\dfrac{v}{v-2g}\right)$

Solution (d) $v_S = 0 + g(2) = 2g$

and $f_{app} = f_0 \dfrac{v}{v-v_S} = f_0\left(\dfrac{v}{v-2g}\right)$.

18. An open pipe is suddenly closed at one end. As a result the frequency of third harmonic of the closed pipe is found to be higher by 100 Hz. The fundamental frequency of open pipe is

(a) 200 Hz   (b) 30 Hz

(c) 240 Hz   (d) 480 Hz

Solution (a) $f_{0(closed)} = \dfrac{v}{\lambda} = \dfrac{v}{4l}$

third harmonic of closed pipe $= 3f_{0(closed)} = \dfrac{3v}{4l}$

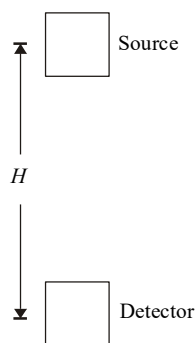$\dfrac{3v}{4l} - \dfrac{v}{2l} = 100$ or $\dfrac{v}{4l} = 100$ and

$f_{0(open)} = \dfrac{v}{2l}$

$\dfrac{v}{2l} = 200$.

19. As a wave propagates

(a) the wave intensity remains constant for a plane wave.

(b) the wave intensity decreases as the inverse of the distance from source for a spherical wave.

(c) the wave intensity falls as the inverse square of the distance from a spherical wave.

(d) total intensity of the spherical wave over the spherical surface centred at the source remains constant at all times.

Solution (a), (c) and (d).

20. Two monatomic ideal gases 1 and 2 of molecular masses m_1 and m_2 respectively are enclosed in separate containers kept at the same temperature. The ratio of the speed of sound in gas 1 to gas 2 is given by

(a) $\dfrac{m_1}{m_2}$ (b) $\sqrt{\dfrac{m_1}{m_2}}$

(c) $\dfrac{m_2}{m_1}$ (d) $\sqrt{\dfrac{m_2}{m_1}}$

Solution (d) As $v = \sqrt{\dfrac{\gamma RT}{M}}$ $\therefore$ $\dfrac{v_1}{v_2} = \sqrt{\dfrac{m_2}{m_1}}$.

21. A siren placed at a railway platform is emitting sound of frequency 5 kHz. A passenger sitting in a moving train A records a frequency of 5.5 kHz when the train approaches the siren. During his return journey in a different train B he records the frequency of 6 kHz while approaching the same siren. The ratio of velocity of train B to train A is

(a) $\dfrac{242}{252}$ (b) $\dfrac{5}{6}$

(c) 2   (d) $\dfrac{11}{6}$

Solution (c) $\left(\dfrac{v+v_{L1}}{v}\right)5 = 5.5$, $\left(\dfrac{v+v_{L2}}{v}\right)5 = 6$

or $\dfrac{v_{L1}}{v} = 0.5$ or $\dfrac{v_{L2}}{v} = 1$ or $\dfrac{v_{L2}}{v_{L1}} = 2$

22. A piezo electric quartz crystal of thickness 0.005 m is vibrating in resonate conditions. Calculate the fundamental frequency f_0 for quartz.

$Y = 8 \times 10^{10} \text{Nm}^{-2}$ and $\rho = 2.65 \times 10^3 \text{ kgm}^{-3}$

(a) 5.5 MHz   (b) 55 MHz

(c) 0.55 MHz   (d) 5.5 kHz

Solution (c) $v = \sqrt{\dfrac{Y}{\rho}} = \sqrt{\dfrac{8 \times 10^{10}}{2.69 \times 10^3}}$

$= 5.5 \times 10^3 \text{ms}^{-1}$;

$f = \dfrac{v}{\lambda} = \dfrac{5.5 \times 10^3}{2 \times 0.005} = 5.5 \times 10^5 \text{Hz}$.

23. Calculate the ratio of speed of sound wave in Neon to that in H_2O vapours at any temperature.

(a) $\dfrac{9}{8}$

(b) $\dfrac{3}{2\sqrt{2}}$

(c) $\dfrac{3}{2}$

(d) $\dfrac{8}{9}$

[Roorkee 1992]

Solution (b) $\dfrac{v_{Ne}}{v_{H_2O}} = \sqrt{\dfrac{\gamma_{Ne} M_{H_2O}}{M_{Ne} \gamma_{H_2O}}}$

$= \sqrt{\dfrac{5/3 \times 18}{4/3 \times 20}} = \sqrt{\dfrac{9}{8}} = \dfrac{3}{2\sqrt{2}}$.

24. Find the speed of sound in a mixture of 1 mole of He and 2 mole of O_2 at 27^0C.

(a) $480\ ms^{-1}$

(b) $621\ ms^{-1}$

(c) $401\ ms^{-1}$

(d) $601\ ms^{-1}$

[IIT 1995]

Solution (c) $M_{mix} = \dfrac{n_1 M_1 + n_2 M_2}{n_1 + n_2}$

$= \dfrac{1 \times 4 + 2 \times 32}{1+2} = \dfrac{68}{3}$

$C_{V(mixtue)} = \dfrac{n_1 C_{V1} + n_2 C_{V2}}{n_1 + n_2} = \dfrac{\left(1 \times \dfrac{3}{2} + 2 \times \dfrac{5}{2}\right) R}{1+2}$

$= \dfrac{13}{6} R$

$C_{P(mix)} = C_V + R = \dfrac{19}{6} R$ or $\dfrac{C_P}{C_V} = \dfrac{19}{13} R$

$v = \sqrt{\dfrac{19}{13} \times \dfrac{8.31 \times 300}{\dfrac{68}{3} \times 10^{-3}}} = 400.9\ ms^{-1}$.

25. The velocity of sound is v_S in air. If density of air is increased twice then the new velocity of sound will be

(a) v_S

(b) $\dfrac{v_S}{\sqrt{2}}$

(c) $\sqrt{2}\, v_S$

(d) $\dfrac{3}{2}\, v_S$

[BHU 2003]

Solution (b) $v = \sqrt{\dfrac{\gamma P}{\rho}}$, that is, $\dfrac{v_s'}{v_s} = \sqrt{\dfrac{\rho}{2\rho}} \Rightarrow$

$v_s' = \dfrac{v_s}{\sqrt{2}}$.

26. Two radio stations broadcast their programmes at the same amplitude A and at slightly different frequencies ω_1 and ω_2 respectively where $\omega_2 - \omega_1 = 1$ kHz. A detector receives the signals from the two stations simultaneously. It can only detect signals of intensity $> 2A^2$. Find the interval between successive maxima of the intensity of the signal received by the detector.

(a) 2×10^{-3}s

(b) 4×10^{-3}s

(c) 1.5×10^{-3}s

(d) 10^{-3}s

Solution (d) $y_1 = A \sin 2\pi\omega_1 t$ and $y_2 = A \sin 2\pi\omega_2 t$

$y = y_1 + y_2 = A \sin 2\pi\omega_1 t + A \sin 2\pi\omega_2 t$

$= 2A \sin 2\pi \dfrac{(\omega_2 + \omega_1)}{2} t \cos 2\pi \dfrac{(\omega_2 + \omega_1)}{2} t$

$A' = 2A \cos 2\pi \dfrac{(\omega_2 + \omega_1)}{2} t$

$= 2A \cos \pi(\omega_2 - \omega_1)t$

$I \propto A'^2 = 4A^2 \cos^2 \pi(\omega_2 - \omega_1)t$

For I to be maximum $\cos \pi(\omega_2 - \omega_1)t = \pm 1$

or $\pi(\omega_2 - \omega_1)t = 0,\ \pi,\ 2\pi,\ ...$

$T = t_2 - t_1 = \dfrac{1}{\omega_2 - \omega_1}$

$= 10^{-3}$s.

27. Which of the following will pair up to produce stationary wave?

(a) $Z_1 = A \cos(kx - \omega t)$

(b) $Z_2 = A \cos(kx + \omega t)$

(c) $Z_3 = A \cos(kx - \omega t)$

(d) $Z_4 = A \cos(kx + \omega t)$

(a) 1 and 2

(b) 2 and 3

(c) 3 and 4

(d) 1 and 3

[IIT 1993]

Solution (a) The waves must be travelling in opposite directions and have same amplitude and same frequency.

28. A quartz crystal is used to produce ultrasonic. The frequency will be inversely related to

(a) Young's modulus.

(b) thickness.

(c) density.

(d) length.

Solution (b) $f \propto 1/t$.

TYPICAL PROBLEMS

29. Two successive resonance frequencies in an open organ pipe are 1944 and 2592 Hz. Find the length of the tube. The speed of sound in air is 324 ms^{-1}

(a) 25 cm   (b) 50 cm

(c) 12.5 cm   (d) none of these

Solution (d) $f_0 = 2592 - 1944 = 648$ Hz

$$\lambda = \frac{v}{f} = \frac{324}{648} = \frac{1}{2} \text{ m}$$

or $\quad l = \dfrac{\lambda}{2} = 25$ cm.

30. A cylindrical metal tube has a length of 50 cm and is open at both ends. Find the frequencies between 1 kHz to 2 kHz at which the air column in the tube resonates. The temperature on that day is 20°C.

(a) 1020, 11360, 1700 Hz   (b) 1026, 1368, 1710 Hz

(c) 1328, 1660, 1922 Hz   (d) none of these

Solution (b) $v\,(T) = 330\sqrt{1 + \dfrac{20}{273}}$

$$= 330\sqrt{\frac{293}{273}} = 342 \text{ ms}^{-1}$$

$$f = \frac{v}{\lambda} = \frac{342}{1} = 342 \text{ Hz}.$$

wavelengths allowed between 1000 Hz and 2000 Hz are 1026 Hz, 1368 Hz, 1710 Hz.

31. A tuning fork produces 4 beats per second with another tuning fork of frequency 256 Hz. The first one is now loaded with a little wax and number of beats heard are 6 per second. The original frequency of the tuning fork is

(a) 252 Hz   (b) 260 Hz

(c) 250 Hz   (d) 262 Hz

Solution (a) $f = 256 \pm 4$ Hz.

On loading the first one the number of beats increase. Therefore, the frequency of the tuning fork must be 252 Hz. As it will decrease further on loading and number of beats/s increase.

32. Two stereo speakers are separated by a distance of 2.4 m. A person stands at a distance of 3.2 m as shown directly in front of one of the speakers. Find the frequencies in audible range for which the listener will hear a minimum sound intensity.

Speed of the sound in air is 320 ms^{-1}.
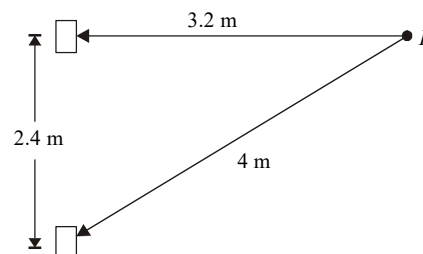
Fig. 14.17

(a) $160(2n + 1)$ (b) $320(2n + 1)$

(c) $200(2n + 1)$ (d) $100(2n + 1)$

Solution (c) $\sqrt{3.2^2 + 2.4^2} = 4$ m

Path difference $= 0.8$ m $= (2n + 1)\dfrac{\lambda}{2}$

$$\lambda = \frac{1.6}{(2n+1)} \text{ using } f = \frac{v}{\lambda} = \frac{320}{1.6}(2n + 1)$$

$$= 200(2n + 1) \text{ Hz}.$$

$n = 1, 2, 3, ... 49$ are allowed.

33. A bullet passes past a person at a speed 220 ms^{-1}. Find the fractional change in the frequency of the whistling sound heard by the person as the bullet crosses the person. Speed of sound $= 330$ ms^{-1}.

(a) 0.67   (b) 0.8

(c) 1.2   (d) 3.0

Solution (b) Limiting cases when it is just at the verge of crossing and when it has just crossed are taken.

$$f_1 = \frac{v}{v + v_S} f = 0.6f \text{ and}$$

$$f_2 = \frac{v}{v + v_S} f = 3f$$

$$f_{\text{net}} = \frac{f_1 + f_2}{2} = \frac{3.6f}{2} = 1.8f$$

$$\Delta f = 0.8f \text{ or } \frac{\Delta f}{f} = 0.8.$$

34. A source of sound emitting 1200 Hz note travels along a straight line at a speed of 170 ms^{-1}. A detector is placed at a distance 200 m from the line of motion of the source. The frequency of the sound received by the detector when it is closest is (velocity of sound is 340 ms^{-1})

(a) 1600 Hz   (b) 800 Hz

(c) 2400 Hz   (d) none of these

Solution (a)$f_1 = \dfrac{v}{v+v_S} f = \dfrac{340}{510} \times 1200 = 800$ Hz;

$$f_2 = \dfrac{v}{v-v_S} f = \dfrac{340}{170} \times 1200 = 2400 \text{ Hz}$$

$$f = \dfrac{f_1+f_2}{2} = \dfrac{800+2400}{2} = 1600 \text{ Hz}.$$

35. A driver of a car approaching a vertical wall notices that the frequency of his car horn has changed from 440 to 480 Hz when it gets reflected from the wall. Find the speed of the car if the speed of the sound is 330 ms^{-1}

(a) 16.3 ms^{-1} (b) 15.3 ms^{-1}

(c) 14.3 m/s   (d) none of these

Solution (c) Let the velocity of car be u
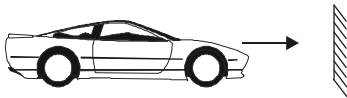
Fig. 14.18

Then $480 = \dfrac{v+u}{v-u} 440$ or

$$\dfrac{48}{44} = \dfrac{v+u}{v-u} \text{ or } u = \dfrac{330}{23} = 14.3 \text{ ms}^{-1}.$$

36. Two sources of sound S_1 and S_2 vibrate at the same frequency and are in phase. The intensity of sound detected at a point P is I_0. If $\theta = 45°$, what will be the intensity of sound reaching P if one of the sources is switched off. What will be the intensity if $\theta = 60°$
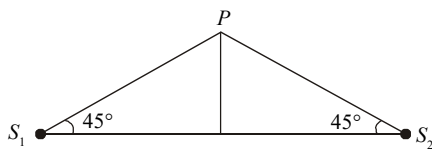
Fig. 14.19

(a) $\dfrac{I_0}{4}, \dfrac{I_0}{8}$ (b) $\dfrac{I_0}{4}, \dfrac{I_0}{2\sqrt{2}}$

(c) $\dfrac{I_0}{4}, \dfrac{I_0}{4}$ (d) $\dfrac{I_0}{4\sqrt{2}}, \dfrac{I_0}{8}$

Solution (c) Since the waves reach in phase $I_0 = 4I$

$$I_{max} \; \alpha \; (y_{01} + y_{02})^2 = (2y_{02})^2 = 4 \, y_{02}^2 = 4I$$

$$\therefore I = \dfrac{I_0}{4} \text{ It is independent of } \theta.$$

37. An electric train in Japan runs with a speed 1.3 Mach. It is approaching a station and blows a whistle of frequency 800 Hz. The frequency of the whistle heard by a stationary observer on the platform is

(a) 800 Hz   (b) 1600 Hz

(c) 1040 Hz   (d) insufficient data.

Solution (a) Since the velocity of source > velocity of sound, Doppler effect is inapplicable.

38. A person P is 600 m away from the station when train is approaching station with 72 km/h, it blows a whistle of frequency 800 Hz when 800 m away from the station. Find the frequency heard by the person. Speed of sound $= 340 \text{ ms}^{-1}$
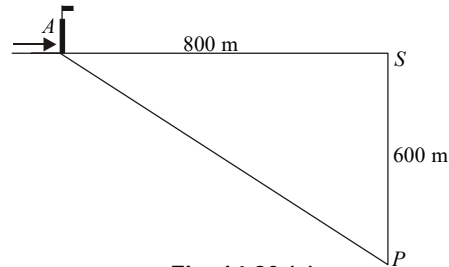
Fig. 14.20 (a)

(a) 800 Hz   (b) 839.5 Hz

(c) 829.5 Hz   (d) 843.5 Hz

Solution (b)$f_{app} = \dfrac{v}{v - v_S \cos\theta} f$

$$= \dfrac{340}{340-16} \times 800 = 839.5 \text{ Hz}$$
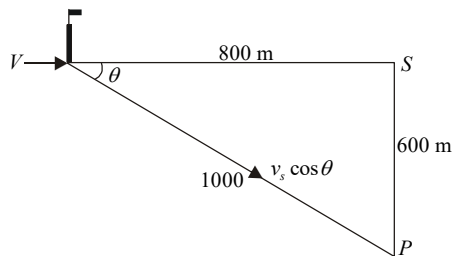
Fig. 14.20 (b)

39. Phenomenon of beats can take place

(a) for longitudinal waves only.

(b) for transverse waves only.

(c) for both longitudinal and transverse.

(d) for sound waves only.

Solution (c)

40. In the absence of teacher a class of 50 students make a noise level of 50 dB. 50 more students enter the class. Assuming each student on an average produces same intensity of sound then the noise level increases by

(a) 50 dB   (b) 25 dB

(c) 8.33 dB   (d) 3 dB

Solution (d) Let initial intensity be I then $10 \log \dfrac{I}{I_0}$

$= 50$ on arrival of 50 more students, new intensity $= 2I$

$$S_L = 10 \log \dfrac{2I}{I_0}$$

$$= 10 \log \dfrac{I}{I_0} + 10 \log 2$$

$$= 50 + 10(.3010) = 53 \text{ dB}$$

$$\Delta S_L = 53 - 50 = 3 \text{ dB}.$$

PASSAGE 1

Read the following passage and answer the questions given at the end.

The propagation speed of longitudinal as well as transverse waves is determined by the mechanical properties of the medium, Figure 14.21 shows a fluid (liquid or gas) of density ρ in a tube of cross-sectional areas A and under a pressure P. In figure 14.21 (a) the fluid is at rest. At time $t = 0$ the piston at the left end of the tube is set in motion towards the right with a speed v. Figure 14.21 (b) shows the fluid after a time t elapsed. All portions of the fluid at the left of point P are moving with speed v, whereas all portions at the right of P are still at rest. The boundary between the moving and the stationary portions travels to the right with the speed of propagation c. At time t the piston has moved a distance vt and the boundary has advanced a distance ct. As in the case of transverse disturbance in a string, the speed of propagation can be computed from the impulse momentum theorem.

The quantity of fluid set in motion in time t is the amount that originally occupied a volume of length ct and of cross-sectional area A. The mass of this fluid is therefore ρctA and the longitudinal momentum it has acquired is

Longitudinal momentum $= \rho ct\, Av$.

We next compute the increase of pressure, ΔP, in the following fluid. The original volume of the moving fluid, Act has been decreased by an amount Avt. From the definition of bulk modulus B.

(a) (b)
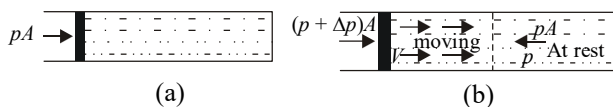
Fig. 14.21

$$B = \dfrac{\text{Change in Pressure}}{\text{Fractional Change in Volume}}$$

$$= \dfrac{\Delta P}{Avt\,/\,Act}$$

There fore,

$$\Delta P = B\, \dfrac{v}{c}$$

1. Pick up the correct relation.

   (a) $c > v$ (b) $c = v$
   (c) $c < v$ (d) none of these

2. In a string, longitudinal wave

   (a) can be produced. (b) cannot be produced.
   (c) may not be produced.

3. Sound wave with velocity v_0 cause condensation and rarefaction. If B is the bulk modulus of the medium and y_0 is amplitude of the wave and ω is angular frequency then maximum change in pressure ΔP is given by

   (a) $\Delta P = \dfrac{By_0\omega}{v_0}$ (b) $\dfrac{Bv_0}{y_0\omega}$
   (c) B (d) $B\,y_0w$

4. Sound wave does not show

   (a) diffraction. (b) interference.
   (c) refraction. (d) polarization.

Solution 1. (a)
Solution 2. (a)
Solution 3. (a)
Solution 4. (d)

PASSAGE 2

Read the following passage and answer the questions given at the end.

The total power carried across a surface by a sound wave equals the product of the intensity at the surface and the surface area, if the intensity over the surface is uniform. The average total power developed as sound waves by a person speaking in an ordinary conversational tone is about 10^{-5} W, while a loud shout corresponds to about 3×10^{-2} W. Since population of the city of New York is about eight million persons the acoustical power developed, if all were to speak at the same time would be about 80 W, or enough to operate a moderate-sized electric light .On the other hand, the power required to fill a large auditorium with loud sound is considerable. Suppose the intensity over the surface of a hemisphere 20 m in radius is 1W m^{-2}. The area of the surface is about 2500 m^2. Hence, the acoustic power output of a speaker at the center of the sphere would have to be

(1W m^{-2}) (2500 m^2) = 2500 W.

or 2.5 kW. The electrical power input to the speaker would need to be considerably larger, since the efficiency of such devices is not very high.

1. A class of 50 student produces a noise of 50 dB. 50 more students enter the class. The noise level increases by ——dB. Assume each student on an average produces equal sound intensity.

(a) 50 *dB*   (b) 15 *dB*

(c) 3 *dB*   (d) none

2. The intensity level at 10 m away is 40 dB. What will be the intensity level 100 m away? Assume isotropic source.

    (a) 4 *dB*   (b) 0.4 *dB*

    (c) 30 *dB*   (d) 20 *dB*

    (e) none of these

3. Sound level is a measure of intensity produced to minimum intensity which can be heard. The minimum intensity which can be heard is

    (a) 10^{-5} W m^{-2} (b) 10^{-6} W m^{-2}

    (c) 10^{-8} W m^{-2} (d) 10^{-12} W m^{-2}

4. $y_1 = 5\sin(10^3\pi t - 0.2x)$ and $y_2 = 10\sin(2\pi \times 10^3 t - 0.4x)$ will have intensity ratio

    (a) $\dfrac{1}{8}$ (b) $\dfrac{1}{4}$

    (c) $\dfrac{1}{16}$ (d) $\dfrac{1}{32}$

5. In doppler effect

    (a) only frequency changes.

    (b) both intensity and frequency change.

    (c) only speed changes.

    (d) both speed and frequency change.

Solution   1. (c) case (i) $50 = 10\log\dfrac{I}{I_0}$

case (ii) $y = 10\log\dfrac{2I}{I_0}$

$= 10\log\dfrac{I}{I_0} + 10\log 2$

$= 50 + 10(.3010) = 53\ dB$

Change in sound level $= 53 - 50 = 3\ dB$

Solution   2. (d) Case (i) $40 = 10\log\dfrac{\frac{P}{4\pi 10^2}}{I_0}$

Case (ii) $x = 10\log\dfrac{\frac{P}{4\pi 100^2}}{I_0}$

or $40 - x = 10\log\dfrac{100^2}{10^2}$

or $40 - x = 10\log 10^2$

or $x = 40 - 20 = 20\ dB.$

Solution   3. (d)

Solution   4. (c) $\dfrac{I_1}{I_2} = \dfrac{Y_{01}^2 f_1^2}{Y_{02}^2 f_2^2} = \dfrac{5^2 \times (10^3)^2}{10^2 \times (2\times 10^3)^2} = \dfrac{1}{16}$

Solution   5. (a)

PASSAGE 3

Read the following passage and answer the questions given at the end.

When a source of sound, or a listener or both are in motion relative to the air, the pitch of the sound, as heard by the listener, is in general not the same as when source and listener are at rest. The most common example is the sudden drop in pitch of sound from an automobile horn as one meets and passes a car proceeding in the opposite direction. This phenomenon is called the Doppler effect.

Let V_2 and V_3 represent the velocities of a listener and a source relative to the air. We shall consider only the special case in which the velocities lie along the line joining listener and source. Since these velocities may be in the same or opposite directions, and the listener may be either ahead or behind the source, a convention of signs is required. We shall take the positive direction of V_2 and V_3 as that from the position of the listener to ward the position of the source. The speed of propagation of sound waves, C_1 will always be considered positive.

We consider first listener L moving with velocity V_2 towards a stationary source S, as in Figure P_1. The source emits a wave with frequency f_s and wave length $\lambda = c/f_s$. The figure shows several wave crests, reparated by equal distance λ. The waves approaching the moving listener have a speed of propagation relative to him of $(c + V_1)$. Thus, the freuency f_L with which the listener encounters wave crests, i.e., the frequency he hears, is

$$f_L = \frac{C + V_L}{\lambda} = \frac{C + V_L}{C/f_S} = \frac{f_S(C + V_L)}{C}$$

1. A car is moving towards a vertical wall with 10 ms^{-1}. The driver blows a horn of frequency 400 Hz. The frequency heard by the driver is ____ $V_{sound} = 340$ ms^{-1}
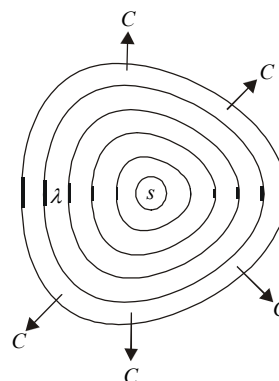
Fig. 14.22

(a) 400 Hz   (b) 424 Hz

(c) 430 Hz   (d) none

2. Two trains are moving on parallel tracks with 4 ms⁻¹ in opposite direction each. Number of beats heard by a person sitting in one of the trains if both the trains blows whistl of 400 Hz. $V_{sound} = 340$ ms⁻¹. The whistles were blown when they are facing one another.

(a) 4.7 beats s⁻¹   (b) 8.2 beats s⁻¹

(c) 7.9 beats⁻¹   (d) 9.3 beats⁻¹

3. A police man is standing. A bullet just crosses his ear with 175 ms⁻¹. If the frequency is 800 Hz. Find the frequency heard by the policeman. $v_S = 350$ ms⁻¹

(a) 1067 Hz   (b) 1600 Hz

(c) 533 Hz   (d) none of these

4. The maximum number of beats that can be heard per second.

(a) 5   (b) 10

(c) 15   (d) 20

(e) any number between 20 Hz and 20 kHz

Solution   1. (b) $f_{wall} = f \dfrac{V_{sound}}{V_{sound} - V_{ear}}$

$$f_{driver} = f_{wall} \dfrac{V_{sound} - V_{ear}}{V_{sound}}$$

$$= f \dfrac{V_{sound} + V_{ear}}{V_{sound} - V_{ear}} = 400 \times \dfrac{350}{330}$$

$$= 424\,\text{Hz}.$$

Solution   2. (d) $f^1 = 400 \dfrac{340 - 4}{340 + 4}$

$$= 400 \times \dfrac{336}{344} = 100 \dfrac{336}{86} = \dfrac{16800}{43}$$

$$= 390.7\,\text{Hz}.$$

number of beats heard per second = 400 – 390.7 = 9.3 beats S⁻¹

Solution   3. $f_1 = f_0 \dfrac{v_s}{v_s + v_b} = \dfrac{800 \times 350}{350 - 175}$

$$= 1600\,\text{Hz. (while approching)}$$

$$f_2 = f_0 \dfrac{v_s}{v_s + v_b} = \dfrac{800 \times 350}{525}$$

$$= \dfrac{800 \times 2}{3} = \dfrac{1600}{3}\,\text{Hz (while receding)}$$

$$f = \dfrac{f_1 + f_2}{2} = \dfrac{1600 + \dfrac{1600}{3}}{2}$$

$$= \dfrac{3200}{3} = 1067\,\text{Hz}$$

Solution   4. (b)

PASSAGE 4

Read the following passage and answer the questions given at the end.

The analysis of the radiation pattern from a circular piston can be carried out in the same way as that for a long rectangle. The piston is subdivided into narrow circular zones instead of long strips, and the effect of the waves from all the zones is summed at a distant point. There is a maximum of intensity along the axis of the piston, as would be expected. The angle α at which the first minimum occurs is given by.

$$\sin \alpha = 1.22 \dfrac{\lambda}{D}$$

where D is now the piston diameter. If $D = 0.3$ m, $\lambda = 0.15$ m.

$$\sin \alpha = 1.22 \left(\dfrac{0.15m}{0.3m} \right) = 0.61.$$

$$\alpha \approx 38$$

About 85 percent of the radiated energy is concentrated within a cone of this half angle, other minima and maxima of rapidly decreasing intensity surround the central maximum.

1. The radiations emitted from a rectangular base will show a maxima if

(a) d sin $\theta = \lambda$.   (b) d sin $\theta = \lambda/2$.

(c) 2d sin $\theta = \lambda/2$.   (d) none of these.

2. Where d is width of the strips. Fringe visibility is defined as

(a) $\dfrac{I_{max} - I_{min}}{I_{max} + I_{min}}$ (b) $\dfrac{I_{max} + I_{min}}{I_{max} - I_{min}}$

(c) $\dfrac{I_{max} - I_{min}}{I_{max}}$ (d) $\dfrac{I_{max} + I_{min}}{I_{max}}$

3. Two waves of sound $y_1 = 10 \sin (404 \pi t - .2x)$ and $y_2 = 8 \sin (400 \pi t - .2x)$ superpose. As a result

(a) at several places maximum intensity and at other places minimum intensity will be heard.

(b) 4 beats will be heard in a second.

(c) 2 beats will be heard in a second

(d) there will be no change in intensity of the sound rather two separate waves would be heard.

4. To produce interference in sound waves

(a) sources shall emit monochromatic wavelength.

(b) sources shall emit monochromatic wavelenght in same phase (i.e., source be Coherent).

(c) sources shall emit sound of same intensity irrespective of frequency.

(d) sources shall not be very far away.

Solution 1. (a)

Solution 2. (a)

Solution 3. (c)

Solution 4. (a), (d)

PASSAGE 5

Read the following passage and answer the questions given at the end.

Horseshoe bats (genus Rhinolophus) emit sounds from their nostrils, then listen to the frequency of the sound reflected from their prey to determine the prey's speed. The horse shoe that gives the bat its name is a depression around the nostrils that acts like a focussing mirror so that the bat emits sound in a narrow beam like a flash light. A Rhinolophus is flying at a speed v_{bat} and emits sound of frequency f_{bat}; the sound it hears reflected from an insect flying toward it has higher frequency f_{ref}. Speed of sound is v_s.

1. Find the speed of the insect $v_{insect} =$

(a) $v_s \left[\dfrac{f_{ref}(v_s - v_{bat}) - f_{bat}(v_s + v_{bat})}{f_{ref}(v_s - v_{bat}) + f_{bat}(v_s + v_{bat})} \right]$

(b) $v_s \left[\dfrac{f_{ref}(v_s + v_{bat}) - f_{bat}(v_s - v_{bat})}{f_{ref}(v_s + v_{bat}) + f_{bat}(v_s - v_{ref})} \right]$

(c) $v_s \left[\dfrac{f_{bat}(v_s + v_{bat}) - f_{ref}(v_s - v_{bat})}{f_{ref}(v_s - v_{bat}) + f_{bat}(v_s + v_{bat})} \right]$

(d) $v_s \left[\dfrac{f_{ref}(v_s + v_{bat}) + f_{bat}(v_s - v_{bat})}{f_{ref}(v_s - v_{bat}) - f_{bat}(v_s + v_{bat})} \right]$

2. If $f_{bat} = 80.7$ kHz, $f_{ref} = 83.5$ kHz and $v_{insect} = 2$ ms^{-1}. Find v_{bat}.

(a) 4.9 ms^{-1} (b) 3.9 ms^{-1}

(c) 5.9 ms^{-1} (d) 4.1 ms^{-1}

Solution 1. (a) $f_1 = f_{bat} \dfrac{v_s + v_{in}}{v_s - v_{bat}}$

and $f_{ref} = f_1 \dfrac{v_s + v_{bat}}{v_s - v_{in}}$

$\dfrac{f_{ref}}{f_{bat}} = \dfrac{(v_s + v_{in})(v_s + v_{bat})}{(v_s - v_{in})(v_s - v_{bat})}$

or $\quad \dfrac{f_{ref}}{f_{bat}} v_s (v_s - v_{in})(v_s - v_{bat})$

$= v_s^2 + v_{in}(v_s + v_{bat}) + v_s v_{bat}$

$\dfrac{f_{ref}}{f_{bat}} [v_s^2 - v_{in}(v_s - v_{bat}) - v_s v_{bat}]$

$= v_{in}(v_s + v_{bat}) + v_s^2 + v_s v_{bat}.$

$v_{in} \left[(v_s + v_{bat}) + \dfrac{f_{ref}}{f_{bat}}(v_s - v_{bat}) \right]$

$= \dfrac{f_{ref}}{f_{bat}} v_s(v_s - v_{bat}) - v_s(v_s + v_{bat})$

$v_{in} = v_s \left[\dfrac{\dfrac{f_{ref}}{f_{bat}}(v_s - v_{bat}) - (v_s + v_{bat})}{(v_s + v_{bat}) + \dfrac{f_{ref}}{f_{bat}}(v_s - v_{bat})} \right]$

$= v_s \left[\dfrac{f_{ref}(v_s - v_{bat}) - (v_s + v_{bat})f_{bat}}{f_{bat}(v_s + v_{bat}) + f_{ref}(v_s - v_{bat})} \right]$

Solution 2. (b)

$2 = \left[\dfrac{83.5(340 - v_{bat}) - (340 + v_{bat})80.7}{80.7(340 + v_{bat}) + 83.5(340 - v_{bat})} \right]$

solving for v_{bat} we get $v_{bat} = 3.9$ ms^{-1}

PASSAGE 6

Read the following passage and answer the questions given at the end.

When a sound wave enters the ear it sets the ear drum into oscillation, which in turn causes oscillation of the three tiny bones in the middle ear called the ossicles. This oscillation is finally transmitted to the fluid-filled inner ear. The motion of the fluid disturbs hair cells within the inner ear, which transmit nerve impulses to the brain with the information that a sound is present. The moving part of the eardrum has an area of about 43 mm^2, and the area of the stirrup (The smallest of the ossicles) where it connects to the inner ear is about 3.2 mm^2. A moderate loudness sound of maximum pressure variation are of the order of 3×10^{-2} Pa above and below atmospheric pressure of 10^5 Pa.

1. Find the maximum displacement in the fluid of inner ear if frequency of the wave is 1 kHz. $v_{fluid} = 1500$ ms^{-1}

   (a) 4.4×10^{-11} m   (b) 4.4×10^{-10} cm

   (c) 4.4 A^0 (d) 4.4 pm

2. Find the pressure amplitude consider mass of the ossicles = 58 mg and Bulk modulus of fluid = $(45.8 \times 10^{-11})^{-1}$

   (a) 0.3 Pa   (b) 0.4 Pa

   (c) 0.22 Pa   (d) 0.8 Pa

Solution 1. (a) $R_{inner\,ear} = \dfrac{\omega}{v} = \dfrac{1000 \times 2\pi}{1500} = \dfrac{4\pi}{3}$

$$y_0 = \frac{P_{max}(inner)}{B_{fluid}R_{inner\,ear}}$$

$$= \frac{0.4 \times 45 \times 10^{-11}}{\dfrac{4\pi}{3}} = 4.4 \times 10^{-11}\,\text{m}$$

Solution 2. (b) $P_{max} = \dfrac{F_{max}}{\text{area of stirrup}}$

$$= \frac{3 \times 10^{-2} \times 43}{3.2} = 0.4\,\text{Pa}$$

QUESTIONS FOR PRACTICE

1. When both source and listener move in the same direction with a velocity equal to half the velocity of sound, the change in frequency of the sound as detected by the listener is

   (a) 50%   (b) 25%

   (c) zero   (d) none of these

2. The wavelength of the sound produced by a source is 0.8 m. If the source moves towards the stationary listener at 32 ms^{-1}, what will be apparent wavelength of the sound? The velocity of sound is 320 ms^{-1}

   (a) 0.80 m   (b) 0.72 m

   (c) 0.40 m   (d) 0.32 m

3. The wavelength of light received from a galaxy is 10% greater than that received from an identical source on the earth. The velocity of the galaxy relative to the earth is

   (a) 3×10^6 ms^{-1} (b) 3×10^5 ms^{-1}

   (c) 3×10^8 ms^{-1} (d) 3×10^7 ms^{-1}

4. The velocity of sound in air is 330 ms^{-1}. To increase the apparent frequency of the sound by 50%, the source should move towards the stationary source with a velocity equal to

   (a) 110 ms^{-1} (b) 105 ms^{-1}

   (c) 220 ms^{-1} (d) 330 ms^{-1}

5. A source of sound moves towards a stationary listener with the velocity of sound. If the actual frequency of the sound produced by the source be f, then change in frequency will be

   (a) f (b) $f/2$

   (c) $f/4$ (d) none of these

6. A train is approaching the platform with a speed of 4 ms^{-1}. Another train is leaving the platform with the same speed. The velocity of sound is 320 ms^{-1}. If both the trains sound their whistles at frequency 230 Hz, the number of beats heard per second will be

   (a) 10   (b) 8

   (c) 7   (d) 6

7. A man runs towards a source of sound at 10 ms^{-1}. The frequency of the sound produced by the source is 400 Hz and heard is 410 Hz. The speed of the sound perceived by the man will be

   (a) 330 ms^{-1} (b) 400 ms^{-1}

   (c) 350 ms^{-1} (d) 340 ms^{-1}

8. A pendulum vibrates with a time period of 1 s. The sound produced by it is in the

   (a) audible range.   (b) infrasonic range.

   (c) ultrasonic range.   (d) super sonic range.

9. Which of the following characteristics successively increases in the musical scale?

   (a) quality   (b) pitch

   (c) loudness   (d) none of these

10. To change the quality of sound produced by an instrument, we need to vary the

    (a) number of wavertones.   (b) pitch.

    (c) loudness.   (d) amplitude.

11. Two sound waves given by $y_1 = 5 \sin(300\,\pi t)$ and $y_2 = 4 \sin(302\,\pi t)$ superimpose. The ratio of the maximum to minimum intensity of the sound waves will be

    (a) 302/300   (b) 81

    (c) 9   (d) 5/4

12. The pressure of air increases by 100 mm of Hg the temperature decreases by 1^{0}C. What will be the change in the speed of sound in air?

    (a) 61 ms^{-1} (b) 61 mm^{-1}

    (c) 61 cms^{-1} (d) none of the above

13. A sound wave propagating in air may be treated either as a displacement wave or a pressure wave. What is the phase difference between the displacement and pressure wave?
    (a) 180°   (b) 90°
    (c) 45°   (d) zero

14. If A is the amplitude of sound wave after covering a distance r, then
    (a) $A \propto 1/r$ (b) $A \propto r^2$
    (c) $A \propto 1/r^2$ (d) $A \propto r$

15. If the loundness changes from 30 dB to 60 dB. What is the ratio of the intensities in two cases?
    (a) 10,000   (b) 1000
    (c) 100   (d) 10

16. The power of a loud speaker is increased from 20 W to 400 W. What is the power increase as compared to the original value?
    (a) 13 dB   (b) 7 dB
    (c) 4 dB   (d) 2 dB

17. What is the ratio of the speed of sound in neon and water vapour at the same temperature. It is nearest to
    (a) 2.5   (b) 2
    (c) 1.5   (d) 1

18. The wavelength of a sound wave is reduced by 50%. Then the percentage change in its frequency will be
    (a) 100%   (b) 200%
    (c) 400%   (d) 800%

19. A resonance tube of length 1 m is resonated with a tuning fork of frequency 300 Hz. If the velocity of sound in air is 300 ms^{-1} then the number of harmonics produced in the tube will be
    (a) 1   (b) 2
    (c) 3   (d) 4

20. The velocity of sound in dry air at 0°C and at 74 cm of Hg preassure is 332 ms^{-1}, then the velocity of sound at 50°C and 77.5 cm of Hg pressure in ms^{-1} will be
    (a) 322.7   (b) 347.1
    (c) 352.4   (d) 361.1

21. The frequency of sound in oxygen at room temperature is v. The frequency of sound in a mixture of oxygen and hydrogen at the same temperature will be
    (a) uncertain.   (b) equal to v.
    (c) less than v. (d) more than v.

22. Beats are the result of
    (a) constructive and destructive interference in time.
    (b) constructive and destructive interference in space.
    (c) destructive interference in space.
    (d) constructive interference in space.

23. In Kundt's tube experiment wavelength in the metallic rod and air are 80 cm and 16 cm respectively. If the velocity of sound in air is 300 ms^{-1} then the velocity of sound in rod will be
    (a) 80 ms^{-1} (b) 3.75 ms^{-1}
    (c) 240 ms^{-1} (d) 1500 ms^{-1}

24. The velocity of sound in air is 332 ms^{-1}. The length of a closed pipe whose frequency of second overtone is 332 Hz, will be
    (a) 0.51 m   (b) 0.75 m
    (c) 1.25 m   (d) 1.75 m

25. A closed organ pipe, of length 1.2 m and filled with a gas, is resonated in its fundamental mode with a fork. Another open pipe of same length but filled with air resonates with the same fork. The room temperature is 40°C. If the speed of sound in air at 40°C is 360 ms^{-1}, then the speed of sound in gas at 40°C will be
    (a) 341.5 ms^{-1} (b) 637 ms^{-1}
    (c) 633 ms^{-1} (d) 720 ms^{-1}

26. The velocity of sound in dry air at 0°C and 74 cm pressure is 332 ms^{-1} then the velocity of sound at 50°C and 77.5 cm pressure in ms^{-1} will be
    (a) 322.7   (b) 347.1
    (c) 352.4   (d) 361.1

27. In Kundt's tube experiment the metallic rod executes
    (a) transverse vibration.
    (b) longitudinal vibrations.
    (c) both.
    (d) none of these.

28. Five beats per second are produced on vibrating two closed organ pipes simultaneously. If the ratio of their lengths is 21/20, then their frequencies will be
    (a) 105 Hz and 100 Hz.   (b) 105 Hz and 110 Hz.
    (c) 100 Hz and 105 Hz.   (d) 110 Hz and 105 Hz.

29. If the adiabatic constant for helium and hydrogen gases at the same temperature are 5/3 and 7/5 respectively, then the ratio of velocity of sound in these gases will be
    (a) 42 : 5   (b) $5 : \sqrt{42}$
    (c) $\sqrt{42} : 5$ (d) 5 : 42

30. A source of sound is emitting sound waves in all directions in an absorptionless medium. This source is at distance of 4 m and 16 m from points x and y respectively. The ratio of amplitudes of waves at points x and y will be
    (a) 2 : 4   (b) 4 : 1
    (c) 4 : 2   (d) 1 : 4

31. Two open pipes of length L are vibrated simultaneously. If length of one of the pipes is reduced by y, then the mumber of beats heard per second will nearly be (if the velocity of sound is v and $y < L$)

(a) $\dfrac{vy}{2L}$ (b) $\dfrac{2L^2}{Vy}$

(c) $\dfrac{vy}{2L^2}$ (d) $\dfrac{vy}{L^2}$

32. Two waves of wavelength 1.00 m and 1.01 m produce 10 beats in 3 s in a gas. The speed of sound in the gas will be

(a) 316.6 ms^{-1} (b) 336.6 ms^{-1}

(c) 356.6 ms^{-1} (d) 396.6 ms^{-1}

33. A source of sound of frequency 90 Hz is moving towards an observer with a velocity one-tenth the velocity of sound. The frequency heard by the observer will be

(a) 50 Hz (b) 100 Hz

(c) 200 Hz (d) 300 Hz

34. A source of sound of frequency 512 Hz is moving towards a wall with velocity v equal to that of second. An observer is standing between the source and the wall, then he will listen

(a) no beats s^{-1} (b) 3 beats s^{-1}

(c) 6 beats s^{-1} (d) 12 beats s^{-1}

35. An engine blowing whistle, is approaching a stationary observer with a velocity of 110 ms^{-1}. The ratio of frequencies heard by the observer while engine approaching and receding away from him will be (if $v = 330$ ms^{-1})

(a) 1 : 4 (b) 4 : 1

(c) 2 : 1 (d) 1 : 2

36. Earth is moving towards a stationary star with a velocity 100 kms^{-1}. If the wavelength of light emitted by the star is 5000 Å, then the apparent change in wavelength obseved by the observer on earth will be

(a) 0.67 Å (b) 1.67 Å

(c) 16.7 Å (d) 167 Å

37. An observer measures speed of light to be C when he is stationary with respect to the source. If the observer moves with velocity v towards the source then the velocity of light observed will be

(a) $c - v$ (b) $c + v$

(c) $\sqrt{1 - v^2/c^2}$ (d) c

38. A whistle is revolved with high speed in a horizontal circle of radius R. To an observer at the centre of the circle the frequency of the whistle will appear to be

(a) decreasing. (b) increasing.

(c) both. (d) constant.

39. A source of sound is emitting a waves of wavelength 40 cm in air. If this source starts moving towards east with a velocity one-fourth the velocity of sound then the apparent wavelength of sound in a direction opposite to that of source will be

(a) 20 cm (b) 50 cm

(c) 80 cm (d) 100 cm

40. A siren is producing sound of frequency 930 Hz. This siren is moving away from an observer towards a wall with, velocity of 20 ms^{-1}. The frequency of sound directly coming from the siren will be

(a) 882 Hz (b) 1000 Hz

(c) 930 Hz (d) 977 Hz

41. The apparent wavelength of light from a star moving away from earth is observed to be 0.01% more than its real wavelength. The velocity of star is

(a) 120 kms^{-1} (b) 90 kms^{-1}

(c) 60 kms^{-1} (d) 30 kms^{-1}

42. A star is receding away from earth with a velocity of 10^5 ms^{-1}. If the wavelength of its spectral line is 5700 Å then Doppler shift will be

(a) 0.2 Å (b) 1.9 Å

(c) 20 Å (d) 200 Å

43. The wavelength of H$_\alpha$ line in hydrogen spectrum was found 6563 Å in the laboratory. If the wavelength of same line in the spectrum of a milky way is observed to be 6586 Å then the recessional velocity of the milky way will be

(a) 0.105×10^6 ms^{-1} (b) 1.05×10^6 ms^{-1}

(c) 10.5 ms^{-1} (d) none of these

44. If a soldier jumps from an aeroplane moving with a constant horizontal velocity, then the ratio of the frequency of aeroplane sound heard by him f' and real frequency f will be

(a) 1 : 4 (b) 2 : 1

(c) 1 : 2 (d) 1 : 1

45. A rocket is receding away from earth with velocity 0.2 c. The rocket emits signal of frequency 4×10^7 Hz. The apparent frequency of the signal produced by the rocket observed by the observer on earth will be

(a) 3×10^6 Hz (b) 4×10^6 Hz

(c) 3.2×10^7 Hz (d) 5×10^7 Hz

46. A spectral line is obtained from a gas discharge tube at 5000 Å. If the rms velocity of gas molecules is 10^5 ms^{-1} then the width of spectral line will be

(a) 3.3 Å (b) 4.8 Å

(c) 7.2 Å (d) 9.1 Å

47. When an observer is approaching a stationary source with a velocity v_0 then the apparent change in frequency observed by him will be

    (a) $\dfrac{v}{v+v_0} n$

    (b) $\dfrac{v}{v_0} n$

    (c) $\dfrac{v+v_0}{v} n$

    (d) $\dfrac{v_0}{v} n$

48. A car is moving towards a person. The person observes a change of 2.5% in the frequency of its horn. If the velocity of sound is 320 ms^{-1} then the velocity of car is

    (a) 6 ms^{-1}

    (b) 8 ms^{-1}

    (c) 7.5 ms^{-1}

    (d) 800 ms^{-1}

49. A whistle produces 256 waves per second. If the velocity of sound towards the observer and its magnitude is one-third the velocity of sound in air then the number of waves received by the observer per second will be

    (a) 192

    (b) 200

    (c) 300

    (d) 384

50. When a source moves away from observer then apparent change in freuency is Δn_1. When an observer approaches the stationary source with same velocity v then change in frequency is Δn_2 then

    (a) $\Delta n_1 = \Delta n_2$

    (b) $\Delta n_1 > \Delta n_2$

    (c) $\Delta n_1 < \Delta n_2$

    (d) none of these

51. A SONAR inside sea works at 40 kHz. A submarine is approaching it with a velocity 360 Kmh^{-1}. If the speed of sound in water is 1450 ms^{-1} then the apparent frequency of waves after reflection from submarine will be

    (a) 11.5 kHz

    (b) 36.8 kHz

    (c) 45.9 kHz

    (d) 98.6 kHz

52. When a source of sound approaches a stationary observer with velocity v_s then the apparent frequency observed by the observer will be (v = velocity of sound)

    (a) $\dfrac{v_s}{v-v_s} n$

    (b) $\dfrac{v-v_s}{v} n$

    (c) $\dfrac{v+v_s}{v_s} n$

    (d) $\dfrac{v_s}{v-v_s} n$

53. A supersonic jet is moving with a velocity twice that of sound, the angle of conical wave front produced by the jet will be

    (a) 120°

    (b) 90°

    (c) 60°

    (d) 30°

54. The frequency of radar waves is 7.8×10^9 Hz. The frequency of these waves after reflection from aeroplane is observed to have increased by 2.7×10^4 Hz. The velocity of aeroplane in kmhr^{-1} will be

    (a) 1.872×10^3

    (b) 2.6×10^3

    (c) 3.1×10^3

    (d) 7.398×10^3

55. A boy blowing a whistle, is running away from a wall towards an observer with a speed of 1 ms^{-1}. The frequency of whistle is 680 Hz. The number of beats heard per second by the observer will be (given $v = 340 \text{ ms}^{-1}$)

    (a) zero

    (b) 2

    (c) 4

    (d) 8

56. An ultrasonic scanner is used in a hospital to detect tumour in tissue. The working frequency of the scanner is 4.2 mega Hz. The velocity of sound in the tissue is 1.7 kms^{-1}. The wavelength of sound in the tissue is nearest to

    (a) 4×10^{-3} m

    (b) 8×10^{-3} m

    (c) 4×10^{-4} m

    (d) 8×10^{-4} m

57. In a Kundt's tube experiment the heaps of lycopodium powder are collected at 20 cm separations. The frequency of tuning fork used is

    (a) 660 Hz

    (b) 825 Hz

    (c) 775 Hz

    (d) 915 Hz

58. When a sound wave of frequency 300 Hz passes through a medium, the maximum displacement of a particle of the medium is 0.1 cm. The maximum velocity of the particle is equal to

    (a) 30 cms^{-1}

    (b) $30\pi \text{ cms}^{-1}$

    (c) 60 cms^{-1}

    (d) $60\pi \text{ cms}^{-1}$

59. Which of the following is mechanical wave?

    (a) light waves

    (b) sound wave

    (c) X-rays

    (d) radio waves

60. Which of the following properties of sound is not affected by change in the temperature of air?

    (a) wavelength

    (b) intensity

    (c) amplitude

    (d) frequency

61. A sound wave is represented by $y = a \sin (1000 \pi t - 3x)$. The distance between two points having a phase difference of $\pi/3$ is

    (a) $5\pi/18$

    (b) $2\pi/9$

    (c) $\pi/18$

    (d) $\pi/9$

62. If a tuning fork sends a wave $5 \sin \left(600\omega t - \dfrac{\pi}{0.6} x \right)$ then the amplitude of the intensity heard is
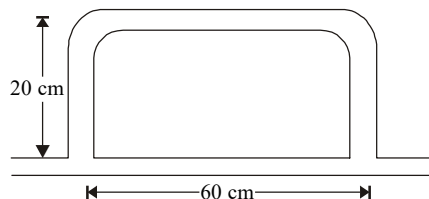

Fig. 14.23

(a) 5   (b) $5\sqrt{2}$

(c) $5\sqrt{3}$ (d) none of these

63. Surface waves strike the rock with their crests 160 m apart. The velocity of the waves is 40 ms^{-1}. The time interval between two crests striking the rock is

(a) 8 s   (b) 4 s

(c) 2 s   (d) 1 s

64. Sound waves in air differ from the electromagnetic waves in that they cannot be

(a) diffracted.   (b) polarised.

(c) reflected.   (d) refracted.

65. When a stone is dropped on the surface of still water the waves produced are

(a) stationary.   (b) transverse.

(c) longitudinal.   (d) none of these.

66. Velocity of sound in a gas is proportional to

(a) square root of isothermal elasticity.

(b) isothermal elasticity.

(c) square root of adiabatic elasticity.

(d) adiabatic elasticity.

67. The velocity of sound in a gas is 300 ms^{-1}. The root mean square velocity of the molecules is of the order of

(a) 4 ms^{-1} (b) 40 ms^{-1}

(c) 400 ms^{-1} (d) 4000 ms^{-1}

68. A man standing unsymmetrically between two parallel cliffs, claps his hands and starts hearing a series of echoes at intervals of 1 s. If the speed of sound in air is 340 ms^{-1}, then the distance between the two parallel cliffs, is

(a) 170 m   (b) 340 m

(c) 510 m   (d) 680 m

69. Compressional wave impulses are sent to the bottom of sea from a ship and the echo is heard after 4 s. If bulk modulus of water is 2×10^9 Nm^{-2} and the mean temperature is 4^{0}C, then depth of the sea is

(a) 2000×10^3 m   (b) 2828 m

(c) 1414 m   (d) 707 m

70. Which of the following cannot produce ultrasonics?

(a) galton whistle.   (b) quartz crystal.

(c) magnetostriction effect. (d) quincke's tube.

71. Velocity of sound in oxygen at NTP is v. The velocity of sound in helium at NTP should be

(a) 2v (b) 4v

(c) $2\sqrt{2}\,v$ (d) none of these

72. A stone is dropped into a well and the sound of impact of stone with the water is heard after 2.056 s of the release of stone from the top. If the acceleration due to gravity is 980 cms^{-2} and the velocity of sound in air is 350 ms^{-1}, then the depth of the well is

(a) 7 m   (b) 19.6 m

(c) 700 m   (d) 1960 m

73. When you speak to your friend, which of the following quantities have a unique value in the sound produced?

(a) amplitude   (b) wave velocity

(c) frequency   (d) wavelength

74. Bullet train in Japan travels with 1.2 Mach. A man standing on the platform will hear the frequency as if the train blows a whistle of 800 Hz while approaching the station.

(a) 800 Hz   (b) 960 Hz

(c) 1960 Hz   (d) none of these

75. A rope of length / and mass m hangs freely from the ceiling. The velocity of transverse wave as a function of position x along the rope is proportional to

(a) $1 / \sqrt{x}$ (b) $\sqrt{x}$

(c) x (d) x^0

76. A sound wave of freequency 500 Hz covers a distance of 1000 m in 5 s between points x and y. Then the number of waves between x and y are

(a) 5000   (b) 2500

(c) 100   (d) 500

77. A string has a mass per unit length of 10^{-6} kgcm^{-1}. The equation of simple harmonic wave produced in it is $y = 0.2 \sin(2x + 80t)$. The tension in the string is

(a) 0.0016 N   (b) 0.16 N

(c) 16 N   (d) 1.6 N

78. The velocity of sound in air is 332 ms^{-1}. If the air consists of nitrogen and oxygen in the ratio 4 : 1, the velocity of sound in oxygen is

(a) 278 ms^{-1} (b) 315 ms^{-1}

(c) 372 ms^{-1} (d) 418 ms^{-1}

79. A jet aeroplane is flying at supersonic speed. When the sound of the jet appears to be coming vertically downwards, the angle of sight of the aeroplane with the horizontal cannot be

(a) 60°   (b) 40°

(c) 30°   (d) 25°

80. The first loud sound is heard in a resonance tube when the air column is 26.2 cm and second load sound is heard when the air column is 80 cm. The diameter of the tube is

(a) 0.6 cm   (b) 1.2 cm

(c) 2.0 cm   (d) 1.6 cm

81. A supersonic jet produces waves in air. The wave front is
    (a) ellipsoidal.
    (b) conical.
    (c) spherical.
    (d) paraboloidal.

82. The train is approaching station with 72 kmh^{-1}. When 1 km away it blows a whistle of frequency 600 Hz. The frequency heard by the person as shown in figure is ($v_{sound} = 350$ ms^{-1})
    (a) 612 Hz
    (b) 625 Hz
    (c) 632 Hz
    (d) none of these

83. A person places his ear at the end of a long steel pipe. He hears two distinct sounds at an interval of 0.5 s when another person hammers at the other end of the pipe. If the speed of the sound in metal and air are 3630 ms^{-1} and 330 ms^{-1} respectively, then the distance between the two persons is
    (a) 90.75 m
    (b) 181.5 m
    (c) 363 m
    (d) 1650 m

84. The wave produced in a sonometer is
    (a) longitudinal.
    (b) timesavers.
    (c) transverse stationary.
    (d) longitudinal stationary.

85. A tube closed at one end and containing air produces, when excited the fundamental note of frequency 512 Hz. If the tube is open at both ends, the fundamental frequency that can be excited is (in Hz)
    (a) 128
    (b) 256
    (c) 512
    (d) 1024

86. The number of beats produced per second by two tuning forks when sounded together is 4. One of them has a frequency of 250 Hz. The frequency of the other cannot be more than
    (a) 252 Hz
    (b) 254 Hz
    (c) 246 Hz
    (d) 248 Hz

87. At what sound level headache begins?
    (a) 120 dB
    (b) 100 dB
    (c) 80 dB
    (d) 60^0 dB

88. A tuning fork is vibrating in the 3rd harmonic. Number of antinodes produced in it are
    (a) 3
    (b) 5
    (c) 7
    (d) 6

89. Which type of wave is produced in the stem of tuning fork?
    (a) transverse
    (b) transverse stationary
    (c) longitudinal
    (d) longitudinal stationary

90. An organ pipe P_1 closed at one end and vibrating in its first overtone and another pipe P_2 open at both ends vibrating in its third overtone are in resonance with a given tuning fork. The ratio of the lengths of P_1 to that of P_2 is

    (a) 3/8
    (b) 1/3
    (c) 1/2
    (d) 8/3

91. Which type of wave is produced in a resonance tube?
    (a) longitudinal
    (b) transverse
    (c) transverse stationary
    (d) longitudinal stationary

92. The intensity level due to two waves of the same frequency in a given medium are 1 dB and 4 dB. The ratio of their amplitudes is
    (a) 1 : 10^4
    (b) 1 : 4
    (c) 1 : 2
    (d) 1 : 10^2

93. The velocity of sound in air is 330 ms^{-1}. The fundamental frequency of an organ pipe open at both ends and length 0.3 m will be
    (a) 200 Hz
    (b) 275 Hz
    (c) 300 Hz
    (d) 550 Hz

94. The relation between the objective measurement of intensity of sound, I and the subjective sensory response called loudness L is given by
    (a) $L = K \log I^2$
    (b) $I = K \log L$
    (c) $L = I$
    (d) $L = K \log I$

95. 20 tuning forks are so arranged in series that each fork gives 4 beats per second with the previous one. The frequency of the 20th fork is three times that of the first. What is the frequency of the first tuning fork?
    (a) 60 Hz
    (b) 57 Hz
    (c) 40 Hz
    (d) 38 Hz

96. The displacement y of a particle executing periodic motion is given by $y = 4 \cos^2(t) \sin(1000\ t)$. This expression may be considered to be a result of the superposition of waves
    (a) 5
    (b) 4
    (c) 3
    (d) 2

97. As an empty vessel is filled with water, its frequency
    (a) increases.
    (b) decreases.
    (c) remains unchanged.
    (d) none of these.

98. Combination of notes that produced jarring effect on the ear is called
    (a) discord.
    (b) harmony.
    (c) noise.
    (d) melody.

99. A pure sine wave is called
    (a) chord.
    (b) melody.
    (c) tone.
    (d) overtone.

100. A tuning fork of frequency f resonates with a closed organ pipe when the length of the shortest air columns are a and b respectively. The speed of sound in air is
    (a) $2f(b + a)$
    (b) $\dfrac{f(v - a)}{2}$
    (c) $2f(b - a)$
    (d) $\dfrac{f(v + a)}{2}$

101. Most of the human ears cannot hear sound of intensity less than

(a) $10^{-12}\,\text{Wm}^{-2}$ (b) $10^{-6}\,\text{Wm}^{-2}$

(c) $10^{-3}\,\text{Wm}^{-2}$ (d) $1\,\text{Wm}^{-2}$

102. Two waves having the intensities in the ratio 9 : 1 produce interference. The ratio of maximum to minimum intensity is equal to

(a) 4 : 1   (b) 9 : 1

(c) 2 : 1   (d) 10 : 8

103. The expression $y = a\sin bx \sin \omega t$ represents a stationary wave. The distance between the consecutive nodes is

(a) $1/b$ (b) $\pi/2b$

(c) $2\pi/b$ (d) π/b

104. A pendulum vibrates with a time period of 1 s. The sound produced by it is in the range of

(a) supersonic range.   (b) ultrasonic range.

(c) audible range.   (d) infrasonic range.

105. In a good auditorium the reverberation time is

(a) $0.17\,\text{V/A}$ (b) $>0.17\,\text{V/A}$

(c) $<0.17\,\text{V/A}$ (d) none of these

106. A sound is said to be of rich quality when it contains

(a) a note of high amplitude.

(b) only the fundamental frequency.

(c) a note of high frequency.

(d) many harmonics.

107. The persistence of sound in a hall is called

(a) reverberation.   (b) resonance.

(c) acoustics.   (d) articulation.

108. The wavelength of light received from milky way is 0.4% higher than that from the same source on earth. The velocity of milky way with respect to earth will be

(a) $0.2 \times 10^6\,\text{ms}^{-1}$ (b) $1.2 \times 10^6\,\text{ms}^{-1}$

(c) $2 \times 10^6\,\text{ms}^{-1}$ (d) $5 \times 10^6\,\text{ms}^{-1}$

109. On a quiet day, when a whistle crosses you then its pitch decreases in the ratio 4/5. Ifa the temperature on that day is 20° C, then the speed of whistle will be (given the velocity of sound at $0^0 = 332\,\text{ms}^1$)

(a) $48.2\,\text{ms}^{-1}$ (b) $68.2\,\text{ms}^{-1}$

(c) $86\,\text{ms}^{-1}$ (d) $48.2\,\text{ms}^{-1}$

110. The pitch of a sound source appears to be 20% decreased to an observer. The velocity of source with respect to the observer will be

(a) $0.825\,\text{ms}^{-1}$ (b) $8.25\,\text{ms}^{-1}$

(c) $82.5\,\text{ms}^{-1}$ (d) $330\,\text{ms}^{-1}$

111. The separation between a node and an antinode in the stationery wave $y = 20\sin(2x)\cos 400\,\pi t$ is

(a) $\dfrac{\pi}{2}$ (b) $\dfrac{\pi}{4}$

(c) $\dfrac{\pi}{6}$ (d) $\dfrac{\pi}{8}$

112. $P = (10^5 \pm 14pa)\sin(600\,\pi t - \pi x)$ is a pressure wave of amplitude 10 cm. The bulk modulus is

(a) $\dfrac{10^6}{\pi}\,\text{Pa}$ (b) $\dfrac{10^2}{\pi}\,\text{Pa}$

(c) $\dfrac{140}{\pi}\,\text{Pa}$ (d) $\dfrac{14}{\pi}\,\text{Pa}$

113. Ultrasonics produced in quartz is due to

(a) magneto striction effect.

(b) pyroelectric effect.

(c) piezoelectric effect.

(d) none of these.

114. If wave length changes by $\Delta\lambda$ then change in propagation vector is

(a) Δk (b) $2\pi\Delta\lambda$

(c) $\dfrac{2\pi}{\lambda}\,\Delta\lambda$ (d) $\dfrac{2\pi}{\lambda^2}\,\Delta\lambda$

115. The pressure amplitude in a sound wave is tripled and frequency halved, the intensity of the sound is increasesd by a factor of

(a) 1.25   (b) 3.25

(c) 9.25   (d) 2.25

116. How many times more intense is a 90 db sound than a 40 db sound

(a) 10^5 (b) 500

(c) 50   (d) 5

117. Beats are produced by two waves $y_1 = a\sin 200\,\pi t$ and $y_2 = a\sin 208\,\pi t$. The number of beats heard per second is

(a) 8   (b) 4

(c) 1   (d) 0

118. For a resonance tube the air columns for the first and the second resonance are 24.5 and 75 cm. The wavelength of the sound wave is

(a) 202 cm   (b) 50.5 cm

(c) 101 cm   (d) 98 cm

119. The speed of sound in air is $350\,\text{ms}^{-1}$. The fundamental frequency of an open pipe 50 cm long will be

(a) 50 Hz   (b) 175 Hz

(c) 350 Hz   (d) 700 Hz

120. A sound source is moving towards a stationary observer with one-tenth of the speed of sound. The ratio of apparent to real frequency is

(a) $(9/10)^2$ (b) $11/10)^2$

(c) $10/9$ (d) $11/10$

121. The frequency of the sound of a car horn as received by an observer towards whom the car is moving differs from the frequency of the horn by 2.0%. Assuming that the velocity of sound of air is 350 ms⁻¹, the velocity of car is

(a) 6.0 ms⁻¹   (b) 7.5 ms⁻¹

(c) 7 ms⁻¹   (d) 8.5 ms⁻¹

122. Fidelity refers to

(a) reproduction of original sound.

(b) reproduction of original image.

(c) reproduction of music.

(d) reproduction of a CD from original copy.

123. On the diatonic scale the frequency of the note Re is 81. The frequency of Ga will be

(a) 93   (b) 90

(c) 87   (d) 84

124. The frequency of the key note on the equally tempered scale is 24. The frequency of the highest note in it will be

(a) 72   (b) 60

(c) 48   (d) 36

125. Which analysis is applied to convert a complex sound into notes

(a) millman theorem.   (b) de morgan laws.

(c) lissajous theorem.   (d) fourier theorem.

126. Which of the following can be used to determine the velocity of sound in solids, liquids as well as in gases

(a) resonance tube.   (b) kundt's tube.

(c) sonometer.   (d) organ pipe.

127. Bass control in a stereo system increases the power of

(a) low frequencies.   (b) high frequencies.

(c) medium frequencies.   (d) ultrasonics.

128. Two waves each of loudness L superimpose to produce beats. The maximum loudness of the beats will be

(a) $4L$ (b) L

(c) $2L$ (d) none of these

129. Three sources of sounds of equal intensities have frequencies 251, 252 and 253 Hz respectively. When sounded together, the number of beats heard per second will be

(a) 3   (b) 2

(c) 1   (d) none of these

130. Sound waves in air cannot be polarised because they are

(a) progressive.   (b) stationary.

(c) transverse.   (d) longitudinal.

131. Which of the following is essential for interference of sound waves?

(a) constant phase difference.

(b) same frequency.

(c) same amplitude.

(d) none of these.

132. The number of beats produced per second by two tuning forks when sounded together is 4. One of them has a frequency of 250 Hz and if waxed, number of beats become 6. The frequency of the other tuning fork is

(a) 254 Hz   (b) 252 Hz

(c) 248 Hz   (d) 246 Hz

133. What happens when two sound waves of frequencies differing by more than 10 Hz reach our ear simultaneously?

(a) beats are not produced.

(b) the waves destroy each other's effect.

(c) iterference of sound does not take place.

(d) beats are produced but cannot be heard.

134. Velocity of sound in the atmosphere of a planet is 600 ms⁻¹. The minimum distance between the source of sound and the obstacle to hear echo should be

(a) 60 m   (b) 25 m

(c) 30 m   (d) 17 m

135. Radio waves of wavelength λ are sent from a RADAR towards an aeroplane. If the aeroplane is moving towards the RADAR station, the wavelength of the radiowaves received after reflection from the aeroplane will be

(a) λ (b) $> \lambda$

(c) $< \lambda$

(d) more or less than λ, depending on the speed of aeroplane

PASSAGE 1

Read the following passage and answer the questions given at the end.

Two small loud speakers A and B are driven by the same amplifier as shown in Fig and emit pure sinusoidal waves in phase. Speaker A is 1 m away as shown and speaker B is 2 m away from the amplifier. The microphone is 4 m away from the amplifier in transverse direction as indicated in the Fig.
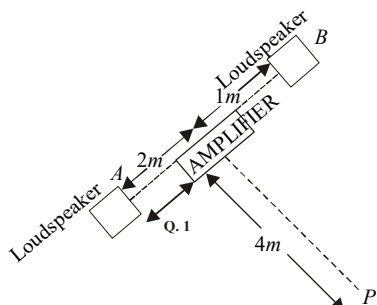
Fig. 14.24

1. For what frequencies constructive interference will occur at P (microphone point)
   (a) 1000 Hz, 2000 Hz, ...
   (b) 500 Hz, 1500 Hz ....
   (c) 550 Hz, 1100 Hz, ...
   (d) 500 Hz, 1000 Hz, 1500 Hz, ...

2. For what frequencies destructive interference will occur at P.
   (a) 500 Hz, 1500 Hz, 2500 Hz, ...
   (b) 500 Hz, 1000 Hz, 1500 Hz, ...
   (c) 1250 Hz, 1750 Hz, 2250 Hz, ...
   (d) 1000 Hz, 2000 Hz, ...

Solution 1. (a) $\Delta x = AP - BP = \sqrt{4^2 + 2^2} - \sqrt{4^2 + 1}$

$= 4.47 - 4.12 = 0.35 \, \text{m}$

for constructive interference path difference $= n\lambda$ where

$n = 0, 1, 2, ... = \dfrac{nv}{f}$

or $f = \dfrac{nv}{\Delta x} = n\dfrac{350}{0.35} \Rightarrow 10000 \, \text{Hz}, 2000 \, \text{Hz}, 3000 \, \text{Hz},$

......

Solution 2. (a) For destructive interference $\Delta x = (2n-1)$

$\dfrac{\lambda}{2} = \dfrac{(2n-1)}{2}\dfrac{v}{f}$ where $n = 1, 2, ...$

or $f = \dfrac{(2n-1)v}{2\Delta x} \Rightarrow 500 \, \text{Hz}, 1500 \, \text{Hz}, 2500 \, \text{Hz}, ...$

PASSAGE 2

Read the following passage and answer the questions given at the end.

A man marries a great Wagnerism Soprano but alas, he discovers he can not stand wagnerian opera. In order to save his eardrums, the unhappy man decides he must silence his lark-like wife for good. His plan is to tie her to the front of his car and send car and soprano speeding towards a brick wall. This soprano, however is quite shrewd, having studied physics in her student days at the music conservatory. She realized that this wall has a resonant frequency of 600 Hz. That is the wall will fall down if a continuous sound wave of 600 Hz hit it, and she will be saved to sing again. The car is heading towards the wall at 30 ms^{-1}. Take $v_s = 330$ ms^{-1}.

1. At what frequency must the soprano sing so that the wall will crumble?
   (a) 545.45 Hz   (b) 550.2 Hz
   (c) 560 Hz   (d) 565.3 Hz

2. What frequency the soprano will hear reflected from the wall just before it crumbles?
   (a) 545.45 Hz   (b) 555 Hz
   (c) 654.54 Hz   (d) 628.38 Hz

Solution 1. (a) $600 = \dfrac{330}{330 - 30} f_0$

or $f_0 = \dfrac{600 \times 300}{330} = \dfrac{6000}{11}$

$= 545.45 \, \text{Hz}$

Solution 2. (c) $f_L = \dfrac{600 \times (330 + 30)}{330}$

$= \dfrac{600 \times 360}{330} = \dfrac{7200}{11}$

$= 654.54 \, \text{Hz}$

PASSAGE 3

Read the following passage and answer the questions given at the end.

The B string of a guitar is made of steel (density 7800 kg m^{-3}), is 63.5 cm long and has diameter 0.406 mm. The frequency of fundamental mode is 247 Hz. A new admision in a music school, not understanding the importance of tension slightly disturbs the tension by ΔT. The music teacher explains the importance of tension and length and retunes to the said value. The tuning was made at 18.5 ^{0}C. The sternous playing can make the temperature of the string to rise to 29.5 ^{0}C. The steel string has a Young's modulus 2×10^{11} Pa and coefficient of linear expansion 1.2×10^{-5} K^{-1}.

1. What effect on frequency is observed when the newcomer disturbed the tension?
   (a) $\dfrac{\Delta f}{f} = \dfrac{\Delta T}{T}$ (b) $\dfrac{\Delta f}{f} = \dfrac{3}{2}\dfrac{\Delta T}{T}$
   (c) $\dfrac{\Delta f}{f} = \dfrac{\Delta T}{2T}$ (d) $\dfrac{\Delta f}{f} = \dfrac{2\Delta T}{T}$

2. Assuming temperature of the body of guitar remains same. When the temperature of the string rises then frequency
   (a) falls by 4.25 Hz   (b) rises by 4.25 Hz
   (c) falls by 8.5 Hz   (d) rises by 8.5 Hz

3. What is the Tension in tuned string and thereafter rigorous playing.
   (a) 99.4 N, 102.6 N   (b) 99.4 N, 96.2 N
   (c) 102.6 N, 99.4 N   (d) 96.2 N, 99.4 N

Solution 1. (c) $f = \dfrac{1}{2l}\sqrt{\dfrac{T}{\mu}}$, Thus $\dfrac{\Delta f}{f} = \dfrac{1}{2}\dfrac{\Delta T}{T}$

Physics by Saurabh Maurya (IIT-BHU)

$\Delta T = A \ \alpha \ Y\Delta T = \pi(2 \times 10^{-4})^2 \times 1.2 \times 10^{-5} \times 2 \times 10^{11} \times 11 = 3.2N$

Solution 2. (a) since the length increases, tension decreases.

$$\Delta f \ = \ \frac{1}{2} \ \frac{\Delta T}{T} \ \times f = \frac{1}{2} \times \frac{3.2}{99.4} \times 247 = 4.25 \text{ Hz}$$

∴ frequency falls by 4.25 Hz

Solution 3. (a) $T = f^2(2l)^2\mu = f^2(4l^2)(A\rho)$

$T \ = \ (247 \times 1.27)^2 (\pi \times 4 \times 10^{-8} \times 7800)$

$= \ 99.4 N$

PASSAGE 4

Read the following passage and answer the questions given at the end.

A geologist is in a 81 m deep mine. One end of a nylon rope is tied to a stationary support at the top of a vertical mine shaft. The rope is 80 m deep. The other end of the rope is tied to a box of mineral samples weighing 20 kg. The weight of the box keeps the rope taut. The mass of the rope is 2 kg. The geologist in the mine signals to his colleagues at the top by jerking the rope side-ways. A point on the rope vibrates with a transverse SHM of 2 Hz.

1. The speed of transverse waves on the rope is
   (a) 90 ms^{-1} (b) 88.5 ms^{-1}
   (c) 40 ms^{-1} (d) 60.6 ms^{-1}
   (e) none

2. The number of cycles in the rope's length is
   (a) 2 cycles   (b) 1.6 cycles
   (c) 1.42 cycle   (d) 1.81 cycles
   (e) none

Solution 1. (b) $v = \sqrt{\dfrac{T}{\mu}} = \sqrt{\dfrac{20g}{\frac{2}{80}}} = 88.5 \text{ ms}^{-1}$

Solution 2. (d) $\lambda = \dfrac{v}{f} = \dfrac{88.5}{2} = 44.2$

number of cycles $= \dfrac{L}{\lambda} = \dfrac{80}{44.2} = 1.81$

PASSAGE 5

Read the following passage and answer the questions given at the end.

The power, or loudness, of sound is measured on a scale of increases by a factor of 100 (= 10^2), the sound is called twice as loud and when it increases 10,000 (= 10^4) times it is called four times as loud. The exponent of ten is called a bel and one decible is one tenth of a bel. Zero decibel is chosen as the intensity of the slowest sound which is just audible or is on the threshold of hearing whereas the intensity of loudest sound is about 170 decibel.

1. Sound intensities above a level of nearly........... descibels produce a feeling of pain.
   (a) 60   (b) 120
   (c) 140   (d) 170

2. The intensity of ordinary conversation is rated as nearly
   (a) 10 decibel   (b) 25 decibel
   (c) 40 decibel   (d) 60 decibel

3. A sound of 60 decibel is.............times more intense than a sound of 40 decibel.
   (a) 20   (b) 100
   (c) 10^{20} (d) none of the above

Solution 1. (b)

Solution 2. (b)

Solution 3. (b)

Answers to Questions for Practice

1.	(c)	2.	(a)	3.	(d)	4.	(a)	5.	(d)	6.	(c)	7.	(b)
8.	(b)	9.	(b)	10.	(a)	11.	(b)	12.	(c)	13.	(b)	14.	(a)
15.	(b)	16.	(a)	17.	(d)	18.	(a)	19.	(b)	20.	(d)	21.	(d)
22.	(a)	23.	(d)	24.	(b)	25.	(d)	26.	(d)	27.	(b)	28.	(c)
29.	(b)	30.	(b)	31.	(c)	32.	(b)	33.	(b)	34.	(a)	35.	(c)
36.	(b)	37.	(d)	38.	(d)	39.	(b)	40.	(a)	41.	(d)	42.	(b)
43.	(b)	44.	(d)	45.	(c)	46.	(a)	47.	(d)	48.	(b)	49.	(d)
50.	(b)	51.	(c)	52.	(d)	53.	(c)	54.	(a)	55.	(c)	56.	(c)
57.	(b)	58.	(d)	59.	(b)	60.	(d)	61.	(d)	62.	(a)	63.	(b)
64.	(b)	65.	(b)	66.	(c)	67.	(c)	68.	(c)	69.	(b)	70.	(d)
71.	(c)	72.	(b)	73.	(b)	74.	(a)	75.	(b)	76.	(b)	77.	(b)
78.	(b)	79.	(a)	80.	(c)	81.	(b)	82.	(c)	83.	(b)	84.	(c)
85.	(d)	86.	(b)	87.	(c)	88.	(c)	89.	(c)	90.	(a)	91.	(d)
92.	(d)	93.	(d)	94.	(d)	95.	(d)	96.	(c)	97.	(a)	98.	(a)
99.	(c)	100.	(c)	101.	(a)	102.	(a)	103.	(d)	104.	(d)	105.	(a)
106.	(d)	107.	(a)	108.	(b)	109.	(c)	110.	(c)	111.	(a)	112.	(c)
113.	(c)	114.	(d)	115.	(d)	116.	(a)	117.	(b)	118.	(c)	119.	(c)
120.	(c)	121.	(c)	122.	(a)	123.	(b)	124.	(b)	125.	(d)	126.	(b)
127.	(a)	128.	(a)	129.	(c)	130.	(d)	131.	(d)	132.	(a)	133.	(d)
134.	(c)	135.	(c)										

EXPLANATION

48. (b) $\dfrac{\Delta f}{f} = \dfrac{v}{V}$ or $v = 320 \times \dfrac{2.5}{100} = 8 \text{ ms}^{-1}$.

58. (d) $\dfrac{\lambda}{2} = 0.1 \text{ cm}, v = f\lambda = 60 \ \pi\text{cms}^{-1}$.

62. (a) $\Delta x = 0.4 \text{ m}$,

$\phi = k\Delta x = \dfrac{2\pi}{3} = \sqrt{5^2 + 5^2 + 2 \times 5 \cos(2\pi/3)}$

$= 5$.

67. (c) $v_{\text{rms}} = v_{\text{sound}} \sqrt{\dfrac{3}{\gamma}}$.

68. (c) $x = \dfrac{vt}{2} = 340 \times \dfrac{3}{2} = 510 \text{ m}$.

88. (c) Number of antinodes $= (2n+1) = 2(3+1) = 7$.

112. (c) $P_0 = \dfrac{By_0\omega}{v}$ or $B = \dfrac{140}{\pi}$.

114. (d) $k = \dfrac{2\pi}{\lambda}$ differentiating $dk = \dfrac{-2\pi}{\lambda^2} d\lambda$

123. (b) $f \dfrac{9}{10} = 81$ or $f = 90 \text{ Hz}$.