Chapter = 08

WAVES

Wave: It is the mechanism by which energy is transferred from one place to another.
Types of waves: There are following types of waves
Mechanical waves: The waves which need material for their propagation are called mechanical waves. For example water waves, sound waves, string waves.
Electromagnetic waves: The waves which do not need material medium for their propagation are called electromagnetic waves. For example radio waves, light waves etc.
Matter waves: The waves which are associated with motion of particles are matter waves. For example motion of electron.
Progressive/travelling waves: The waves which transfer energy by moving away from the source of disturbance are called progressive or travelling waves. They have two types (i) transverse waves (ii) longitudinal waves.
Transverse waves: The waves in which particles of medium are perpendicular to direction of propagation of waves are called travelling waves. Waves produced in water and rope.
Longitudinal/compressional waves: The waves in which particles of medium are parallel to direction of propagation of waves are called longitudinal waves. For example sound waves.
Why sound waves are longitudinal in nature: Both types of waves can be set up in solids. In fluids, however, transverse wave die out very quickly and usually cannot produced at all. That's why, sound waves in air are longitudinal in nature.
Periodic waves: The waves which are produced by the continuous and rhythmic disturbances in medium are called periodic waves. For example waves in oscillating mass spring system.
Transverse periodic waves: The periodic waves in which the displacement of particles of medium is perpendicular to the direction of motion of waves are called transverse periodic waves.
Crest: The part of transverse waves which is above the mean level is called crest
Trough: The part of transverse wave which is below the mean level is called trough
Wavelength: The distance b/w two consecutive crest or two trough denoted by Greek letter λ is wavelength.
Amplitude: The maximum displacement of point in crest or trough of wave is called amplitude
Time period: The time for which a wave travel a distance of wavelength is called time period.
Frequency: The number of waves passing through a medium in one second is called frequency. f=1/T.
Speed of wave: The distance covered by a wave in 1 second is called speed of wave.
Prove that v=fλ:

$$\text{Speed} = \frac{\text{Distance covered by wave}}{\text{Time interval}}$$

$$v = \frac{\lambda}{T} = \lambda * \frac{1}{T} = \lambda f \quad \text{as } \frac{1}{T} = f$$

$$v = f\lambda$$

Phase angle of wave: $\varphi = \frac{2\pi x}{\lambda}$

Longitudinal/ Compressional periodic waves: The periodic waves in which particles of medium vibrate along the direction of motion of waves are called longitudinal periodic waves.

Derive Newton and Laplace formula for Speed of sound in air.

Speed of sound depends upon as $v = \sqrt{E/\rho}$

(i) Compressibility of medium
(ii) Inertia(density) of medium

Newton formula for speed of sound in air: Newton assumed that sound waves passing through air at constant temperature (isothermal process) so by using Boyle law, he calculated the formula for speed of sound

$P_1V_1 = P_2V_2$

When sound waves passes pressure increases and volume decreases so,

$PV = (P + \Delta P)(V - \Delta V)$

$PV = PV - P\Delta V + V\Delta P - \Delta P\Delta V$, As $\Delta P\Delta V$ is small quantity so it is neglected

$PV = PV - P\Delta V + V\Delta P$

$0 = -P\Delta V + V\Delta P$

$P\Delta\Delta = V\Delta\Delta$

$$P = \frac{\Delta P}{\Delta V / V} = \frac{\text{Stress}}{\text{Strain}} = E$$

$P = E$ putting in speed of sound formula $V = \sqrt{E/\rho}$ we get

$V = \sqrt{P/\rho}$, AT STP, $P = 1.01*10^5\ Nm^{-2}$, $\rho = 1.29\ kgm^{-3}$,

$V = \sqrt{1.01*10^5/1.29} = 280$ m/s. and experimental value of speed of sound is 332 m/s which is 16% more this.

Laplace correction: Laplace assumed that during compression and rarefaction temperature of system changes but during compression and rarefaction energy is transferred from one place to other due to fast response under adiabatic.

$PV^{\gamma} = \text{Constant}$ And $\gamma = Cp/Cv$ and for air $\gamma = 1.4$.

Process. In this case Boyle law becomes

$$PV^{\gamma} = (P + \Delta P)(V - \Delta V)^{\gamma}$$

$$PV^{\gamma} = (P + \Delta P)V^{\gamma}(1 - \frac{\Delta V}{V})^{\gamma}$$

$P = (P + \Delta P)(1 - \frac{\Delta V}{V})^{\gamma}$, now using bionomial expansion $(1 - x)^n = 1 - nx +$ higher power terms...

$$P = (P + \Delta P)(1 - \gamma\frac{\Delta V}{V} + ...)$$

$P = P - \gamma P\frac{\Delta V}{V} + \Delta P - \gamma\Delta P\frac{\Delta V}{V}$, neglecting $\gamma\gamma\Delta\ \frac{\Delta V}{V}$ due to small value

$$P = P - \gamma P\frac{\Delta V}{V} + \Delta P$$

$$\gamma P\frac{\Delta V}{V} = \Delta P$$

$$\gamma P = \frac{\Delta P}{\frac{\Delta V}{V}} = \frac{stress}{strain} = E$$

$\gamma P = E$ putting the formula of speed of sound in air $v = \sqrt{\frac{E}{\rho}}$

$v = \sqrt{\frac{\gamma P}{\rho}}$ This is the laplace formula for speed of sound in air.

$\gamma = 1.4$ $P = 1.01*10^5$ Pa, $\rho = 1.29\ kgm^{-3}$

$v = \sqrt{\frac{1.4*1.01*10^5}{1.29}} = 333$ m/s This is close to the experimental value of speed of sound.

Describe Effects of variation of pressure density and temperature on speed of sound in air.

Effect of pressure on speed of sound: Speed of sound remains same $v=\sqrt{\frac{\gamma P}{\rho}}$ as density is proportional to the pressure. When pressure of gas is increased, density of gas also increases.

Effect of density on speed of sound: As $v=\sqrt{\frac{\gamma P}{\rho}}$, so at constant temperature and pressure Speed of sound is inversely proportional to square root of density. $v \propto \frac{1}{\sqrt{\rho}}$.

Speed of sound is four time to its speed in oxygen as density of oxygen is 16 times as that of oxygen.

Effect of temperature on speed of sound: As when a gas is heated at constant pressure then its volume increased and density decreased so speed of sound increased due to increase of temperature. $v_t = v_o + 0.61t$.

The formula for ratio of speed at t°C and 0°C is $\frac{v_t}{v_o}=\sqrt{\frac{T}{T_o}}$

Prove that Vt=Vo+0.61t.

Using the formula For ratio of speed of sound at 0° C and t°C, The ratio of speed of sound

$$\frac{v_t}{v_o}=\sqrt{1+t/273}$$

$$\frac{v_t}{v_o}=\left(1+t/273\right)^{1/2}$$

$$v_t = v_o\left(1+t/273\right)^{1/2}, \text{ using bionomial expansion}$$

$$v_t = v_o\left(1+\frac{1}{2}t/273\right)$$

$$v_t = v_o + v_o t/546$$

$$v_t = v_o + 333t/546$$

$$v_t = v_o + 0.61t.$$

This shows that with one degree Celsius rise in temperature, speed of sound increased by 0.61 m/s.

State Principle of superposition. Define its three cases.

Principle of superposition. "If a particle of medium is simultaneously acted upon number of waves then the resultant displacement of particle is algebraic sum of their individual displacements" $Y = Y_1 + Y_2 + Y_3 + \ldots$..

Cases of superposition principle: There are following three cases of principle of superposition.

Interference: The phenomenon in which two waves having same frequency travelling in same direction

Beats: The phenomenon in which two waves of slightly different frequencies and travelling in same direction

Stationary waves: The phenomenon in which two waves of same frequency travelling in opposite direction.

What is Interference? Define constructive interference and destructive interference.

Interference: The phenomenon in which two waves having same frequency travelling in same direction superpose is called interference.

Constructive interference: when the path difference is an integral multiple of wavelength, displacement of two waves are added up $\Delta s = n\lambda$, this effect is called constructive interference

Destructive interference: when path difference is odd integral multiple of half of the wavelength, the displacement of two waves cancel the effect of each other. This effect is called destructive interference.
$\Delta s = (n+1/2)\lambda$.

What are Beats? Write its uses.

The phenomenon in which two waves of slightly different frequencies travelling in same direction overlap each other is called beats. f_1-f_2= no of beats per second.

Beats are the periodic vibration of sound b/w maximum and minimum loudness.

Beats are the result of constructive and destructive interference. It means basic principle of beats is interference.

If the frequency difference b/w two waves is greater than 10Hz, than it is difficult to recognize.

Uses of beats: there are following uses of beats

i. Beats produce variety in music
ii. To find unknown frequency of vibrating body
iii. To tune a musical instruments.

What is Reflection of waves? State two cases of reflection in media?

The bouncing back of wave from the boundary of medium is called reflection of waves..

i. When a wave in rare medium is incident on denser medium, it is reflected such that phase of 180° is produced(path difference of $\lambda/2$)
ii. If transverse wave in denser medium is incident on a rare medium is reflected without any change in phase(no path difference).

What are Stationary waves?

The waves which are produced by superposition of two waves of having same frequency travelling in opposite direction are called stationary waves.

Node: The points of zero displacement in stationary waves are called node

Antinode: The points of maximum displacement in stationary waves are called antinodes

The distance b/w two consecutive nodes and anti-nodes is **$\lambda/2$**. The distance b/w node and anti-node is **$\lambda/4$.**

When antinodes are at their extreme position the whole energy is P.E while at passing through equilibrium position, the whole energy is K.E.

Why stationary waves are called standing waves: As nodes remains at rest so the energy remains standing in medium b/w nodes so energy cannot flow through these points, that's why stationary waves are called standing waves.

What are stationary waves? Explain Stationary waves in a stretched string.

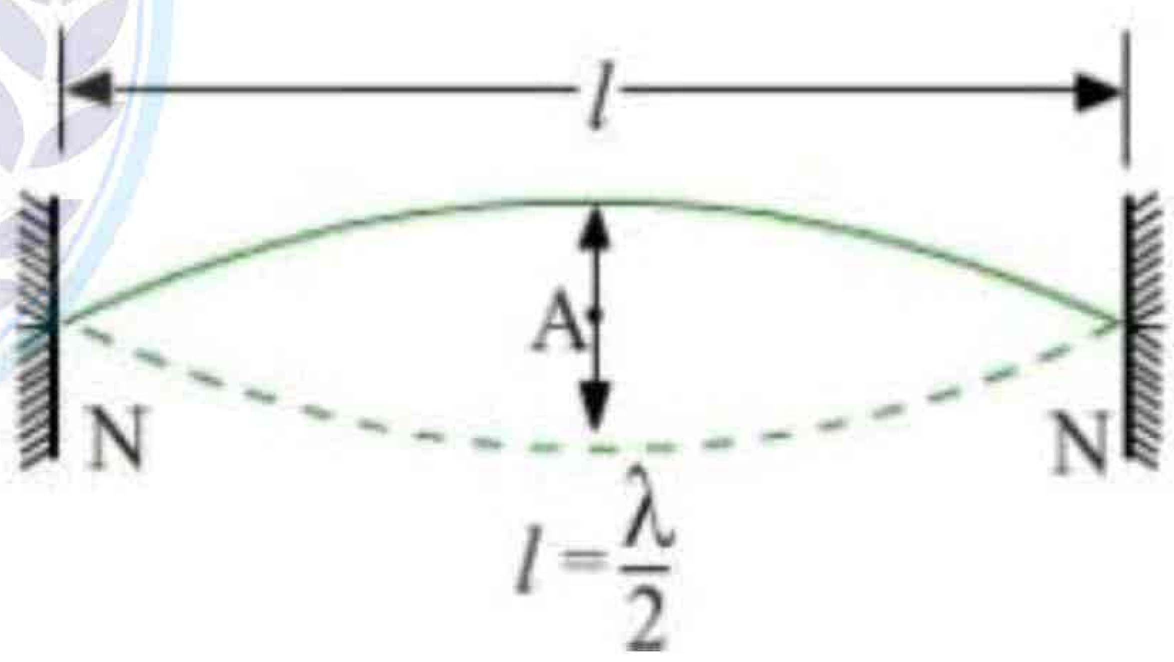
The waves which are produced by superposition of two waves of having same frequency travelling in opposite direction are called stationary waves.

Let us consider a string of length l stretched and is clamped at its two ends with rigid support. The tension in the string is F.

Speed of wave depends upon tension F in the string and mass per unit length $v = \sqrt{\frac{F}{m}}$.

<u>Case 01: First mode of vibration</u>: when the string is plucked at the middle of its length then string vibrates in a single loop as shown in fig. such a mode is called fundamental mode of vibration.

Distance b/w two consecutive nodes = l = $\lambda/2$



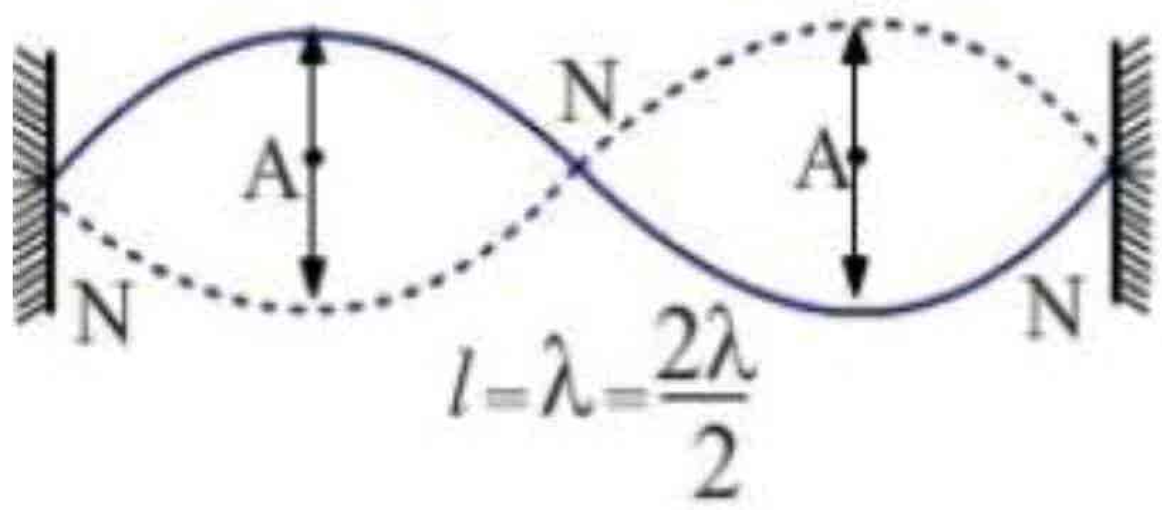
$$l = \frac{\lambda_1}{2} \Rightarrow \lambda_1 = 2l$$

$$\text{As speed of wave} = v = f_1\lambda_1$$

$$f_1 = \frac{v}{\lambda_1} = \frac{v}{2l}$$

$$f_1 = \frac{1}{2l}\sqrt{\frac{F}{m}}$$ This is the formula for fundamental frequency

<u>Case 02: second mode of vibration</u>: When the string is plucked from one quarter (1/4) of its length the string vibrates into two loops as shown in fig. f_2 is the frequency of 2^{nd} mode vibration.



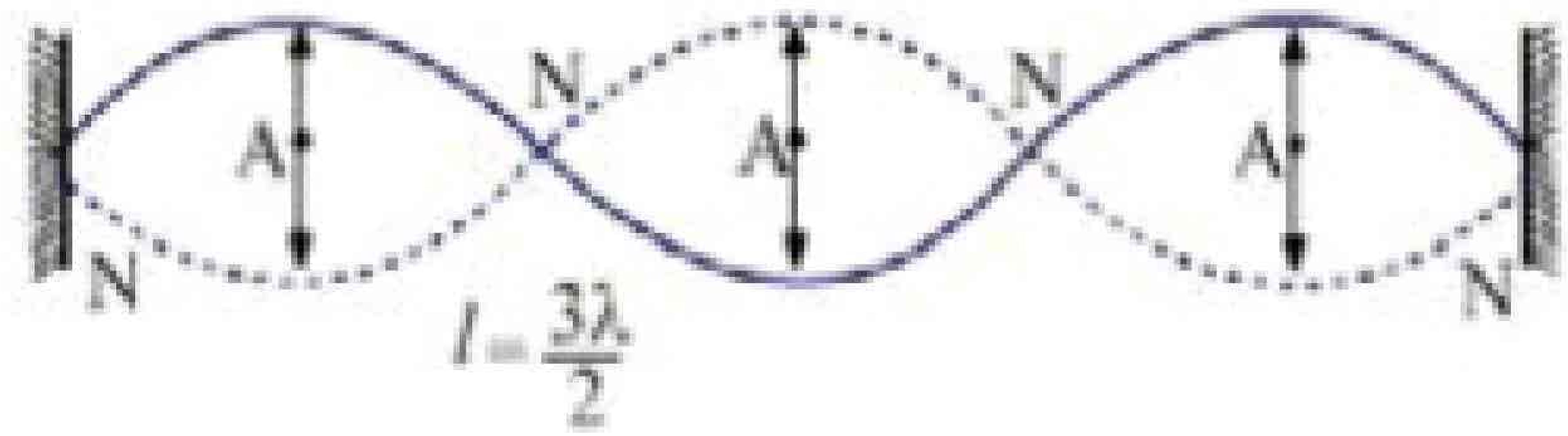
$$l=\frac{\lambda}{2}+\frac{\lambda}{2}$$

$$l=\lambda_2 \qquad \Rightarrow \lambda_2 = l$$

$$f_2=\frac{v}{\lambda_2}=\frac{1}{l}\sqrt{\frac{F}{m}}$$

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

$$f_2=2f_1$$



Thus when the string vibrates in two loops, its frequency becomes double then when it vibrates in one loop.
Similarly by plucking the string properly, it can be made to vibrate in 3 loops then
$f_3=3f_1$ and so on for nth loop
$f_n=nf_1$ $\qquad$ n=1,2,3…..
As these discrete and quantized value of frequencies f_1, $2f_1$, $3f_1$,….nf_1 which are called harmonic series.
If the frequency of string on musical instrument changes by changing the tension in string and length of string.

What are stationary waves? Explain Stationary waves in air column?

The waves which are produced by superposition of two waves of having same frequency travelling in opposite direction are called stationary waves.

<u>**Organ pipe**</u>: An organ pipe is a wind instrument in which sound is produced due to setting up of stationary waves in air column is called organ pipe.

Stationary waves can be set up in air column inside a pipe or tube. A common example of vibrating air column is an organ pipe.

It consists of a hollow long tube both ends open or with one end open and other is closed.

<u>**Case 01: Mode of vibration when both ends are open**</u>: Let us consider an organ pipe of length l which is open at both ends. In fundamental mode of vibration there is only one node at the middle of the pipe and two anti-nodes at ends. If λ1 is the wavelength of wave then

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

$$\lambda_1=2l$$

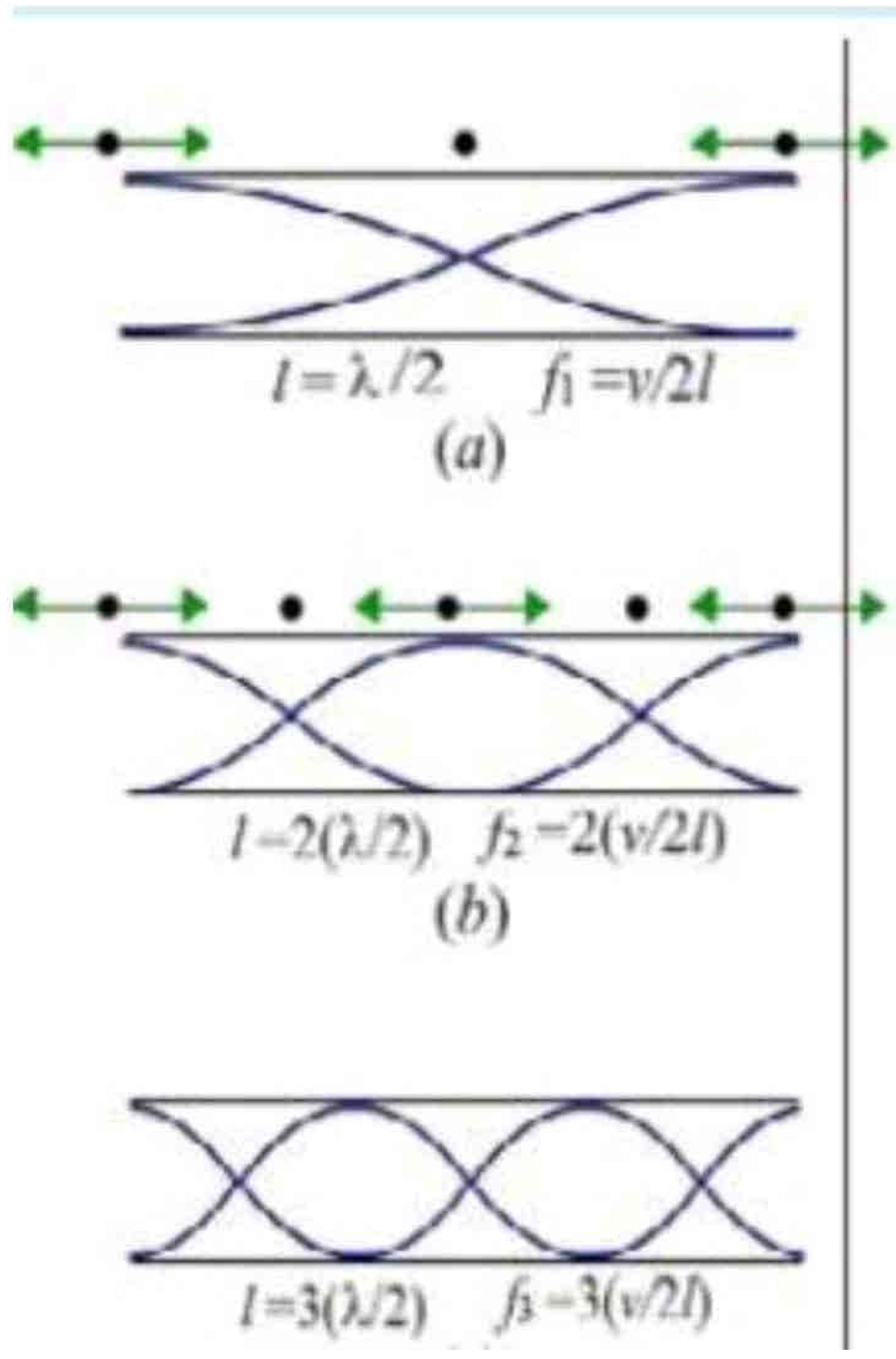
$$f_1=\frac{v}{\lambda_1}$$

$f_1=\frac{v}{2l}$ This frequency is called fundamental frequency or first harmonic

In second mode of vibration there are anti nodes and two nodes

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

$l=\lambda_2$ for 2nd mode of vibration



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

$$f_2=\frac{v}{l}=2*\frac{v}{2l}=2f1$$

$f_2=2f_1$ This frequency is for 2nd harmonic, and similarly for nth mode of vibration

$f_n=nf_1$ where n = 1,2,3....

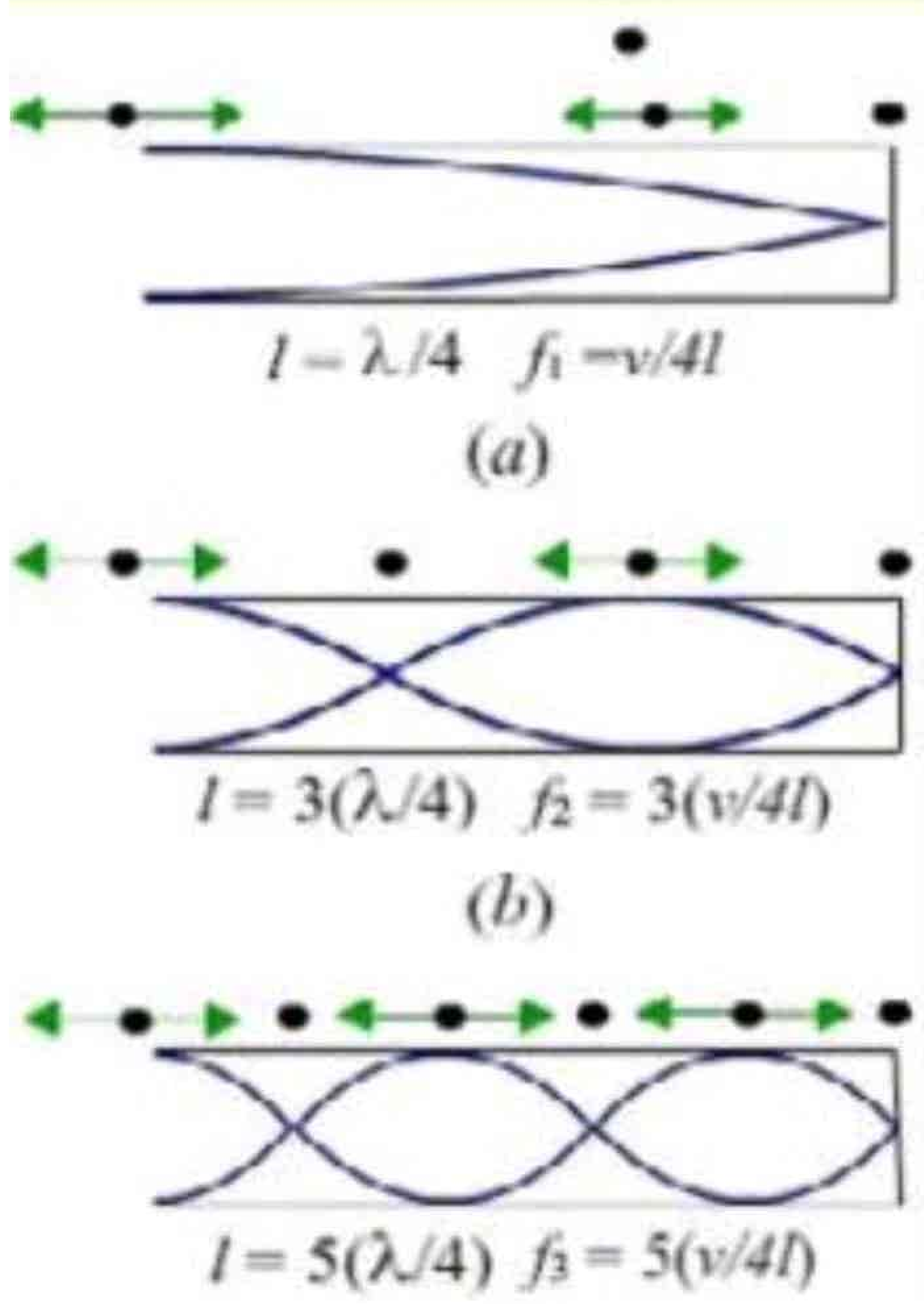
<u>**Case 02: Modes of vibration in organ pipe closed at one end**</u>**:** let us consider an organ pipe of length l which is closed at one end. At closed end we get

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

$$\lambda_1 = 4l$$

$$f_1 = \frac{v}{\lambda_1}$$

$$f_1 = \frac{v}{4l}$$ This is frequency for fundamental frequency



In second mode of vibration there are anti nodes and two nodes

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

$$l = \frac{3\lambda}{4}$$

$$\lambda_2 = 4l/3$$

$$f_2 = \frac{v}{4l/3} = 3\frac{v}{4l}$$

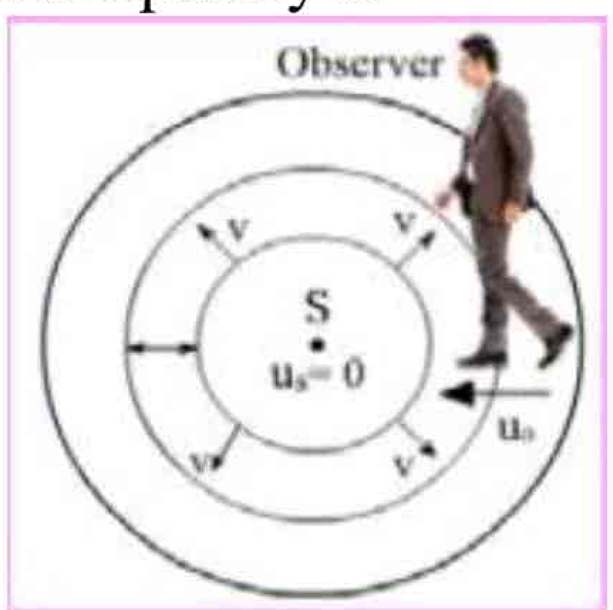
$f_2 = 3f_1$ This frequency is for 2nd harmonic, and similarly for nth mode of vibration

$f_n = nf_1$ n is odd

What is Doppler Effect. Explain its cases.

Definition: The apparent change in the frequency of waves due to relative motion b/w source and observer is called Doppler Effect. This effect was firstly observed by John Doppler while he was observing the frequency of light emitted from a star. In this topic we take the example of source of sound S and an observer O and their relative motion is studies

Case 01: When observer moves towards stationary source: Let us consider an observer A moves towards the source with velocity u_o then the relative velocity of waves and observer is v+ u_o. The relation for frequency is

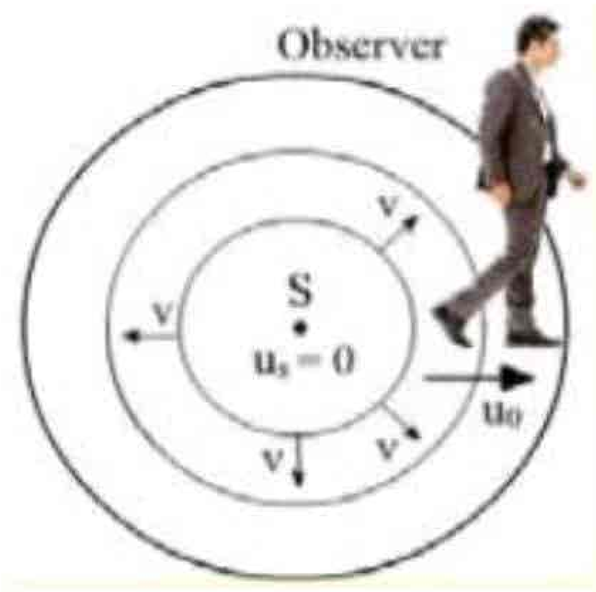


$$f_A = \left[\frac{v+u_o}{\lambda}\right] = \left[\frac{v+u_o}{v/f}\right]$$

$$f_A = \left[\frac{v+u_o}{v}\right]f \quad \text{as} \quad \left[\frac{v+u_o}{v}\right] > 1$$

$f_A > f$ Result : The apparent frequency/pitch of sound heared by observer will increase

Case 02: When observer moves away from the stationary source: Consider observer B moves away from the source with velocity uo then relative velocity of waves and observer v- u_o.



$$f_B = \left[\frac{v-u_o}{\lambda}\right] = \left[\frac{v-u_o}{v/f}\right]$$

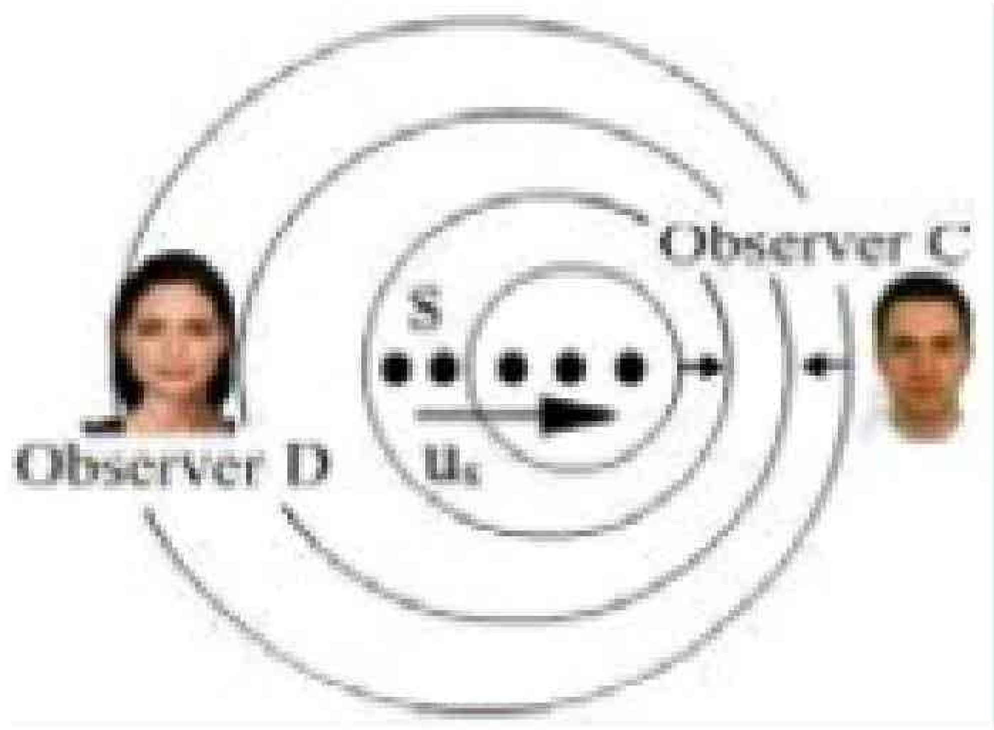
$$f_B = \left[\frac{v-u_o}{v}\right]f \quad \text{as} \quad \left[\frac{v-u_o}{v}\right] < 1$$

$f_B < f$ Result : The apparent frequency/pitch of sound heared by observer will decrease

Case03: When source moves towards the stationary observer: When source moves towards the stationary observer C with velocity then waves are compressed and wavelength is reduced , this decrease in wavelength in one second is called Dopper shift.and is calculated as follows

$$\lambda_c = \frac{v - u_s}{f} = \frac{v}{f} - \frac{u_s}{f}$$

$$\lambda_c = \lambda - \Delta\lambda \qquad \text{as } \Delta\lambda = \frac{u_s}{f} \text{ also we know that}$$



$$f_c = \frac{v}{\lambda_c} = \frac{v}{\frac{v-u_s}{f}}$$

$$f_c = \left[\frac{v}{v-u_s}\right] f \qquad \frac{v}{v-u_s} > 1$$

$f_c > f$ Result : Apparent frequency/pitch of sound heard by observer will increase

Case04: When source moves away from the stationary observer: When source moves away the stationary observer D with velocity then waves are expanded and wavelength is increased and is calculated as follows.

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

$$\lambda_D = \lambda + \Delta\lambda \qquad \text{as } \Delta\lambda = \frac{u_s}{f} \text{ also we know that}$$

$$f_D = \frac{v}{\lambda_D} = \frac{v}{\frac{v+u_s}{f}}$$

$$f_D = \left[\frac{v}{v+u_s}\right] f \qquad \frac{v}{v+u_s} < 1$$

$f_D < f$ Result : Apparent frequency/pitch of sound heard by observer will decrease.

Explain Applications of Doppler Effect.

There are following applications of Doppler Effect

1) **RADAR:** RADAR stands radio detection and ranging, it is a device which transmits and receives radio waves and used to find the height and speed of aero plane is called RADAR. The system emits radio waves which are reflected from aero plane and received by system.
2) **SONAR**: SONAR stands for sound navigation and ranging. It is technique for detecting the presence of objects under water by echo location. This system uses ultra sound waves because they travel longer distance in water.
3) **Speed of satellite:** Speed of satellite determined by sending EM waves from earth, when these waves are reflected back after striking with satellite, then these waves are received on earth. The value of Doppler shift in wavelength gives the speed of satellite.
4) **Speed of star:** Doppler effect can be used to calculate the speed of star w.r.t Earth. It is done by comparing the line spectrum of light coming from a distant star and the light emitted from lab source.

Blue shift: The frequency of light emitted by star increases (wavelength decreases) if it is moving towards the Earth as compared to light emitted.

Red shift: The frequency of light emitted by star decreases (the wavelength increases) if it is moving away (receding) from earth red shift.

5) **Speed of car:** Microwaves are emitted from a source in form of short bursts. Each burst is reflected back by any moving car, in their way the reflected bursts are detected and Doppler shift is observed and speed is calculated by computer program.

Uses of ultrasonic waves and high frequency radio waves: Ultrasonic waves are useful for undersea communication and detection systems. High frequency radio waves used in radar travel just a few centimeter in water. Whereas highly directional beams of ultrasonic waves can be made to travel many kilometers.

Range of hearing

Organisms	Frequencies(Hz)
Dolphin	150-150,000
Bat	1000-120,000
Cat	60-70,000
Dog	15-50,000
Human	20-20,000

Types of gas	γ
Monoatomic	1.67
Diatomic	1.40
Polyatomic	1.29

1) **What happens when a jet plane like Concorde flies faster than speed of sound? OR What is sonic boom?**

A conical surface of concentrated sound energy sweeps over the ground as a supersonic place passes overhead. It is known as sonic boom.

2) **Under what condition a standing wave pattern is formed?**

A standing wave pattern is formed when the length of string is an integral multiple of half wavelength, otherwise no standing wave is formed.

3) **What is primary driving mechanism in organ pipe**?

It is wavering. Sheet like jet of air from flute slit which interacts with the upper lip and air column in pipe to maintain a steady oscillation.

4) **How dolphin use echolocation?**

Echolocation allows the dolphins to detect small differences in the shape, size and thickness of objects.

5) **How Doppler Effect used to monitor blood flow?**

Doppler Effect can be used to monitor blood flow through major arteries. Ultrasound waves of frequencies 5MHz to 10MHz are directed towards the artery and receiver detects the back scattered signal.

6) **On which apparent frequency of blood flow depend**?

The apparent frequency depends on the velocity of flow of the blood.

7) **How bat navigate & find food**?

Bat navigate and find food by echolocation

Exercise Short Questions

1 .*What features do longitudinal waves have in common with transverse waves?*

1) In both waves, particles of the medium vibrate about their mean position. 2) Transport energy and momentum but not matter. 3) When propagate in a medium they obey, $v = f\lambda$

2. (a) trace B represents the loudest note. b) trace B represents the highest frequency**.**

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

No. It is not possible. For stationary waves two identical waves should travel in opposite direction along a string.

4.A wave is produced along a stretched string but some of its particles permanently show zero displacement. What type of wave is it?

Stationary wave. Here nodal points show permanently zero displacement.

5 Explain the terms crest, trough, node and antinode.

Crest: "The portion of a transverse wave above the mean level".

Trough: "The lower portion of transverse wave below the mean level".

Node: "The point of zero displacement in stationary waves" are called nodes

Antinode: "The point of maximum displacement on a stationary wave" are called anti nodes.

6. Why does sound travel faster in solids than in gases?

In the relation $v = \sqrt{E/\rho}$ Elastic modulus E is greater for solids than in gases. The effect of density, ρ is very less as compared to E. so sound travel faster in solids then in gases.

7. How are beats useful in tuning musical instruments?

A new instrument is tuned. The new, and standard musical instruments are sounded together, beats are produced. The frequency of the new instrument is made to change until the resonance occurs.

8. Correct answer is (iii) ($f_1 - f_2$)

Number of beats per second is equal to the difference between the frequencies of the tuning forks.

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

Sound waves travel faster in solids than in air. The sound waves produced by the explosion travel two paths. One through earth reaches faster than traveling through atmosphere. This accounts for the time difference.

10 ***Explain why travels sound faster in warm air than in cold air.***

$v \propto \sqrt{T}$ The speed of sound varies directly as the square root of absolute temperature. That's why sound travels faster in warm air than in cold air. As the temperature of air increases, the pressure increases and density decreases. So speed of sound increases.

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

If the relative velocity b/w source and observer is zero, there will no change in frequency of sound. For example when observer is at origin and source moves along the circumference of circle or both source and observer are moving in same direction with same velocity.

Numerical problems

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

$$\text{Given data: wavelength} = \lambda_1 = 1500\text{m}, f_1 = 2000KHz, f_2 = 1000KHz, \lambda_2 = ?, v = ?$$

$$sol: v = f_1\lambda_1 = 2000*10^3 x1500 = 30*10^8 \text{m/s}, \text{v} = \text{f}_2\lambda_2 \Rightarrow \lambda_2 = \frac{\text{v}}{\text{f}_2} = \frac{3*10^8}{1000*10^3} = 300m$$

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

$$\text{Given Data: frequency} = \text{f} = 344\text{ Hz}, \text{path diff} = \lambda = \text{S}_2\text{P} - \text{S}_1\text{P} = 5 - 4 = 1m, v = ?$$

$$sol: v = f\lambda = 344*1 = 344Hz$$

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

$$\text{Given Data: length of string} = \text{l} = 120\text{cm} = 120/100 = 1.2\text{m}, \text{ n} = 4, \text{ f}_4 = 120\text{ Hz}, \lambda = ?, \text{f}_1 = ?$$

$$\text{sol}: \lambda = \text{l}/2 = 1.2/2 = 0.6\text{m}, \quad \text{f}_n = \text{nf}_1 \Rightarrow \text{f}_4 = \text{nf}_1 \Rightarrow \text{f}_1 = \frac{\text{f}_4}{n} = \frac{120}{4} = 30Hz$$

8.4: The frequency of the note emitted by a stretched string is 300 Hz. What will be the frequency of this note when; (a) the length of the wave is reduced by one-third without changing the tension. (b) The tension is increased by one-third without changing the length of the wire.

$$\text{(a) f} = 300, \text{f} = ? \text{ when wavlength is reduced by one third}$$

$$v = f\lambda ---(1), v = f'(\lambda - \lambda/3) = 2f'\lambda/3 -----(2) \text{ comparing both (1) \& (2)}$$

$$\text{f}\lambda = 2\text{f}'\lambda/3 \Rightarrow \text{f} = 2\text{f}'/3 \Rightarrow \text{f}' = 3\text{f}/2 = 3*300/2 = 450\text{ Hz}$$

$$\text{(b) f} = \frac{1}{2\text{l}}\sqrt{\frac{\text{F}}{\text{m}}} ----(1), \text{f}' = \frac{1}{2\text{l}}\sqrt{\frac{\text{F}+\text{F}/3}{\text{m}}} = \text{f}' = \frac{1}{2\text{l}}\sqrt{\frac{4\text{F}/3}{\text{m}}} ----(2) \text{dividing both eq}$$

$$\frac{\text{f}'}{\text{f}} = \frac{\frac{1}{2\text{l}}\sqrt{\frac{4\text{F}/3}{\text{m}}}}{\frac{1}{2\text{l}}\sqrt{\frac{\text{F}}{\text{m}}}} \Rightarrow \text{f}' = \sqrt{\frac{4}{3}}f = \sqrt{\frac{4}{3}}*300 = 346Hz$$

8.5: An organ pipe has a length of 50 cm. Find the frequency of its fundamental note and the next harmonic when it is (a) Open at both ends. (b) Closed at one end. $(Speed\ of\ sound = 340ms^{-1})$.

length of pipe $= l = 50cm = 50/100m = 0.5m$, $v = 350$ m/s, fundamental frequencies in both cases = ?

(a) when pipe is open at both ends: $f_n = \frac{nv}{2l}, f_1 = \frac{(1)(350)}{2(0.5)} = 350Hz, f_2 = \frac{(2)(350)}{2(0.5)} = 700Hz$

(a) when pipe is closed at one end: $f_n = \frac{nv}{4l}, f_1 = \frac{(1)(350)}{4(0.5)} = 175Hz, f_2 = \frac{(3)(350)}{4(0.5)} = 525Hz$

8.6: A church organ consists of pipes, each open at one end, of different lengths. The minimum length is 30 mm and the longest is 4 m. calculate the frequency range of the fundamental notes $(Speed\ of\ sound = 340ms^{-1})$

given data: $l_{min} = 30mm = 30*10^{-3}m$, $l_{max} = 4m$, $v = 340$ m/s, $f_{min} = ?$, $f_{max} = ?$

$$f_{max} = \frac{nv}{4l_{min}} = \frac{1*340}{4*30*10^{-3}} = 2833Hz, f_{min} = \frac{nv}{4l_{max}} = \frac{1*340}{4*4} = 21.25Hz$$

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

Given Data: $f_1 = 256$ Hz, beat frequency before load wax = 3Hz, Beat f after loading = 1Hz, $f_2 = ?$

$f_1 - f_2 = \pm n \Rightarrow f_2 = f_1 \pm n = 256 \pm 3 = 259Hz$ or $253Hz$, As the no. of beats per sec decrease on loading first fork is one so correct answer is 253Hz

8.8: Two cars P and Q are travelling along a motorway in the same direction. The leading car travels at a steady speed of 12ms-1; the other car Q, travelling at a steady speed of 20 ms-1, sound its horn to emit a steady note which P's driver estimates, has a frequency of 830 Hz. What frequency does Q's own driver hear? $(Speed\ of\ sound = 340ms^{-1})$.

given data: speed of car $= v_p = 12m/s$, $u_Q = 20m/s$, $v = 340$ m/s, $f_p = 830$ Hz, $f_Q = ?$

$$u_s = u_Q - u_p = 20 - 12 = 8m/s, \Rightarrow f' = (\frac{v}{v - u_s})f \Rightarrow 830 = (\frac{340}{340 - 8})f \Rightarrow f = 810.5Hz$$

Multiple choice questions

1) Which waves are particularly useful for undersea communication an detection system?

a) Ultra sonic waves	b) Micro waves	c) Radio waves	d) Sound waves

2) High frequency radio waves travel --- in water

a) Few meter	**b) Few centimeter**	c) Few kilometer	d) Few milli meter

3) Highly directional beam of ultrasonic waves can be mad to travel

a) Few meter	b) Milli meter	**c) Many kilo meter**	d) None

4) Speed of sound in lead at 20°C

a) 1320 m/s	b) 3600 m/s	c) 5100 m/s	d) 5130 m/s

5) Speed of sound in copper at 20°C

a) 1320 m/s	**b) 3600 m/s**	c) 5100 m/s	d) 5130 m/s

6) Speed of sound in aluminum at 20°C

a) 1320 m/s	b) 3600 m/s	**c) 5100 m/s**	d) 5130 m/s

7) Speed of sound in iron at 20°C

a) 1320 m/s	b) 3600 m/s	c) 5100 m/s	**d) 5130 m/s**

8) Speed of sound in glass at 20°C

a) 5100 m/s	**b) 5500 m/s**	c) 5130 m/s	d) 3600 m/s

9) Speed of sound in methanol at 20°C

a) 1320 m/s	b) 3600 m/s	c) 5100 m/s	**d) 1120 m/s**

10) Speed of sound in water at 20°C

a) 1320 m/s	**b) 1483 m/s**	c) 5100 m/s	d) 5130 m/s

11) Speed of sound in CO_2 at STP

a) 258 m/s	b) 315 m/s	c) 332 m/s	d) 972 m/s

12) Speed of sound in oxygen at STP

a) 315 m/s	b) 332 m/s	c) 333m/s	d) 345 m/s

13) Speed of sound in helium at STP

a) 258 ms	b) 315 m/s	**c) 972 m/s**	d) 1286 m/s

14) Speed of sound in hydrogen at STP

a) 258 ms	b) 315 m/s	c) 972 m/s	**d) 1286 m/s**

15) Range of hearing for dolphin is(Hz)

a) 150-150,000	b) 1000-120,000	c) 60-70,000	d) 15-50,000

16) Range of hearing for bat is(Hz)

a) 150-150,000	**b) 1000-120,000**	c) 60-70,000	d) 15-50,000

17) Range of hearing for cat is(Hz)

a) 150-150,000	b) 1000-120,000	**c) 60-70,000**	d) 15-50,000

18) Range of hearing for dog is(Hz)

a) 150-150,000	b) 1000-120,000	c) 60-70,000	**d) 15-50,000**

19) Range of hearing for human is(Hz)

a) 150-150,000	b) 1000-120,000	c) 60-70,000	**d) 20-20,000**

20) Which waves cause the candle flame to flicker

a) Light waves	**b) Sound waves**	c) Heat waves	d) None

21) A conical surface of concentrated sound energy sweeps over the ground as supersonic place passes overhead is known as

a) Beats	b) Echo	**c) Sonic beam**	d) Doppler shift

22) A standing/stationary wave pattern is formed when the length of string is an integral multiple of--

a) Half wavelength	b) Wavelength	c) Double wavelength	d) One fourth wavelength

23) In organ primary driving mechanism is

a) Beats	b) Stationary waves	c) Sound waves	**d) Wavering**

24) Which allow the dolphin to detect small differences in the shape, size and thickness of objects?

a) Beats	b) Sound waves	**c) Echo location**	d) None

25) Doppler effect can be used to monitor blood flow through major arteries in which ultrasound of frequencies are directed toward the artery and receiver detect the back scattered signal

a) 5 MHz to 10 MHz	b) 5 KHz to 10 KHz	c) 5 Hz to 10 Hz	d) 5 GHz to 10 GHz

26) The apparent frequency in artery of blood flow depends upon

a) Velocity of flow of blood	b) Shape of flow of blood	c) Size of flow of blood	d) None

27) --- is used in radar to detect the motion of an aero plane

a) Frequency shift	b) Wave shift	c) Nature of medium	d) Shape of medium

28) Bats navigate and find food by

a) Echo location	b) Shape of flow of blood	c) Size of flow of blood	d) None

Previous all Punjab Board Exams Solved MCQs

	Questions	Option A	Option B	Option C	Option D
1)	The distance between compression and adjacent rarefaction	**λ/2**	λ/4	λ	2λ
2)	A 2m long pipe is open at both ends. What is its harmonic frequency?	42.5 Hz	220 Hz.	**85 Hz**	None of these.
Put L=2m, v=340, n=1 in formula to get the result	f=nv/2L= 1*340/2*2=340/4=85 Hz				
3)	A standing wave pattern is formed when the length of string is an integral multiple of __________ wavelength.	Triple	**Half**	Full	Double
4)	Transverse waves cannot be setup in	Metals	**Fluids**	Solids	Soil
	Because there is no mechanism for driving motion perpendicular to the propagation of wave				
5)	The error in the speed of sound calculated by Newton at S.T.P is about	14%	15%	**16%**	17%
6)	Speed of the waves is equal to:	fλ	λ/T	λT	**Both A and B**
7)	What is it that we use to calculate the speeds of distant stars and galaxies?	**Doppler Effect**	Beats	Interference	All of the above
8)	The profile of periodic waves generatred by a source executing SHM is represented by	**Sine wave**	Circle	Tangent wave	Cosine wave
9)	If the pressure of gas is doubled then speed of sound	Is doubled	Is half	**Is not affected**	Becomes four times
10)	Two sound waves having the same amplitudes are moving in the same direction are out of phase. The amplitude of the resultant wave is	**Zero amplitude**	Difference of the amplitudes of the two waves	The sum of amplitude of the two waves	Double the amplitude of either wave
11)	On increasing the tension, the frequency of vibration is	**Increases**	Decreased	Remains same	None of these
12)	A source 'Y' of unknown frequency produces 4 beats with a source of 240 Hz and 8 beats with a sound of 252 Hz. Frequency of the source 'Y' is	**244 Hz** Apply beats formula to get result as 252-8=244 Hz with y source	248 Hz	236 Hz	246 Hz
13)	The wavelength of fundamental node of vibration of both end closed pipe of length l is	l	l/2	**2l**	4l
14)	The spectrum of a star's light is measured and the wavelength of one of the lines as the sodium's line is found to be 589 nm. The same line has the wavelength of 497 nm when observed in the laboratory. This means the star is	**Moving away from the earth** By applying Doppler shift relation	Stationary	Moving towards the north	Revolving around the planet
15)	A source of sound wave emits waves of frequency 'f'. If 'v' is speed of sound waves, then what will be the wavelength of the waves	$\frac{v}{f}$ **ans**	vf	$\frac{v + u_o}{f}$	$(v - u_o)f$
16)	An organ pipe closed at one end has a length of 25 cm. Wavelength of the fundamental note is	25 cm	**100 cm** λ=4L=4*25=100cm	50 cm	75 cm
17)	Speed of sound has maximum value in	Oxygen	**Hydrogen**	Helium	Air
18)	The distance between two consecutive anti node is	**λ/2**	λ/4	λ	2λ
19)	If 332 waves pass through a medium in one second with speed of 332 m/s, then wavelength is	**1 m**	7 m	332 m	664 m
	As we know that frequency is no of waves passes in one second so f=332 Hz, v=332 m/s, λ=v/f=332/332=1m				
20)	Louder the sound, the greater will be its	**Amplitude**	Wavelength	Speed	Frequency

21)	A metallic wire of length 2m hooked between two points has tension 10N. If mass per unit length is 0.004 kg/m, their fundamental frequency emitted by wire on vibration is	48 Hz	6.25 Hz	24 Hz	**12.5 Hz** apply formula for fundamental frequency of vibration
22)	Beats are used to find	**Frequency**	Wavelength	Speed	Intensity
23)	Speed of sound in air depends upon	Temperature	Density	Humidity	**All of these**
24)	Which one of these media both transfer longitudinal and transverse waves?	**Solid**	Liquid	Gas	Plasma
25)	Audible frequency range for younger person is	20-200 Hz	20-2000 Hz	**20-20000 Hz**	2000-20000Hz
26)	For same mass and length if tension of vibrating string is four times then speed of wave increase by	**2 times**	4 times	6 times	8 times
Speed of wave is directly proportional to sq.rt of tension					
27)	Beats are easily detectable upto frequency upto two frequency difference between two sounds	2 Hz	6Hz	**10 Hz**	32 Hz
28)	The velocity of sound is maximum at 20°C in	Lead	Copper	**Glass**	Iron
29)	Which one is correct relation for one end closed pipe fn=?	2l/n	4l/n	nv/l	**nv/4l**
30)	Speed of sound at t^oC is given by	**Vt=v0+0.61t**	V0=vt+0.61t	Vt=0.61t	Vt=280+0.61t
31)	Distance between crest and trough is	λ	λ/2	**λ/4**	2λ
32)	Speed of sound at 2^oC is given as at 0^oC is 332 m/s	**333.2 m/s**	33 m/s	335 m/s	232 m/s
As Vt=Vo+0.61t, put Vo=332, t=2, Vt=332+0.61*2=332+1.2=333.2 m/s					
33)	Stationary waves are generated on string of length l its fundamental frequency is given by	$f_1 = v/l$	$f_1 = 2v/l$	**$f_1 = v/2l$**	$f_1 = v2l$
34)	Two identical tuning fork vibrating simultaneously, the number of beats per second is equal to	**Zero**	One	Two	Three
35)	Sound waves can only travel through	Vaccume	Ether	**Material medium**	Non metals
36)	Laplace formula for velocity of air	$v = \sqrt{\frac{P}{\rho}}$	**$v = \sqrt{\frac{\gamma P}{\rho}}$**	$v = \sqrt{\frac{\gamma}{\rho}}$	None of these
37)	In stationary waves, particle velocity at node is	Maximum	Minimum	**Zero**	Medium
38)	Longitudinal waves do not show	Reflection	Diffraction	Refraction	**Polarization**
39)	Speed of sound is greater in solids then in gases due to high value of	Density	Pressure	**Elasticity**	All of these
40)	When two note of f1 and f2 and f1>f2 then frequency of beat is	**f_1-f_2**	f_2-f_1	½ (f_1-f_2)	½ (f_2-f_1)
41)	How much velocity of sound changes when rise of 1^oC temp	0.61 cm/sec	**0.61 m/s**	61 m/s	6.1 m/s
42)	Speed of sound at 20^oC is given as at 0^oC is 332 m/s	348.2 m/s	**344.2 m/s**	340m/s	348 m/s
As Vt=Vo+0.61t, put Vo=332, t=20, Vt=332+0.61*20=332+12.2=344.2 m/s					
43)	Number of node between two consecutive anti node is	**1**	2	3	0
44)	Periodic alternation between sound of maximum and minimum loudness is called	Destructive interference	**Beats**	Reflection	Diffraction

45)	The frequency of vibration for nth mode of vibration for stationary longitudinal waves in a pipe open at both ends	$fn = \frac{nv}{4l}$	**$fn = \frac{nv}{2l}$**	$fn = \frac{2l}{nv}$	$fn = \frac{4l}{nv}$
46)	The waves which propagate by the oscillation of material particle are called	**Matter waves**	Magnetic waves	EM waves	Mechanical waves
47)	To monitor blood flow ultrasonic waves of frequency are used	**5MHz to 10 MHz**	25MHz to 30 MHz	9MHZ to 90MHz	20MHz to 200MHz
48)	Density is increased four times then speed of sound	Increase four times	**Decrease two times**	Decrease four times	Remains same
49)	The portion of wave below the mean level is	Crest	**Trough**	Node	Anti-node
50)	When a transverse waves is reflected on going from a denser medium to a rare medium then	There is 180^o phase shift	**There is no change in phase**	A crest is covered with trough	A trough is covered into crest
51)	A set of frequencies which is the multiple of fundamental frequency is called	Beat frequency	**Harmonics**	Doppler frequencies	Nodal frequencies
52)	The ratio Cp/Cv for diatomic gas is	1.67	1.5	**1.4**	1.29
53)	The waves which donot require any medium for their propogation	Mechanical waves	Matter waves	**EM waves**	Compressional waves
54)	When a star is receding the earth it show	Blue shift	**Red shift**	Green shift	Yellow shift
55)	The louder the sound, greater will be	Speed	**Amplitude**	Frequency	Wavelength
56	Speed of sound is independent of	**Pressure**	Density	Temperature	All of these
57)	The point of maximum displacement on a stationary wave is called	Node	**Anti-node**	Crest	Trough
58)	Speed of sound in vacuum is	332 m/s	340 m/s	**0 m/s**	1000 m/s
59)	Star moving away from the earth shows	**Red shift**	Blue shift	Doppler shift	Frequency shift
60)	A mechanical wave is represented by	Light	Sound	**Compressional wave**	Heat
61)	The fixed ends of a vibrating string are	Anti-node	**Node**	Over tones	Neither node nor anti node
62)	The distance b/w 1st node and 4th anti node is	**7λ/4**	5λ/4	13λ/4	11λ/4
	As distance b/w two consecutive node and anti node is λ/4 so distance from 1st node to 4th anti node is				
63)	The string of length l fixed at both ends is vibrating in two segments the wavelength of wave is	**l**	2l	l/4	4l
64)	When two identical wave move in the same direction they give rise to	Standing wave	**Interference**	Beats	None of these
65)	A stretched string 4m long and it has 4 loops of stationary wave. Wavelength	1m	**2 m**	3 m	4m
	As for 4 loops l=2λ so λ=l/2=4/2=2m				
66)	Theory of waves used in "Sonar" are	EM waves	Matter waves	Water waves	**Sound waves**
67)	With rise of temperature the velocity of sound	Decrease	**Increase**	Remains constant	Becomes zero
68)	The wavelength of stationary waves produced in a string of length l in first mode of vibration will equal	l/2	L	**2l**	l/4
69)	Two waves having same frequency and travelling in opposite direction will produce	**Stationary waves**	Constructive interference	Destructive interference	Beats
70)	At the open end of an organ pipe	Nodes are formed	**Anti-nodes are formed**	Both node and anti-node formed	Neither anti node nor node formed
71)	A stationary wave is established in a string which vibrates in four segments at	15Hz	**30 Hz**	60 Hz	480Hz

	a frequency of 120Hz, its fundamental frequency is				
As $f_n=nf_1$, $120=4f_1$, $f_1=120/4=30$ Hz					
72)	Which EM waves are used as medium in satellite communication system	**Micro waves**	Radio waves	Infra-red waves	Ultra violet waves
73)	The portion of wave above mean level is	**Crest**	Trough	Node	Anti-node
74)	The location of submarines can be detected by	**Doppler effect**	Temperature effect	Diffraction	Compton effect
75)	Sound waves cannot be	Reflected	Refracted	**Polarized**	Diffracted
76)	Radar system is an application of	Interference	Beats	Stationary waves	**Doppler effect**
77)	Sound waves cannot travel through	Air	Water	Material medium	**Vaccum**
78)	The speed of sound in air would become double then its speed at 20°C at	313°C	586°C	1172°C	**899°C**
For explanation see exp no 8.1, T=20°C=20+273=293K by using short formula Vt=factor^2*given temperature =2^2*293=1172K again conversion into centigrade, 1172-273=899°C					
79)	Two fork of frequencies 260Hz and 257 Hz are sounded together, number of beats per second is	Zero	4	**3**	257
No of beats=f1-f2=260-257=3					
80)	Car A has siren sounding a note of 540Hz. A listener in car B has 544 Hz move in same direction one conclude that	B lead A and moves faster	B is behind A and moves slower	Both moves with same speed	**B lead A and moves slower**
81)	Two waves can interfere only if they have	**Phase coherence**	Same velocity	Different frequencies	Different wavelength
82)	On reflection from denser medium light wave undergoes a phase change of	π radian	**2π radian**	3 π/2 radian	π/2 radian
83)	The stationary waves consist of	Crest and trough	Compression and elongations	**Nodes and anti-node**	Reflection and rarefaction
84)	The pitch of sound depends upon	Intensity of sound	Loudness of sound	Wavelength of sound	**Frequency of sound**
85)	In order to produce beats, the two waves should have	Same amplitude	Slightly different amplitude	The same frequency	**Slightly different frequencies**
86)	When a wave is reflected from the denser medium then phase of wave changes by	0°	90°	**180°**	270°
87)	A star is moving towards earth show	**Blue shift**	Violet shift	Red shift	White shift
88)	The basic principle of beats is	**Interference**	Reflection	Diffraction	Refraction
89)	Newton calculated the value of speed of sound in air?	332 m/s	340 m/s	350 m/s	**280 m/s**
90)	Speed of sound is greatest in	Air	**Steel**	Ammonia	Water
91)	The distance covered by wave in 1 second	Wavelength	Wave number	Frequency	**Wave speed**
92)	Tuning fork is a source of	Energy	Heat	Light	**Sound**
93)	Longitudinal waves are also known as	Stationary waves	Transverse waves	**Compressional waves**	Electro Magnet waves
94)	The value of "γ for monoatomic	**1.67**	1.40	1.29	1
95)	Half wavelength corresponds to	0°	90°	**180°**	360°
96)	Sound travels faster in	CO_2	**H_2**	O_2	He
97)	What is the value of β in expression? $Vt = Vo + \beta t$	273	1/273	**0.61**	1.42

98)	The apparent change in the pitch of sound due to relative motion is called	Carnot theorem	Interference	**Doppler effect**	Beats
99)	Tuning fork is a source of	Energy	Heat	Light	**Sound**
100)	Speed of sound in hydrogen is higher than oxygen is	1	2	3	**4**
101)	A spectator watching a cricket match sees the bat striking the ball and hears the sound this about half sec later due to light wave and sound waves difference of	Amplitude	Intensity	Frequency	**Speed**
102)	If 20 waves are passing through a medium in 1 sec with speed 20 m/s, the wavelength is	0.5 m	**1 m**	20m	2m
	Time period=time/no of vib=1/20 then λ=vT=20*1/20=1 m				
103)	A standing wave pattern is formed when length of string is	**Integral multiple of half wave length**	Integral multiple of full wavelength	Both A and B	None
104)	In organ pipe,primary driving mechanism	Slattering	**Wavering**	Fighting	Vibrating
105)	Sound waves are	Electromagnetic Waves	**Compressional waves**	Transverse waves	Matter waves
106)	The speed of sound at 40°C is if at 0°C is 332 m/s	340.6 m/s	346.6 m/s	**356.4 m/s**	332 m/s
	As Vt=Vo+0.61t, put Vo=332, t=40, Vt=332+0.61*40=332+24.4=356.4 m/s				
107)	If a stretched string vibrates in three loops, the relation b/w its length and wavelength of stationary wave is	$l = \frac{\lambda}{3}$	$l = \frac{2\lambda}{3}$	**$l = \frac{3\lambda}{2}$**	$l = 3\lambda$
	$L = \frac{\lambda}{2} + \frac{\lambda}{2} + \frac{\lambda}{2} = 3\frac{\lambda}{2}$				