Wave Motion

7.0 Indroduction :

Q.l. What is wave motion?

Ans:

i. *A wave motion is a periodic or oscillatory disturbance in a medium which is propagated from One place to another with a finite speed.*

ii. In wave motion, energy is propagated without transport of matter.

Q.2. What is wave? State different types of waves with examples.

Ans:

i. *An oscillatory disturbance which propagates energy through a material medium without migration of particles is called wave.*

Example: Sound wave, light wave, water wave, string wave, etc.

ii. There are two types of waves.

a. Electromagnetic wave:

Waves which do not require material medium for their propagation are called electromagnetic waves. Electromagnetic waves consist of oscillating electric and magnetic fields.

Example: Light waves, ultravoilet waves, radio waves, etc.

b. Mechanical wave:

Waves which require material medium for their propagation are called mechanical waves.

OR

An oscillatory disturbance travelling through a medium without change of form is called mechanical waves.

Example:Sound wave, water wave, string wave, etc.

Q.3. Define transverse waves. State its characteristics.

Ans: Definition:

The waves in which particles of the medium vibrate in a direction perpendicular to the direction of propagation of waves are called transverse waves.

Example: Water waves, light waves etc.

Characteristics of transverse wave:

i. When transverse wave passes through the medium, the medium is divided into alternate crests and troughs.

ii. A crest and an adjacent trough form a transverse wave. The distance between any two successive crest or trough is called wavelength of the wave.

iii. Crests and troughs advance in the medium and are responsible for transfer of energy.

iv. When transverse waves advance through a medium, there is no change of pressure and density at any point of the medium.

Q.4. Define longitudinal waves. State the characteristics of longitudinal waves.

Ans: Definition:

The waves in which the particles of the medium vibrate in a direction parallel to the direction of propagation of waves are called longitudinal waves.

Example: Sound wave, spring wave, etc.
Characteristics of longitudinal waves:

i. When longitudinal wave passes through a medium, the medium is divided into alternate compressions and rarefactions.

ii. A compression and adjacent rarefaction form a longitudinal wave. The distance between any two successive compression or rarefactions is called wavelength of the wave.

iii. For propagation of longitudinal waves, the medium should possess the property of elasticity of volume. So the longitudinal waves can travel through solids, liquids and gases.

iv. Longitudinal waves cannot travel through vacuum or empty space.

v. The compressions and rarefactions advance in the medium and are responsible for transfer of energy.

Q.5. Define amplitude and period of a wave.

Ans: Amplitude:

The maximum displacement of any particle from its mean position is called amplitude of the wave.

It is denoted by A and is measured in metre.
Period:

The time taken for any particle to complete one vibration is called period of the wave.

It is denoted by T and is measured in second.

Q.6. Define:

i. Frequency ii. Wavelength

Ans:

i. Frequency (n):

The number of vibrations performed per second by a particle of the medium is calledfrequency of the wave.

OR

The number of waves that pass per unit time across a given point of the medium is called frequency of the wave.

It is given by, $n = \frac{1}{T}$

Unit: Hz in SI system

Dimensions: $[M^0L^0T^{-1}]$

ii. Wavelength (l):

The distance between two consecutive particles of the medium which are in the same phase or which differ in phase by 2p is called wavelength of the wave.

Unit: m in SI system and cm in CGS system.

Dimensions: [M⁰L’T°]

Q.7. What is wave velocity ?

Ans:

i. The distance travelled by a wave in one second is called wave velocity.

ii. Unit: m/s in SI system and cm/s in CGS system.

iii. Dimensions: $[M°L^{1r}T^{1}]$

***Q.8. Obtain the relation between wave velocity ‘v’, wavelength ‘A,’ and frequency ‘n’ of a wave.**

Ans: Relation between v, l and n:

Velocity of wave is given by,

$$v = \frac{\text{Displacment}}{\text{Time}}$$

\ $v = \frac{1}{T}$ But $\frac{1}{T} = n$

\ v = nl

Q.9. What is wave number?

Ans:

i. Number of waves per unit distance is called wave number.

ii. It is denoted by v and given by, $\overline{v} = \frac{1}{l}$

iii. Unit: m^{-1} in SI system and cm^{-1} in CGS system.

iv. Dimensions: $[M°L^{-1}T°]$

Q.10. Explain double periodicity of wave motion.

Ans:

i. When waves travel through a medium, it is observed that at any point of the medium, the form of waves repeats itself after equal intervals of time. This shows that wave motion is periodic in time.

ii. Also at that instant, the form of waves repeats itself at equal distances. This shows that wave motion is periodic in space.

iii. Hence, wave motion possesses double periodicity. It is periodic in space and periodic in time.

Note:

1. During the propagation of waves, particles of the medium vibrate about the mean position.

2. In electromagnetic wave, electric and magnetic field vectors are perpendicular to each other.

7.1 Simple harmonic progressive

Q. 11. What is simple harmonic progressive wave?

Ans:

i. *The wave which is generated due to simple harmonic oscillations of the particles and travels continuously in a particular direction is called simple harmonic progressive wave.*

It is also called travelling wave.

ii. Longitudinal and transverse waves are simple harmonic progressive waves.

iii. Waves reach different particles of the medium at different instant of time.

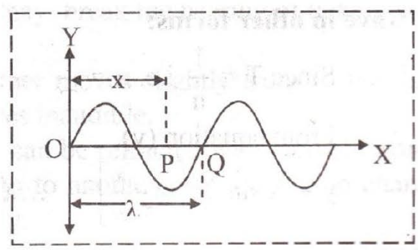
iv. Hence, there is a phase difference between the vibrations of different particles of the medium, though all particles vibrate with the same amplitude and period.

***Q.12. Derive an expression for a one dimensional simple harmonic progressive wave travelling in the direction of the positive X-axis. Express it in different forms. [Oct 09]**

OR

Derive an equation of a simple harmonic progressive wave. Express it in various forms. [Feb 03, 04, Oct 06]

Ans: Equation of simple harmonic progressive wave:



i. Consider a simple harmonic progressive wave travelling in the direction of the positive X-axis. The vibrations of the particles of the medium is parallel to the Y-axis.

ii. At time t = 0, particle is at origin O i.e., the mean position. At instant 't', displacement of the particle is,

$y = A\sin\omega t$ ......(i)

where, A = amplitude,

ω = angular velocity

iii. Consider a particle P situated at a distance 'x' from O. If 'δ' be the phase difference between the particle P and O, then displacement of the particle of the medium at P in instant 't' is given by,

$y = A\sin(\omega t - \delta)$ .... (ii)

iv. A path difference of λ between two particles of a medium corresponds to a phase difference of 2π between them (e.g. particle O and Q). Since the path difference between P and O is 'x', so the phase difference 'δ' between them is given by,

$$\delta = \frac{2\pi x}{\lambda} \quad \text{....... (iii)}$$

Substituting equation (iii) in equation (ii) we have

$$y = A\sin\left[\omega t - \frac{2\pi x}{\lambda}\right] \quad \text{.....(iv)}$$

This equation gives the displacement of any particle of the medium at any instant. Hence, it is called equation of a simple harmonic progressive wave.

v. Since,

$$T = \frac{2\pi}{\omega} \text{ i.e. } \omega = \frac{2\pi}{T}$$

From equation (iv),

$$y = A\sin\left[\frac{2\pi t}{T} - \frac{2\pi x}{\lambda}\right]$$

$$\therefore \quad y = A\sin 2\pi\left[\frac{t}{T} - \frac{x}{\lambda}\right] \quad \text{...... (v)}$$

Equation of simple harmonic progressive wave in other forms:

i. Since $T = \frac{1}{n}$ i.e. $n = \frac{1}{T}$

$\therefore$ From equation (v),

$$y = A\sin 2\pi\left[nt - \frac{x}{\lambda}\right] \quad \text{..... (vi)}$$

ii. Also velocty of the wave is given by,

$$v = n\lambda \text{ i.e. } n = \frac{v}{\lambda}$$

From equation (vi),

$$y = A\sin 2\pi\left[\frac{vt}{\lambda} - \frac{x}{\lambda}\right]$$

$$\therefore \quad y = A\sin\frac{2\pi}{\lambda}[vt - x] \quad \text{...... (vii)}$$

iii. Since $v = n\lambda$ i.e. $\lambda = \frac{v}{n}$

From equation (vi),

$$y = A\sin 2\pi\left[nt - \frac{nx}{v}\right]$$

$$\therefore \quad y = A\sin 2\pi n\left[t - \frac{x}{v}\right] \quad \text{...... (viii)}$$

All the above equations represent one-dimensional simple harmonic progressive wave, travelling in the direction of the positive X-axis.

Note:

Equation of simple harmonic progressive wave in negative direction of X-axis is given by,

$$y = A\sin 2\pi\left(\frac{t}{T}+\frac{x}{\lambda}\right)$$

In other forms replace negative sign by plus sign.

***Q.13.State the main characteristics of simple harmonic progressive wave.**

Ans: Characteristics of simple harmonic progressive wave:

i. All the particles off a medium perform **S.H.M.** when wave passes through the medium.

ii. All particles vibrate with same amplitude.

iii. All particles vibrate with same frequency.

iv. It possesses double periodicity i.e., periodic in time and periodic in space.

v. Energy is transmitted through the medium.

Note:

In equation $y = A\sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$, $\frac{2\pi}{\lambda}$ is a constant called propagation constant.

It is equivalent to,

i. $k = \frac{2\pi}{\lambda} = \frac{2\pi n}{\lambda n} = \frac{\omega}{v}$

ii. $k = \frac{2\pi}{\lambda} = \frac{2\pi x}{\lambda x} = \left(\frac{2\pi x}{\lambda}\right)\frac{1}{x} = \frac{\delta}{x}$

iii. $k = \frac{2\pi}{\lambda} = 2\pi\left(\frac{1}{\lambda}\right)2\pi\bar{v}$

7.2 Reflection of transversal and longitudinal waves

Q.14. What is reflection of wave (energy)? Compare the reflection of light wave and sound wave.

Ans: Reflection of wave (energy):

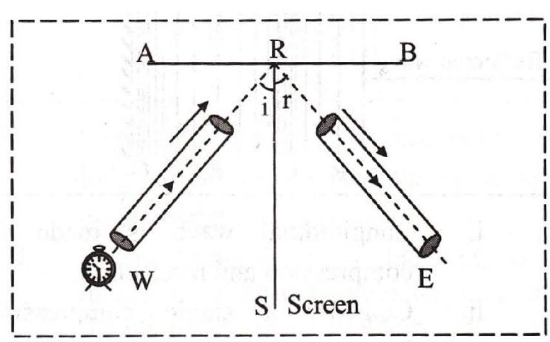
When wave (energy) travelling in a homogeneous medium meets a boundary of some other medium, it has a tendency to travel in the opposite direction. This is called reflection of wave (energy).

Comparison of light wave and sound wave:

Sr. No.	Light wave (energy)	Sound wave (energy)
i.	Small surface is enough for reflection of light waves.	Large surface is required for reflection of sound waves.
ii.	The wavelength of light wave is very small.	Wavelength of sound wave is large as compared to wavelength of light wave.
iii.	It is expressed in angstrom $1\ \text{Å} = 10^{-10}$ m	It is expressed in millimeter (mm). $1\ \text{mm} = 10^{-3}$ m

Q.15. Explain the reflection of longitudinal wave (sound wave) from plane reflecting surface.

Ans: Reflection of longitudinal wave (sound wave) from plane reflecting surface:



i. Consider a hollow tube kept inclined to a plane reflecting surface AB. A mechanical clock W is kept at the end of the tube.

ii. The ear is held close to one end of another tube, open at both ends.

iii. Screen S is used to block the sound of the watch from reaching the ear directly.

iv. Inclination of the second tube is adjusted so that the ticking of the watch can be clearly heard.

v. By measuring Ð WRS and Ð ERS it is found that m Ð WRS = m Ð ERS,

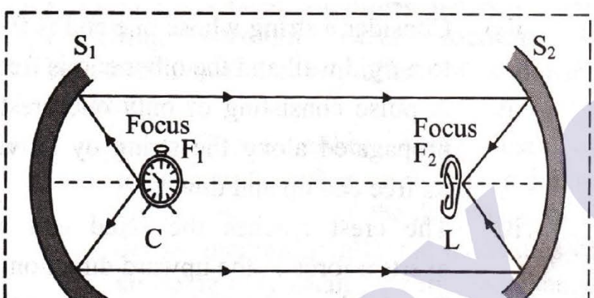
i.e. angle of incidence Ð i = angle of reflection Ð r.

Also, incident wave, reflecting wave and normal all lie in the same plane.

vi. Hence, longitudinal wave can be reflected from plane reflecting surface and obey laws of reflection.

***Q.16. Explain reflection of longitudinal waves (sound wave) from curved reflecting surface.**

Ans: Reflection of longitudinal waves from curved reflecting surface:



S_1, S_2: Concave reflectors, C: Mechanical clock, L: listener

i. Two large concave reflectors are placed coaxially, facing each other and at a fairly large distance apart.

ii. A mechanical clock C is held at the focus of Si of the surface.

iii. A listener L, keeps his ear on the focus of S_2.

iv. A ticking sound is produced at every one second. It reaches to surface S_1 as incident wave and reflects in direction of S_2.

v. Wave S_1S_2 acts as incident wave for surface S_2 and reflected in direction S_2 F_2 where listener kept his ear. Every ticking is heard by the listener at a certain position, i.e., at the focus of S_2.

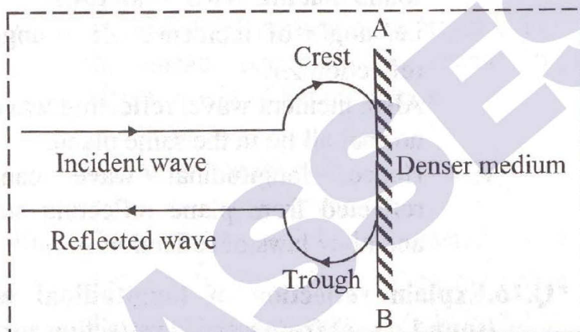
vi. Slight change in position of L from F_2 may break the hearing of ticking sound.

Note:

1. If listener moves slightly from F_2 then sound becomes inaudible.
2. Sound can be refracted when travels from one medium to another medium due to change in velocity.

***Q.17. Explain the reflection of transverse waves from a denser medium.**

Ans: Reflection of transverse waves from a denser medium:



i. A transverse wave consists of crests and troughs.

ii. Consider a string whose one end is fixed to a rigid wall and the other end is free.

iii. A pulse consisting of only one crest is propagated along the string by moving its free end up and down.

iv. The crest reaches the fixed end and exerts a force in the upward direction.

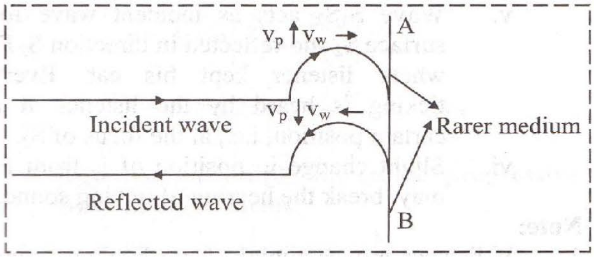
v. Due to the equal and opposite reaction, the velocity is reversed. Thus, a trough travels in opposite direction.

vi. Similarly, instead of a crest, if a trough is propagated, it reflects as crest.

vii. Thus, when transverse wave is incident on the surface of denser medium, crest is reflected as trough and trough is reflected as crest.

***Q.18. Explain the reflection of transverse wave from rarer medium.**

Ans: Reflection of transverse wave from rarer medium:



i. Consider a string crest of transverse wave along a string incident normally on the surface of rarer medium AB, as shown in figure.

ii. When crest is incident, direction of particle velocity (v_p) is in upward direction and direction of wave velocity (v_w) is towards the surface of rarer medium.

iii. The particle of the medium at which crest is incident is free to vibrate. Thus, particle of the medium will not exert the force of reaction on the crest, so it will vibrate in the same direction of the crest.

iv. The direction of particle velocity is in the same direction of the crest. Therefore the direction of particle velocity does not change.

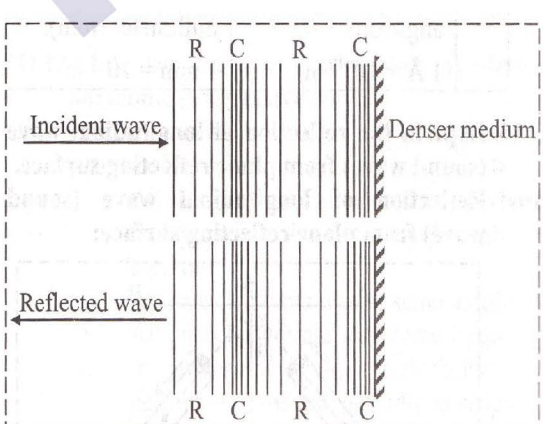
v. Thus, crest reflects as crest.

vi. Similarly, instead Of a crest if a trough is propagated it reflects back as a trough.

vii. Thus, when a transverse wave is incident on surface of rarer medium, crest is reflected as crest and trough is reflected as trough.

***Q.19.Explain the reflection of longitudinal wave from denser medium.**

Ans: Reflection of longitudinal wave from denser medium:



i. Longitudinal wave is made up of compression and rarefaction.

ii. Consider a single compression of longitudinal wave (sound wave) incident on the surface of denser medium, as shown in figure.

iii. When compression is incident, both direction of particle, velocity v_p and direction of wave velocity v_w are directed towards the surface of denser medium.

iv. The particle of the medium at f which compression is incident, is not free to vibrate. According to Newton's third law of motion, medium exerts equal and opposite force of reflection on the compression.

v. Due to this force of reflection, both particle velocity and wave velocity is reversed i.e., away from the surface of denser medium.

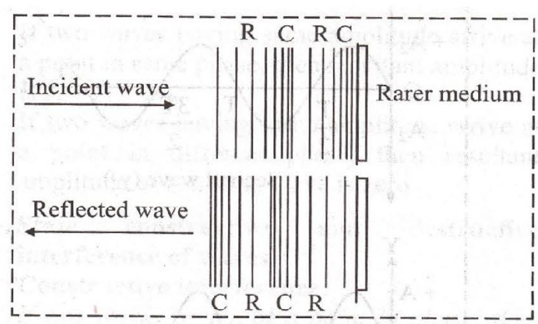
vi. Thus, a compression reflects as compression. Hence there is a change of phase of n radian or 180° in the particle velocity.

vii. Similarly, we can explain that rarefaction is reflected as rarefaction from denser medium.

viii. Thus, when longitudinal wave is incident on the surface of denser medium, compression is reflected as compression and rarefaction is reflected as rarefaction.

***Q.20.Explain the reflection of longitudinal wave from rarer medium.**

Ans: Reflection of longitudinal wave from rarer medium:



i. Consider a single compression of longitudinal wave (sound wave) incident on the surface of rarer medium.

ii. When compression is incident, both direction of particle velocity (v_p) and direction of wave velocity (vw) are directed towards the surface of rarer medium.

iii. The particles of the medium at which compression is incident are free to vibrate. Thus, particle of the medium will not exert the force of reaction on the compression. So it will vibrate in the same direction of the compression.

iv. The direction of particle velocity is in the same direction of the compression. Therefore, the direction of particle velocity does not change.

v. Thus, compression reflects as rarefaction. Hence there is no change in phase.

vi. Similarly, we can explain that rarefaction is reflected as compression from rarer medium.

vii Thus, when longitudinal wave is incident on the surface of rarer medium, compression is reflected as rarefaction arid rarefaction as compression.

7.3 Change of Phase

Q.21. Explain the change of phase when a wave travelling through rarer medium is reflected from the boundary of a denser medium.

Ans:

i. If a wave either longitudinal or transverse travelling in a rarer medium (air) is incident on the boundary of a denser medium (wall), the molecules of air being very small rebound and change the direction of their velocities by 180° i. e. the phase of the wave changes by p radians.

ii. A compression of a longitudinal wave is reflected back as a compression and it travels in opposite direction.

iii. Similarly, a rarefaction is reflected back as a rarefaction.

iv. In case of a transverse Wave, a crest is reflected back as a trough and vice- versa.

Q.22. Explain the change of phase when a wave travelling through denser medium is reflected from the boundary of rarer medium.

Ans:

i. If a wave travelling in a denser medium (water) is incident on the boundary of a rarer medium (air), there is practically, negligible resistance.

ii. Thus, for a transverse wave, a crest is reflected as a crest and a trough is reflected as a trough.

iii. In case of a longitudinal Wave, a compression is reflected as a rarefaction and a rarefaction is reflected as a compression.

Table to learn change of phase:

Types of wave	Reflection from boundary of	After reflection	Change of phase
Transverse wave	Denser medium	Crest as trough and vice-versa	π
	Rarer medium	Crest as crest and trough as trough	0
Longitudinal wave	Denser medium	Compression as compression and rare-faction as rarefaction.	π
	Rarer medium	Compression as rarefaction and vice-versa	0

Note:

1. When a wave travels from a medium, particles of the medium vibrate and perform velocity of particle is given by,

$$v_p = w\sqrt{A^2 - x^2}$$

2. When a wave travels from one medium to another, its frequency remains constant but its velocity changes.

i.e. $\frac{v_1}{v_2} = \frac{l_1}{l_2}$

3. In the same medium velocity remains same, so $n_1 l_1 = n_2 l_2$.

7.3 Superposition of waves

***Q.23.State and explain the principle of superposition of waves. [Oct 99]**

Ans: Principle:

When two or more waves travelling through a medium arrive at a point of the medium simultaneously, each wave produces its own displacement at that point independent of the others. The resultant displacement at that point is equal to the vector sum of the displacements due to all the waves.

Explanation:

i. Consider two waves travelling along positive direction of X-axis.

Let,

y_1 = displacement due to first wave.

y_2 = displacement due to second wave.

A_1 = amplitude of first wave.

A_2 = amplitude of second wave.

ii. When these two waves arrive at a poim in phase then resultant displacement ai that point is given by, $\vec{y} = \vec{y}_1 + \vec{y}_2$.

iii. The resultant wave having displacement $\vec{y}$ and amplitude A is as shown in fig. (a)

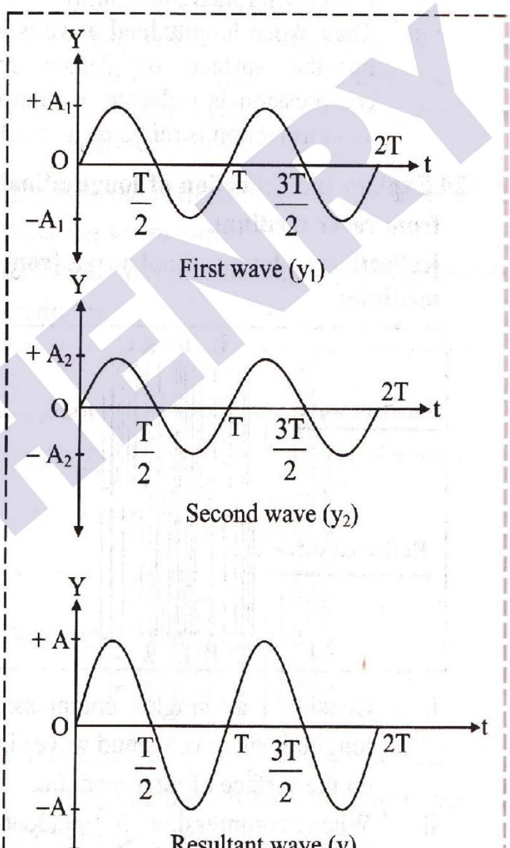


Fig. (a)

iv. If two waves arrive at a point in opposite phase, then resultant displacement at that point is given by,

$$\vec{y} = \vec{y}_1 - \vec{y}_2 (\vec{y}_1 > \vec{y}_2)$$

v. The resulting wave having displacement $\vec{y}$ and amplitude A is as shown in fig. (b).

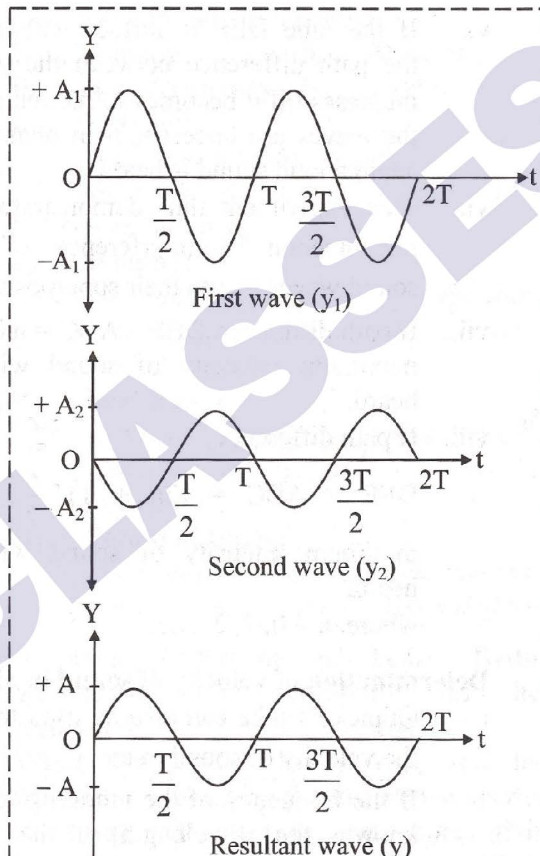


Fig. (b)

Note

1. If two waves having same amplitude arrive at a point in same phase, then resultant amplitude is A + A = 2A.
2. If two waves having same amplitude arrive at a point in different phase, then resultant amplitude of resulting wave is zero.

Q.24. State constructive and destructive interference of waves.

Ans: Constructive interference:

If two waves arrive at a point in phase, then resultant amplitude at that pdtnt is maximum.

This effect is called constructive interference. Resultant amplitude due to superposition of two waves in same phase is given by,

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos d}$$

where d = phase difference

d = 0, 2p, 4p ....

Destructive interference:

If two waves arrive at a point in opposite phase then resultant amplitude at that point is minimum. This effect is called destructive interference.

In destructive interference, resultant amplitude , is given by,

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos d}$$

where, d = phase difference

d = p, 3p, 5d....

we get,

\ $A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos 180^0}$

\ $A = \sqrt{A_1^2 + A_2^2 - 2A_1A_2} = \sqrt{(A_1 - A_2)^2}$

\ $A = A_1 - A_2$

Q.25. Explain constructive and destructive interference when,

i. two transverse waves are superimposed.

ii. two longitudinal waves are superimposed.

Ans:

i. When two transverse waves are superimposed:

a. When two transverse waves arrive at a point in same phase, then crest of one wave coincides with the cre^st and *d*ftpugl? coincides with the trough of the other wave. Hence, the resultant amplitude at that point is maximum. This effect is constructive interference of transverse wave.

b. If crest of one wave coincides with the trough of the other and vice-versa, then resultant amplitude at that point is minimum. This is destructive interference of transverse wave,

ii. When two longitudinal waves are superimposed:

a. If two longitudinal waves arrive at a point such that compression of one wave coincides with the compression of the other wave and rarefaction coincides with the rarefaction of the other wave, then the resultant amplitude of wave is maximum. This effect is constructive interference of longitudinal waves.

b. If compression of one wave fall on the rarefaction of the other wave and vice versa, then amplitude of the resulting wave is minimum. This effect is destructive interference of longitudinal waves.

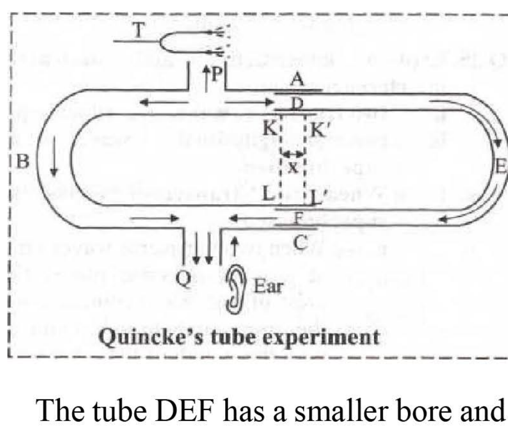
Q.26. Explain Quincke's tube experiment to demonstrate the superposition of sound waves. Hence discuss the method to find velocity of sound in air.

Ans: Aim:

To demonstrate superposition of two sound waves and determining velocity of sound wave in air.

Construction:

i. Quincke's apparatus consists of two U-tubes, ABC and DEF.



Quincke's tube experiment

ii. The tube DEF has a smaller bore and it can slide in the tube ABC. The tube ABC has two openings P and Q as shown in figure. A tuning fork is held near the opening P.

Working:

i. The sound waves enter through the opening P and travel along the paths PBQ and PEQ respectively.

ii. The waves along the two paths recombine at the opening Q. The resulting sound can thus be heard at Q.

iii. If the two paths PBQ and PEQ have path difference nA. and are equal, then the waves arrive in phase and there is constructive interference. Thus, a loud sound is heard,

iv. The tube DEF is slowly withdrawn from the tube ABC. It is observed that the intensity of sound heard keeps on decreasing till it becomes minimum. This is because at a certain point, the path difference between PBQ and PEQ A, is equal to $\frac{1}{2}$ where l, is the wavelength of the sound wave. At this point, the waves arrive out of phase and there is destructive interference. Hence the sound heard is minimum.

v. If the tube DEF is further withdrawn, the path difference between the waves increases till it becomes *X*. At this point the waves are once again in phase and again a loud sound is heard,

vi. This experiment thus demonstrates the phenomenon of interference of two sound waves due to their superposition.

vii. If path difference DEF – ABC = nl then maximum intensity of sound Will be heard.

viii. If path difference,

$$DEF - ABC = (2n + 1)\ \frac{1}{2}$$ then minimum intensity of sound will be heard. where, n = 0, 1,2,

Determination of velocity of sound in air:

i. Quincke's tube can also be used to find the velocity of sound in air.

If the frequency of the vibrating fork is known, the wavelength of the wave produced can be known from two successive position of the tube.

ii. Let distance moved from one position of minimum sound (say KL) to the next position of minimum sound (say K'L') is 'x'.

iii. Wavelength of the Sound wave is given by, A, = 2x.

iv. If n is the frequency of sound source then speed of sound in air is. given by. v = nl.

Thus, velocity of sound in air can be determined easily by measuring x.

7.5 Formation of beats

Q.27. What are beats? State the conditions for the formation of beats.

Ans: Beats:

Periodic variations in the intensity of sound due to the superposition of two sound waves of slightly different frequencies are called beats.

Condition for beats formation:

i. The two waves should have slightly different frequencies.

ii. The amplitude of the two waves should be equal or nearly equal.

28. Define the following terms.

i. Waxing **ii. Waning**

i. Beat frequency **iv. Period of beat**

Ans: i. Waxing:

Maximum intensity (loudness) of sound due to superposition of two sound waves is called waxing.

ii. Waning:

The minimum intensity of sound due to superposition of two sound waves is called waning.

iii. Beat frequency:

Number of times the sound waxes or wanes in one second is called beat frequency.

iv. Period of beats:

Time interval between two successive waxing or waning is called period of beats.

Q.29.Explain production of beats. Deduce analytically the expression for beat frequency. OR

What are beats? Prove that the beat frequency is equal to the difference between the frequencies of two sound notes giving rise to beats.

[Feb 06, Oct 03, 08]

Ans: *Refer Q. 27 fpr definition of beats.*

Production of beats: ;

The alternate waxing and waning of sound after definite intervals of time, due to superposition of two waves of nearly equal frequencies, is called production of beats.

Analytical treatment of beats frequency:

i. Consider two sound waves of equal amplitude but of slightly different frequencies n_1 and n_2 ($n_1 > n_2$), passing simultaneously through a given point in space.

ii. Suppose that the two waves start in phase,' the displacement y_1 and y_2 of the waves may be represented by,

$y_1 = A \sin \omega_1 t = A \sin 2\pi n_1 t$ .... (i)

$y_2 = A \sin \omega_2 t = A \sin 2\pi n_2 t$ ....(ii)

iii. By the principle of superposition of waves, the resultant displacement 'y' is given by,

$$y = y_1 + y_2$$

$$= A \sin 2\pi n_1 t + A \sin 2\pi n_2 t$$

$$y = A(\sin 2\pi n_1 t + \sin 2\pi n_2 t)$$

By using, $\sin C + \sin D$

$$= 2\sin\left(\frac{C+D}{2}\right)\cos\left(\frac{C-D}{2}\right)$$

$$\therefore \quad y = 2A \sin 2\pi\left(\frac{n_1+n_2}{2}\right)t \cos 2\pi\left(\frac{n_1-n_2}{2}\right)t$$

$$\therefore \quad y = 2A \cos 2\pi\left(\frac{n_1-n_2}{2}\right)t \sin 2\pi\left(\frac{n_1+n_2}{2}\right)t \quad \text{..... (iii)}$$

iv. Let, $R = 2A\cos 2\pi\left(\frac{n_1-n_2}{2}\right)t$ ..... (iv)

and $n = \frac{n_1+n_2}{2}$

$\therefore$ $y = R \sin(2\pi nt)$

This is the equaton of simple harmonic motion.

Waxing:

Waxing will be possible, if R is maximum.

i.e. $R = \pm 2A$

From equation (iv),

$$R = 2A\cos 2\pi\left(\frac{n_1-n_2}{2}\right)t = \pm 2A$$

$$\therefore \quad \cos 2\pi\left(\frac{n_1-n_2}{2}\right)t = \pm 1$$

$$\therefore \quad 2\pi\left(\frac{n_1-n_2}{2}\right)t = 0, \pi, 2\pi, 3\pi....$$

Time at which maximum intensity is produced is

$$t = 0, \frac{1}{n_1-n_2}, \frac{2}{n_1-n_2} - \frac{3}{n_1-n_2}, ...$$

Time interval between two successive waxing is,

$$T = \frac{1}{n_1-n_2} - 0 = \frac{2}{n_1-n_2} - \frac{1}{n_1-n_2}$$

$$= \frac{3}{n_1-n_2} - \frac{2}{n_1-n_2} \text{ and so on.}$$

$$\therefore \quad T = \frac{1}{n_1-n_2}$$

Frequency of waxing $\frac{1}{\text{Period}} = \frac{1}{T} = n_1 - n_2$

Waning :

Waning will be possible, if R is minium,

i.e., $R = 0$.

From equation (iv),

$$2A\cos 2\pi\left(\frac{n_1-n_2}{2}\right)t = 0$$

$$\therefore \quad \cos 2\pi\left(\frac{n_1-n_2}{2}\right)t = 0$$

$$\therefore \quad 2\pi\left(\frac{n_1-n_2}{2}\right)t = \frac{\pi}{2}, \frac{3\pi}{2}, \frac{5\pi}{2}, ...$$

Time at which minimum intensity is produced, is

$$t = \frac{1}{2(n_1-n_2)}, \frac{3}{2(n_1-n_2)}, \frac{5}{2(n_1-n_2)} .....$$

The time interval between two successive waning is,

$$T = \frac{3}{2(n_1-n_2)} - \frac{1}{2(n_1-n_2)} = \frac{5}{2(n_1-n_2)} - \frac{3}{2(n_1-n_2)}$$

$$\therefore \quad T = \frac{1}{(n_1-n_2)}$$

Period of wxing = Peiod of waning = Period of beats = T

$\therefore$ Frequency of beats, $N = \frac{1}{T} = n_1 - n_2$

Q.30. Derive an expression for beat frequency by analytical method. [Oct 02,04]

Ans: Refer Q.29

***Q.31.Explain two applications of beats.**

Ans:

i. The phenomenon of beats can be used to produce low frequency notes used in Jazz orchestra or western music,

ii. Frequency of radio receiver is superposed with a locally produced frequency to produce intermediate frequency which is always constant. This makes tuning of the receiver very simple. This is used in superheterodyne oscillators.

***Q.32.Explain the applications of beat to determine unknown frequency,**

Ans:

i. The phenomenon of beats is used to determine an unknown frequency.The sound note of unknown frequency is sounded simultaneously with a note of known frequency which can be changed,

ii. The known frequency is so adjusted that beats are heard.

iii. A small further adjustment is then made to reduce the number of beats to zero. When this is done, frequencies of the two notes are equal.

***Q.33.How application of beats are used to tune the musical instruments?**

Ans:

i. Musical instruments can be tuned by noting the beats produced, when two different instruments are sounded together.

ii. By adjusting the frequency of sound of one of the instrument, the number of beats is reduced to zero.

iii. When this is done, both the instruments are emitting sound waves of same frequency. The instruments are then said to be in unison with each other.

***Q.34. Explain the applications of beats to detect harmful gases in mines.**

Ans:

i. Two identical organ pipes, one filled with pure air and other filled with air from the mine are blown together.

ii. Speed of sound is different in different gases.

iii. If no harmful gases are present in the air from mine, the two pipes will produce notes of the same frequency and beats will not be heard.

iv If mine air is polluted with harmful gases then pipe will produces notes of slightly different frequencies, giving rise to beats.

Note:

1. When sound becomes loud (maximum), it is said to wax.

2. When sound becomes faint (minimum), it is said to wane.

3. One waxing and one waning constitute one beat.

4. Maximum intensity of sound notes at the point of constructive interference is given by, $I_{max} \propto 4A^2$

5. Minimum intensity of sound notes at the point of constructive interference is given by, $I_{min} = 0$

<u>**7.6 Doppler effect in sound**</u>

***Q.35.State and explain Doppler effect in sound. [Oct 98,2000,06]**

Ans: Statement:

The apparent change in the frequency of sound heard by an observer, due to relative motion between the source of sound and the observer is called Doppler effect.

OR

Whenever there is a relative motion between a source of sound and an observer, there is apparent change in frequency of a note (sound) emitted by a source and as heard by the observer.

Explanation:

Let,

n = actual frequency of the source,

n' = apparent frequency of the source

v = velocity of sound in air.

v_s = velocity of the source.

v_0 = velocity of the observer.

Apparent frequency heard by the observer is given by, $n' = n\left[\frac{v \pm v_0}{v \mp v_s}\right]$

Where upper signs (+ ve in numerator and –ve in denominator) indicates that source and observer move towards each other. Lower signs (–ve in numerator and +ve in denominator) indicates that source and listener move away from each other.

Case 1:

Observer is at rest, source is in motion.

In this case $v_0 = 0$.

i. If source is moving towards observer then apparent frequency is given by,

$$n' = n\left[\frac{v}{v - v_s}\right]$$

,i.e., apparent frequency increases.

ii. If source is receding away from observer then apparent frequency is given by,

$$n' = n\left[\frac{v}{v + v_s}\right]$$

,i.e., apparent frequency decreases.

Case 2:

Source is at rest and observer is in motion.

In this case $v_s = 0$.

i. If observer is moving towards source then apparent frequency is given by,

$$n' = n\left[\frac{v + v_0}{v}\right]$$

, i.e., apparent frequency increases.

ii. If observer is receding away from source then apparent frequency is given by,

$$n' = n\left[\frac{v - v_0}{v}\right]$$

, i.e., apparent frequency decreases.

Case 3:

Both the source and observer are at rest. In this case $v_s = 0$, $v_0 = 0$

$\therefore \quad n' = n$

Hence, there is no change in frequency of sound note.

Case 4:

Both source and observer are in motion,

i. If source and observer approach each other then apparent frequency is given by,

$$n' = n\left[\frac{v + v_0}{v - v_s}\right]$$

, i.e., apparent frequency increses.

ii. If source and observer both recede each other then apparent freqency is igven by

$$n' = n\left[\frac{v - v_0}{v + v_s}\right]$$

, i.e., apparent frequency decreases.

Q.36. State four applications of Doppler effect in sound.

Ans: Applications of Doppler effect:

i. It is used in radar.

ii. It is used in determination of speed of star.

iii. Used in medicine.

iv. Used in cosmology.

***Q.37.Explain two uses of Doppler effect of sound in every day life.**

Ans:

i. Doppler sonography:

The ultrasonic waves reflected from body tissues can give information about rate of flow of various fluids including blood,

ii. Traffic speed gun:

The traffic police use speed guns which are fixed for a certain speed. If the vehicle passing by passes at a higher speed, then beats are produced and an alarm is initiated. Thus, the doppler effect is used for speed detection on highways.

***Q.38.Explain the application of Doppler effect in RADAR system.**

Ans:

i. RADAR stands for "Radio Detection And Ranging." It is an instrument used to detect fast moving object such as an aeroplane or a ship.

ii. It continuously emits high frequency electromagnetic waves which on striking the moving object gets reflected back.

iii. Due to the superposition of incident and reflected waves, beats are produced. Knowing the frequency of beats, the speed of the object can be determined.

***Q.39.How can speed of star be determined using Doppler effect?**

Ans:

i. If a star is moving towards the earth, the observed frequency of its light will be more than its actual frequency on account of Doppler effect.

ii. As a result, its wavelength will correspondingly be smaller. Thus the lines in its spectrum get shifted towards the violet end.

iii. Similarly, if the star is moving away from the earth its lines get shifted towards the red end of the spectrum as its wavelength increases.

iv. By measuring the Doppler shift in the wavelength, one can calculate the speed of the moving star.

***Q.40.Explain the use of Doppler effect to calculate speed of rotation of the sun.**

Ans:

i. Light emitting from the east end of the sun are observed to have higher frequencies than those Which originate from the west end.

ii. This is because it rotates in such a way that the east end is approaching the earth while the west side is receding away from the earth.

iii. The shift in the observed frequencies is thus in accordance with the Doppler effect.

iv. By measuring this shift, the speed of the rotating sun can be calculated.

Q.41. Discuss the limitations of Doppler effect of sound.

Ans:

i. The Doppler effect is applicable only when the velocities of the source of sound and observer are much less than velocity of sound.

ii. Doppler effect can? be experienced only when the motion of both the observer and the source are along the same straight line.

iii. The medium such as air, in which the observer and source are situated, is at rest. If direction of motion are different or wind is, blowing then apparent frequency will be changed.

Note:

Apparent frequency heard by observer due to relative motion of source of sound and observer has got effect of wind on it.

<u>SUMMARY:</u>

1. Wave is a type of oscillatory disturbance which is produced due to oscillation of particles of medium.

2. A simple harmonic progressive wave is represented by equation,

$$y = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$$

If the wave is travelling along negative X-axis then form of equation becomes, t

$$y = A\sin 2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right)$$

3. If two points on a wave are separated by a distance x, then phase difference between them $\delta = \left(\frac{2\pi}{\lambda}\right)x$

4. If the incident wave is $y = A\sin(\omega t - kx)$, then reflected wave from the denser medium is. $y = -A\sin(\omega t + kx)$ and from rarer medium $y = A\sin(\omega t + kx)$

5. When a transverse wave is reflected from a rarer medium, the crest is reflected as crest and trough is reflected as trough. If this wave is reflected from denser medium, crest is reflected as trough and vice-versa.

6. When a longitudinal wave is reflected from a rarer medium, the compression is reflected as rarefaction and vice versa.

If the wave is reflected from a denser medium, the compression is reflected as compression and rarefaction is reflected as rarefaction.

7. Beats arc the periodic variation of the intensity of sound due to the superposition of two sounds of slightly different frequencies. The phenomenon of beats produces loud and faint sound at regular intervals of time.

8. Loading of prongs decreases frequency of tuning fork. If we file the prongs of tuning fork to make it thinner, then frequency of fork increases.

9. As per Doppler effect, if n' is apparent frequency and n is natural frequency, then the formula is,

$$n' = n\left[\frac{v \pm v_0}{v \mp v_s}\right]$$ where v is the velocity of sound, v_0 is the velocity of the observer anc v_s is the velocity of source.

10. If N tuning forks are-arranged in order of increasing frequencies and any-two successive forks produces x beats /s, then

Frequency of last fork = $n_L = n_F + (N - 1)\,x$ where, n_F is frequency of first fork.

11. If N tuning forks are arranged in order of decreasing frequencies and any two successive forks produces 'x' beats /s, then,

Frequency of last fork = n_L if $n_F - (N - 1)\,x$

Formulae

1. Velocity of a wave: $v = n\lambda = \lambda/T$
2. Particle velocity: $v = \omega\sqrt{A^2 - x^2}$
3. Equation of simple harmonic progressive wave along positive X direction:

i. $y = A\sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$

ii. $y = A\sin 2\pi\left(nt - \frac{x}{\lambda}\right)$

iii. $y = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

iv. $y = A\sin\frac{2\pi}{\lambda}(vt - x)$

4. **Equation of simple harmonic progressive wave along negative X direction:**

$$y = A\sin 2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right)$$

5. Angular frequency: $\omega = \frac{2\pi}{T} = 2\pi n$
6. Phase difference: $\delta = \frac{2\pi x}{\lambda}$
7. Path difference: $x = \frac{\lambda}{2\pi}\delta$
8. Time difference: $t = \frac{x}{v}$
9. Period of beats: $T = \frac{1}{n_1 - n_2}$
10. Beat frequency: $n = n_1 - n_2$
11. **Doppler formula for apparent frequency:**

i. Source approaching a stationary observer,

$$n' = n\left(\frac{v}{v - v_s}\right)$$

ii. Source receding from a stationary v observer, $n' = n\left(\frac{v}{v + v_s}\right)$

iii. Observer approaching a stationary source,

$$n' = n\left(\frac{v + v_s}{v}\right)$$

iv. Observer receding from a stationary source,

$$n' = n\left(\frac{v - v_0}{v}\right)$$

v. Both source and observer approaching each other, $n' = n\left(\frac{v + v_0}{v - v_0}\right)$

vi. Both source and observer receding from each other, $n' = n\left(\frac{v - v_0}{v + v_0}\right)$

Solved Problems

Example 1

Write the equation of a simple harmonic progressive wave of amplitude 0.02 m and period 0.04 s travelling along the positive X-axis with velocity of 12.5 m/s.

Solution:

Given: A = 0.02 m, T = 0.04 s, v = 12.5 m/s

To find: Equation of simple harmonic progressive wave

Formula : $y = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

Calculation: Since, $\lambda = vT$

$\lambda = 12.5 \times 0.04 = 0.5$ m

From formula,

$$y = 0.02 \sin \pi \left(\frac{t}{0.04} - \frac{x}{0.5}\right)$$

Ans: The equation of the simple harmonic progressive wave is

$$y = 0.02 \sin \pi \left(\frac{t}{0.04} - \frac{x}{0.5}\right)$$

Example 2

A simple harmonic progressive wave of frequency 5 Hz is travelling along the positive X direction with a velocity of 40 m/s. Calculate the phase difference between two points separated by a distance of 0.8 m.

Solution:

Given: n = 5 Hz, v = 40 m/s, x = 0.8 m

To find: Phase difference (ϕ)

Formula: $\phi = \dfrac{2\pi x}{\lambda}$

Calculation: Since, $v = n\lambda$

$$\therefore \quad \lambda = \frac{2\pi \times 0.8}{8}$$

$$\phi = 2\pi \times 0.1$$

$$\therefore \quad \phi = \frac{\pi}{5} \text{ rad}$$

Ans: The phase difference between the two points it separated by a distance of 0.8 m is $\dfrac{\pi}{5}$ rad.

Example 3

The equation of a transverse wave along a stretched string is given by,

$y = 2 \sin 2\pi \left(\dfrac{t}{0.02} - \dfrac{x}{40}\right)$, where the length is the length is expressed in cm and time in second. Calculate the wavelength, frequency and velocity of the wave.

Solution:

Given: $y = 2 \sin 2\pi \left(\dfrac{t}{0.02} - \dfrac{x}{40}\right)$ ..... (i)

To find: Wavelength (A,), Frequency (n), Velocity (v)

Formula: $y = A \sin 2\pi \left(\dfrac{t}{T} - \dfrac{x}{\lambda}\right)$

Calculation :

Comparing equation (i) with formula, we get,

$\lambda = 40$ cm

T = 0.02 sec

$$n = \frac{1}{T} = \frac{1}{0.02} = \frac{100}{2}$$

n = 50 Hz

$v = n\lambda = 50 \times 40 = 2000$ cm/s

v = 20 m/s

Ans: The wavelength, frequency, velocity of the wave are 40 cm, 50 Hz and 20 m/s respectively.

Example 4

A hospital uses an ultrasonic scanner to locate tumour in a tissue. What is the wavelength of sound in the tissue in which the speed of sound is 1.7kms^{-1}? [The operating frequency of the scanner is 4.2 MHz.] (NCERT)

Solution:

Given: $v = 1.7 \text{ km s}^{-1} = 1700 \text{ m s}^{-1}$,

$n = 4.2 \text{ MHz} = 4.2 \times 10^6$ Hz

To find: Wavelength (A,)

Formula: $\lambda = \dfrac{v}{n}$

Calculation: From formula,

$$\lambda = \frac{1700}{4.2 \times 10^6}$$

$\lambda = 4.05 \times 10^{-4}$ m

Ans: The wavelength of sound in the tissue is **4.05×10^{-4} m**.

Example 5

A progressive wave of frequency 50 Hz is travelling with a velocity 350 m/s through a medium. Find

i. the phase difference between two particles separated by 7 m,

ii. the change in phase at a given point in time interval 0.005 second.

Solution:

Given: n = 50 Hz, v = 350 m/s, x = 7 m, t = 0.005

To find: i. Phase difference between two particles (δ_1)

ii. Change in phase (δ_2)

Formula: $\delta = \frac{2\pi x}{\lambda} = 2\pi nt$

Calculation: Since, $\lambda = \frac{v}{n}$

From formula,

$$\delta_1 = \frac{2\pi \times 7}{7}$$

$\delta_1 = 2\pi$ rad

From formula,

$\delta_2 = 2\pi \times 50 \times 0.005$

$$= \frac{2\pi \times 50 \times 5}{1000}$$

$$\therefore \quad \delta_2 = \frac{\pi}{2} \text{ rad}$$

Ans:

i. The phase difference between the two particles separated by 7 m is 2π rad.

ii. The change in phase at a given point in time interval 0.005 second is $\frac{\pi}{2}$ rad.

Example 6

A transverse wave of amplitude 0.01 m and frequency 500 Hz is travelling along a stretched string with a speed of 200 m/s. Find the displacement of a particle at a distance of 0.7 m from the origin after 0.01 sec. Also find the phase difference between the point where wave reaches from the origin. [Mar 12]

Solution:

Given: A = 0.01 m, n = 500 Hz, v = 200 m/s, x = 0.7 m, t = 0.01 s,

To find. Displacement (y), Phase difference (δ)

Formulae: i. $y = A \sin 2\pi\left(nt - \frac{x}{\lambda}\right)$

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

Calculation : Using, $v = n\lambda$ we get,

$$\lambda = \frac{v}{n} = \frac{200}{500} = 0.4\text{m}$$

From formula (i),

$$y = 0.01 \sin 2\pi\left(500 \times 0.01 - \frac{0.7}{0.4}\right)$$

$= 0.01 \sin 2\pi\,(5 - 1.75)$

$= 0.01 \sin 2\pi \times 3.25$

$= 0.01 \sin 2\pi \times \frac{13}{4}$

$= 0.01 \sin 13\frac{\pi}{2}$

$$\textbf{y = 0.01 m} \qquad \left[\because \sin\left(13\frac{\pi}{2}\right) = 1\right]$$

From formula (ii),

$$\delta = \frac{2\pi \times 0.7}{0.4} = \frac{7\pi}{2} \text{ rad}$$

Ans:

i. The displacement of the particle is **0.01 m.**

ii. The phase difference between the point where wave reaches from the origin is $\frac{7\pi}{2}$ rad.

Example 7

A bat emits ultrasonic sound of frequency 1000 kHz in air. If the sound meets a water surface, what is the wavelength of (i) the reflected sound (ii) the transmitted sound? [Speed of sound in air is 340 m s^{-1} and in water 1486 m s^{-1}].

(NCERT)

Solution:

Given: n = 1000 kHz = 1000 × 10^3 Hz = 10^6 Hz, v = 340 m s^{-1}, v_w = 1486 ms^{-1}

To find: i. Wavelength of reflected sound (λ_R)

ii. Wavelength of transmitted sound (λ_T)

Formula : $\lambda = \frac{v}{n}$

Calculation:

i. For reflected sound, medium remains the same.

From formula,

$$\lambda_R = \frac{v_a}{n} = \frac{340}{10^6}$$

$\therefore$ $\lambda_R = 3.4 \times 10^{-4}$ m

ii. For transmitted sound, water is the medium.

From formula,

$$\lambda_r = \frac{v_w}{n} = \frac{1486}{10^6}$$

$\therefore$ $\lambda_T = 1.486 \times 10^{-3}$ m

Ans:

i. The wavelength of reflected sound is **3.4×10^{-4} m.**

ii. The wavelength of transmitted sound is **1.486×10^{-3} m.**

Example 8

The frequency of a tuning fork is 256 Hz and velocity of sound in air is 350 m/s. Find the distance covered by the wave when the fork completes 16 vibrations.

Solution:

Given: n = 256 Hz, v = 350 m/s,

No. of vibrations = 16

To find: Distance (d)

Formula: $v = n\lambda$

Calculation: Distance covered by wave in one vibration is its wavelength (λ).

$\therefore$ Distance covered by wave in 16 vibrations = d = 16 λ

From formula,

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

$$\text{But, } d = 16\,\lambda = 16\left(\frac{v}{n}\right)$$

$$= 16\left(\frac{350}{256}\right) = 21.875$$

Ans: The distance covered by the wave when the fork completes 16 vibrations is **21.875 m**.

Example 9

Two tuning forks have frequencies 412 Hz and 409 Hz respectively. Calculate the period of the beat.

Solution:

Given: $n_1 = 412$ Hz, $n_2 = 409$ Hz

To find: Period (T)

Formula: $T = \frac{1}{n_1 - n_2}$

Calculation : From forrmula,

$$T = \frac{1}{412 - 409} = \frac{1}{3}$$

$\therefore$ T = **0.33 s**

Ans: The period of the beat is **0.33 s.**

**** Example 10***

Two sound waves having wavelength of 87 cm and 88.5 cm respectively, when superimposed, produced 10 beats per second. Find the velocity of sound.

Solution:

Given: $\lambda_1 = 87$ cm = 0.87 m,

$\lambda_2 = 88.5$ cm = 0.885 m

Beat frequency, N = 10 beats per second.

To find: Velocity (v)

Formula: $v = n\lambda$,

Calculation: From formula,

$$v_1 = n_1\lambda_1 \text{ and } v_2 = n_2\lambda_2$$

$$\therefore \quad n_1 = \frac{v}{\lambda_1} \text{ and } n_2 = \frac{v}{\lambda_2}$$

$$\therefore \quad \lambda_2 > \lambda_1 \text{ hence } n_1 > n_2$$

$$\therefore \quad N = n_1 - n_2 = \frac{v}{\lambda_1} - \frac{v}{\lambda_2} = v\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]$$

$$\therefore \quad N = v\left[\frac{1}{0.87} - \frac{1}{0.885}\right]$$

$$10 = v\left[\frac{1}{0.87} - \frac{1}{0.885}\right]$$

$\therefore \quad 10 = v\left[\frac{0.885-0.87}{0.87\times 0.885}\right]$

$\therefore \quad 10 = v\left(\frac{0.015}{0.87\times 0.885}\right)$

$\therefore \quad v = \frac{10\times 0.87\times 0.885}{0.015}$

$\therefore$ v = **513.3 m/s**

Ans: The velocity of sound is **513.3 m/s.**

Example 11

Wavelengths of two notes in air are $\frac{99}{175}$ m and $\frac{90}{173}$ m. Each note produces four beats per second 173 with a third note of fixed frequency. Calculate the frequency of the third note and velocity of sound in air.

Solution:

Given: $\lambda_1 = \frac{90}{175}$ m, $\lambda_2 = \frac{90}{173}$ m

To find: Frequency of third note (n),
Velocity of sound (v)

Formula: $v = n\lambda$

Calculation: For two notes in air, $n_1\lambda_1 = n_2\lambda_2$

$n_1 \times \frac{90}{175} = n_2 \times \frac{90}{173}$

$\therefore \lambda_2 > \lambda_1$

$\therefore n_1 > n_2$

From the given condition of the problem.

$n_1 = n + 4$ and $n_2 = n - 4$

173 (n + 4) = 175 (n – 4)

n = 696 Hz

From formula,

$v = (n+4)\frac{90}{175} = (696+4)\frac{90}{175}$

$\therefore \quad v = 700 \times \frac{90}{175}$

= 360 m/s

Ans:

i. The frequency of the third note is **696 Hz**.

ii. Velocity of sond in air is **360 m/s**.

Example 12

Two sound notes have wavelengths $\frac{83}{170}$ m and $\frac{83}{172}$ m in air. These notes when sounded together produce 8 beats per second. Calculate the velocity of sound in air and frequencies of two notes.

[Mar 09]

Solution:

Given: $\lambda_1 = \frac{83}{170}$ m, $\lambda_2 = \frac{83}{172}$ m

no. of beats = 8/sec.

To find: Velocity (v),
Frequency (n_1, n_2)

Formula: $v = n\lambda$

Calculation: From formula,

$\therefore \quad n_1 = \frac{v}{\lambda_1}$ and, $n_2 = \frac{v}{\lambda_2}$, But $\lambda_1 > \lambda_2$

$\therefore n_2 > n_1$. $\therefore n_2 - n_1 = 8$

$\therefore \quad v\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) = 8$ or $v\left(\frac{173}{83} - \frac{170}{83}\right) = 8$

$\therefore \quad v = \frac{8\times 83}{2} = 332\ \text{m/s}$

$\therefore \quad n_1 = 332 \times \frac{170}{83} = 680\ \text{Hz}$ and

$n_2 = \frac{332\times 170}{83} = 688\ \text{Hz}$

Ans: i. The velocity of sound iar is **332 m/s**.

ii. The frequencies of the two notes are **680 Hz** and **688 Hz**.

Example 13

A sound wave of amplitude 10 cm and frequency 1000 Hz is travelling with a velocity of 300 m/s. Calculate the displacement of a particle at a distance 3 cm from the origin after 1.001 seconds.

Solution:

Given: A = 10 cm = 0.1 m, n = 1000 Hz,
v = 300 m/s, x = 3 cm = 3 x 10 m,

$t = 1.001$ s

To find: Displacement (y)

Formula: $y = A\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

Calculation: Since, $v = n\lambda$

$\therefore \quad \lambda = \frac{v}{n} = \frac{300}{1000}$

$\therefore \quad \lambda = 0.3$ m

$T = \frac{1}{n} = \frac{1}{1000}$

$\therefore \quad T = 1 \times 10^{-3}$ s

From formula,

$$y = 0.1\sin 2\pi\left[\frac{1.001}{1\times 10^{-3}} - \frac{0.3\times 10^{2}}{3}\right]$$

$$= 0.1\sin 2\pi\left[1.001\times 10^{-3} - \frac{3}{0.3\times 10^{2}}\right]$$

$$= 0.1\sin 2\pi\left[1001 - \frac{3}{30}\right]$$

$$= 0.1\sin 2\pi\left[1001 - \frac{1}{10}\right]$$

$$= 0.1\sin\left[2002\pi - \frac{\pi}{5}\right]$$

But, $\sin 2(\pi n - \theta) = -\sin\theta$

$\therefore \quad y = -0.1\sin\left[\frac{\pi}{5}\right]$

$= -0.1 \sin [36^0]$

$\therefore \quad y = -0.1 \times 05878$

$\therefore$ $\mathbf{y = 5.878 \times 10^{-2}}$ **m** (In magnitude)

Ans: The displacement of the particle at a distance 3 cm from the origin after 1.001 seconds is **5.878×10^{-2} m.**

Example 15

A set of 12 tuning forks is arranged in increasing order of frequencies. Each fork produce 'Y' beats per second with previous one. The last tunning fork is an octave of the first, the fifth tuning fork has the frequency 90 Hz. Find Y and hence find the frequency of the last fork.

[Mar 11]

$N = 12$, $n_L = 2n_F$, $n_s = 90$Hz

Number of beats (x),

Frequency of last fork (nL)

Formula : $n_L = n_F + (N - 1)\,x$

Calculation: From formula,

$n_L = n_F + (5 - l)x$

$n_F + 4x = 90$ ....(i)

$nL = n_F + (12 - 1)\,x$

$nL = n_F + llx$ ....(ii)

$n_L = 2n_F$

$n_F = llx$ ....From (ii)

Substituting in equation (i),

$15x = 90$ or $x = 6$ beat/s

$n_F = 11 \times 6 = 66$ Hz

$n_L = 2 \times 66 =$ **132** Hz

Ans: i. The value of Y is 6 beat/s.

ii. The frequency of the last fork is **132 Hz.**

Example 16

A tuning fork C produces 8 beats per second with a tuning fork D of frequency 350 Hz. When the prongs of fork C are loaded with wax, the number of beats heard is 10 per second. Find the original frequency of fork C.

Solution:

$n_D = 350$

$\therefore \quad nc = 350 \pm 8 = 358$ or 342 Hz

When C is loaded with wax, nc decreases

Let original nc = 358 Hz

On loading, nc becomes < 358

Beat frequency should become less than 8.

But beat frequency increases,

$n_c = 350 \pm 8 = 358$ or 342 Hz

$\therefore \quad n_c \neq 358$ Hz

$\therefore \quad \mathbf{n_c = 342}$ **Hz**

Ans: The original frequency of fork **C** is **342 Hz.**

Example 17

A tuning fork A produces 4 beats per second with another tuning fofk B of frequency 346 Hz. Whea the prongs of A are filed a little, the number of beats heard is 6 per second. Find the original

frequency of fork A.

Solution:

$n_B = 346$ Hz

\ $n_A = 346 \pm 4 = 350$ or 342

A is filed.

\ Frequency of A should increase.

Let initial $n_A = 342$

On filing, $n_A > 342$ Hz

\ No. of beats with B decreases.

But no. of beats are increasing

\ n_A ¹ **342 Hz**

\ $n_A =$ **350 Hz**

Ans: The original frequency of fork A is **350 Hz.**

EXERCISE

Section A : Practice problems

1. The equation of a transverse wave along a stretched string is given by,

   $y = 0.01 \sin 100\pi\left(t - \frac{x}{40}\right)$ with all the quantities in SI units. Find the
   i. amplitude
   ii. frequency and
   iii. speed of the wave.

2. Two tuning forks of frequencies 200 Hz and 220 Hz produce sound waves of wavelengths differing by 16 cm in air. Find the speed of sound in air.

3. A train standing at a railway station blows a whistle of frequency 400 Hz. What is the frequency of the whistle heard by a platform observer when the train,
   i. approaches the platform with a speed of 10 m/s.
   ii. recedes from the platform with a speed of 10 m/s.
   [Speed of sound in air is 340 m/s.]

4. An engine sounding a whistle of frequency 2000 Hz is receding from a stationary observer at 72 km/h. What is the apparent frequency for the observer?
   [Velocity of sound in air = 340 m/s.]

5. A simple harmonic progressive wave of amplitude 10 cm and frequency 4000 Hz is travelling with a velocity of 340 m/s. Find the displacement of a particle at a distance of 0.102 m from the origin after 1.001 second.

6. The equation of a simple harmonic progressive wave is,

   $y = 4 \sin 2\pi\left(\frac{t}{0.002} - \frac{x}{35}\right)$ where x and y are in cm and t in second. Calculate:
   i. frequency ii. wavelength
   iii. period of the wave.

7. A set of 8 tuning forks are arranged in a series of increasing order of frequencies. Each fork gives 4 beats per second with the preceding one and the last fork is twice the frequency of the first.
   Find the frequency of the first for

8. The equation of a progressive wave along a stretched string is,
   $y = 0.001 \sin 4\pi t(100t - 10x)$, where all the quantities are expressed in SI units. Find the
   i. amplitude ii. period
   i. frequency iv. wavelength

9. Set of 21 tuning forks is arranged in a series of decreasing frequencies. Each tuning fork gives 4 beats per second with the preceding tuning fork and the first tuning fork is an octave of the last. Find the frequency of the
   i. first tuning fork and
   ii. tenth tuning fork.

10. A set of 26 tuning forks are arranged in a series of increasing frequencies. If each fork gives 4 beats per second with the preceding one and the frequency of last fork is twice the frequency of the first. Find the frequencies of the first and last fork.

11. Two tuning forks P and Q produce 4 beats per second when sounded together. The frequency of the tuning fork P 'is 256 Hz. When the prongs of the tuning fork Q are filed, the number of beats produced per second decreases. Find the natural frequency of the tuning fork Q.

Section B : Theoretical Board Questions

1. Define amplitude wavelength, period and frequency of a wave and derive a relation between velocity, frequency and wavelength. [Mar 96]

2. What is Doppler effect? Give its any two applications. [Mar 97]

3. State the principle of superposition of waves. Show that the beat frequency is equal to the difference in the frequencies of the two sound waves. [Oct 97]

4. What are waxing and waning in the phenomenon of beats? Show that waxing and waning occur periodically. [Mar 98]

5. Explain the effect on the phase of a sound wave when it reflects from
   i. denser medium and
   ii. rarer medium. [Oct 98]

6. Define transverse wave. Explain how phase changes when sound waves are reflected from denser medium. [Feb 02]

7. Two identical progressive waves travelling through a medium in opposite directions interfere with each other. Deduce the equation bf resultant Wave. Hence'show that nodes and antinodes are equally spaced. **[Oct 03]**

8. Define simple'harmonic progressive wave. Obtain the equation for a simple harmonic progressive wave. **[Mar 05]**

9. What are beats? Deduce analytically the expression for beat frequency. **[Oct 11]**

10. Derive an expression for one dimensional simple harmonic progressive wave travelling in the direction of positive X-axis. Express it in'two'different forms. **[Oct 13]**

Section C: Numerical Board Problems

1. Wavelength of two sound notes in air are 85/170 m and 85/172 m. Each of these notes produce 4 beats per second with a third note of fixed frequency. Find the frequency of third note and velocity of sound in air. **[Oct 92, Feb 01]**

2. The, equation of a simple harmonic progressive wave is given by,

   $y = 0.05 \sin 2\pi \left(10t \pm \frac{x}{12}\right)$ where all quantities are in SI units. Calculate the displacement of a particle at a distance 5m from the origin, after 0.1s. Also find the phase difference between two particles separated by a distance of 5 m. **[Oct 96]**

3. Write down the equation of a progressive wave of amplitude 0.02 m and period of 0.05 s travelling along a stretched string with a velocity 10 m/s. **[Oct 97]**

4. A sound note emitted from certain source has a velocity of 300 m/s in air and 1050 m/s in water. If the wavelength of sound note in air is 1.5 m, find wavelength in water. [Mar **98]**

5. A sound wave of amplitude 10 cm and frequency 1000 Hz is travelling with velocity of 300 m/s. Calculate the displacement of a particle at a distance of 3 m from the origin after 1.001 Second. **[Mar 99]**

6. A set of 31 tuning forks are arranged in series of decreasing frequencies. Each fork gives 6 beats per second with the preceding one and the frequency of the first fork is twice the frequency of the last. Find the frequency of the first and last tuning forks. **[Mar 99]**

7. A simple harmonic progressive wave of amplitude 5 cm and frequency 5 Hz is travelling in positive X-direction with speed of 40 m/s. Calculate displacement at x = 30 m and at time t - 1 sec. [Mar **2000]**

8. Wavelengths of two sound waves in air are 82/173 m and 82/171 m. They produce 9 beats/sec. Calculate the velocity of sound in air. [Mar **2000]**

9. A sound wave of amplitude 20 cm and frequency 1000 Hz is travelling with a velocity of 310 m/s. Calculate displacement of a particle at a distance of 3.1 m from the origin after 1.004 second. Find the phase difference between:

   i. two particles in the path of wave separated by 0.0775 m.

   ii. two position of a particle after a time interval of 0.001 second.

   [Oct 2000, Feb 04]

10. The equation of a transverse wave on a stretched string is

    $y = 2 \sin 2\pi \left(\frac{t}{0.04} - \frac{x}{40}\right)$ where distances are in metre and time in second. Find the

    i. amplitude

    ii. frequency

    iii. velocity of the wave. [Feb **01]**

11. The equation of a simple harmonic progressive wave is

    $y = 0.4 \sin 100 \left(t - \frac{x}{40}\right)$ in SI units.

    Calculate

    i. wavelength and

    ii. I speed of the wave. **[Oct 01]**

12. The equation of a simple harmonic progressive wave is

$y = 0.04 \sin \frac{\pi}{17}(340\,t - x)$ where all the quantities are in SI units.

Determine period, wavelength and speed of the wave. **[Oct 02]**

13. A tuning fork C produces 6 beat/sec with another tuning fork D of frequency 320 Hz. When a little wax is put on the prongs of C, then number of beats reduces to 4 per second. Find the frequency of C. **[Feb 03]**

14. The equation of a simple harmonic progressive wave on a stretched string is $y = \sin n\,(20t - 2x)$ where all the quantities are in SI units, find

i. frequency ii. wavelength and

iii. velocity of the wave. **[Oct 03]**

15. A sound wave of amplitude 20 cm having frequency 1000 Hz and wavelength 0.31 m is travelling in air medium. Calculate the displacement of the particle at a distance of 3.1 m from the origin after 1.004 sec. What would be the phase difference for two positions of vibrating particle after an interval of 0.001 sec? **[Feb 04]**

16. Wavelength of two notes in air are $\frac{80}{177}$ m and $\frac{80}{175}$ m. Each produce 4 beats per second with a third note of fixed frequency. Determine velocity of sound in air.

[Oct 04]

17. A progressive wave of frequency 25 Hz is travelling through a medium. Find the phase difference between two positions of a particle at an interval of 0.01 second. **[Mar 05]**

18. Wavelength of two sound notes in air are 70/153 m. and 70/157 m. Each of these notes produces 8 beats per sec with a third note of fixed frequency. What is the velocity of sound in air and the frequency of third note?

[Oct 05]

19. Write down the equation of simple harmonic progressive wave of amplitude 0.05 m and period 0.04 sec, travelling along positive X-axis with a velocity of 12.5 m/s.

[Feb 06]

20. Equation of two simple harmonic progressive waves arriving at a point in the medium simultaneously are given by,

$y_1 = 0.05 \sin 2\pi\left(50t - \frac{x}{1}\right)$ m and

$y_2 = 0.05 \sin 2\pi\left(55t - \frac{x}{2}\right)$ m, calculate

i. Wavelength of the first wave.

ii. Beat frequency when sounded together.

[Mar 07]

21. Eleven tuning forks are arranged in the ascending order of their frequencies. Each tuning fork gives 5 beats per second with the preceding tuning fork. If the frequency of last tuning fork is 1.5 times that of the first, find the frequencies of first and last forks. **[Mar 07]**

22. Wavelengths of two notes in air are $\frac{83}{170}$ m and $\frac{83}{172}$ m. Each of these notes produce 4 beats 172 per second with the third note of fixed frequency. Find the velocity of sound in air. **[Mar 08]**

23. A simple harmonic progressive wave is given by the equation $Y = 0.1 \sin 4\pi\,(50t - 0.1\,x)$ in S.I. units. Find the amplitude, frequency, wavelength and velocity of the wave.

[Mar 10]

24. 32 tuning forks are arranged in descending order of frequencies. If any two consecutive tuning forks are sounded together the number of beats heard is eight per second. The frequency of the first tuning fork is an octave of the last fork. Calculate the frequency of the first, last and the 21st fork.

[Oct 10]

<u>Section D: MuItipleChoice Questions</u>

1. A physical quantity that does not change when a wave enters from one medium to another medium is .

(A) amplitude (B) wavelength

(C) velocity (D) frequency

2. Which of the following properties of a wave is independent of the other properties?

(A) Velocity (B) Amplitude
(C) Wavelength (D) Frequency

3. The speed of a transverse wave (v) along a stretched string is given by **[Mar 08]**

(A) $\sqrt{\frac{T}{m}}$ (B) $\sqrt{\frac{m}{T}}$
(C) $\sqrt{\frac{P}{E}}$ (D) $\sqrt{T.m}$

4. When the prongs of tuning fork are loaded its frequency

(A) decreases.
(B) increases.
(C) remains unchanged.
(D) sometimes increases and sometimes decreases.

5. Which of the following is NOT essential for periodic motion?

(A) It should be oscillatory.
(B) It should be vibratory.
(C) Itshould be stationary.
(D) All of these

6. There is no net transfer of energy by the particles of the medium in --------

(A) longitudinal Wave
(B) transverse wave
(C) progressive wave
(D) stationary wave

7. The equation of a progressive wave is

$$y = 0.02 \sin 2\pi \left[\frac{t}{0.01} - \frac{x}{0.3}\right]$$

Here x and y are in metre and t is in second. The velocity of propagation of the wave is

(A) 300 ms^{-1}
(B) 30 ms^{-1}
(C) 400 ms^{-1}
(D) 40 ms^{-1}

8. If two waves of amplitude 'A' produce resultant wave of amplitude 'A', then two waves have phase difference of

(A) $\pi/3$ (B) $\pi/2$
(C) $2\pi/3$ (D) π

9. The wavelength of sound from a tuning fork of frequency 330 Hz is nearly

(A) 100 cm (B) 1000 cm
(C) 10 cm (D) 330 cm

10. Waxing and waning of sound is noticeable if a waxing and waning repeats at an interval

(A) of less than 1/10 sec.
(B) of more than 1/10 sec.
(C) between 1/10 sec and 1/3 sec.
(D) between 1/3 sec and 1 sec.

11. Equation of a plane progressive wave is given by $y = 1.2 \sin 2\pi \left(t - \frac{x}{2}\right)$.

On reflection from a denser medium its amplitude becomes 2/3 of amplitude of the incident wave. The equation of the reflected wave is

(A) $y = -0.8 \sin 2\pi \left(t + \frac{x}{2}\right)$

(B) $y = 0.8 \sin 2\pi \left(t + \frac{x}{2}\right)$

(C) $y = -0.8 \sin 2\pi \left(t - \frac{x}{2}\right)$

(D) $y = 0.8 \sin 2\pi \left(t - \frac{x}{2}\right)$

12. For the propagation of which one of the following types of waves a material medium is essential? ,

(A) Light waves
(B) Sound waves
(C) Radio waves
(D) Electromagnetic waves

13. Which of the following expression is that of a simple harmonic progressive wave?

(A) A sin πt (B) A sin πt cos kx
(C) A sin (πt-kx) (D) Aco skx

14. From a point source, if amplitude of waves at a distance r is A, its amplitude at a distance 2r will be

(A) A (B) 2A

(C) A/2 (D) A/4

15. Two waves represented by

$y_1 = A \sin wt$ and

$y_2 = A \sin (wt + a)$ with $a = \frac{p}{2}$ are superimposed at any point at a particular instant. The resultant amplitude is

(A) A (B) 4A

(C) $\sqrt{2}$ A (D) Zero

16. Two simple harmonic motions are represented by $yi = 4 \sin (4pt - y_2)$,

$y_2 = 3 \cos (4pt)$. The resultant amplitude is

(A) 7 (B) 1

(C) 5 (D) $2 + \sqrt{3}$

17. A vibrating tuning fork emits sound waves of period 2×10^{-3} second and wavelength 0.7 m in air. The velocity of sound in air is

(A) 175 m/s (B)330 m/s

(C) 340 m/s (D) 350 m/s

18. When a simple harmonic progressive wave travels through the medium, the relation between phase difference and path difference is

(A) Path difference = (2p/l) phase difference

(B) Path difference = (l/2p) of the phase angle

(C) Phase difference = (2p/l) path difference

(D) Phase difference = (p/2l) path difference

19. The distance between two consecutive crests in a wave train produced in a string is 5cm. If 2 complete waves pass through any point per second, the velocity of the wave is

(A) 10 cm/sec (B) 2.5 cm/sec

(C) 5 cm/sec (D) 15 cm/sec

20. The displacement y of a wave travelling in the X-direction is given by,

$y = 10^{-4} \sin (600t - 2x + \frac{p}{3})$ metre, The speed of the wave is

(A) 1200 m/s (C) 300 m/s

(B) 200 m/s (D) 600 m/s

21. Which of the following is not the characteristic of longitudinal waves?

(A) Reflection (B) Refraction

(C) Polarisation (D) Interference

22. The frequency of man's voice is 300 Hz. If velocity of sound waves is 336 ms" , the wavelength of the sound is

(A) 300/336 m (B) 300 x336 m

(C) 1.12 m (D) 11.2 m

23. In the equation of a simple harmonic progressive wave of wavelength l, the propagation constant is given by

(A) $\frac{2p}{l}$ (B) p l

(C) $\frac{p}{l}$ (D) $\frac{1}{2p}$

24. Equation .y = yo sin (kx + wt) represents a wave

(A) travelling in positive Y-direction.

(B) travelling in negative Y-direction.

(C) travelling in positive X-direction.

(D) travelling in negative X-direction.

25. A sound source is moving towards stationary listener with $\left(\frac{1}{10}\right)^{th}$ the speed of sound. The ratio of apparent to real frequency is

(A) $\left(\frac{9}{10}\right)^2$ (B) $\frac{10}{9}$

(C) $\frac{11}{10}$ (D) $\left(\frac{11}{10}\right)^2$

26. If x = acos wt and y = a sin (wt + p/6***)***, then what is the phase difference between the two waves ?

(A) $\frac{p}{3}$ (B) $\frac{p}{6}$

(C) T (D) p

27. A particle on the trough of a wave at any instant will come to the mean position after a time

(A) $\frac{T}{2}$ (B) $\frac{T}{4}$

(C) T (D) 2T

28. The waves $y_1 = 5 \sin 5161$ and $y_2 = 5 \sin 5241$ are travelling in same direction. The number of beats produced per second will be

(A) 8 (B) $4/\pi$

(C) 4π (D) 4

29. When a longitudinal wave is passing through air, the instantaneous acceleration of the particle is proportional to its

(A) velocity

(B) displacement

(C) time period

(D) frequency

30. In a simple harmonic progressive wave of amplitude 10 cm, the maximum particle velocity is two times its wave velocity, then the wavelength of the wave is ....

(A) 3.14 cm (B) 15.7 cm

(C) 31.4 cm (D) 157 cm

31. A wave travelling in positive X-direction with A = 0.2, velocity = 360 m/s and λ = 60 m, then correct expression for the wave is,

(A) $y = 0.2 \sin\left[2\pi\left(6t - \frac{x}{60}\right)\right]$

(B) $y = 0.2 \sin\left[\pi\left(6t - \frac{x}{60}\right)\right]$

(C) $y = 0.2 \sin\left[2\pi\left(6t + \frac{x}{60}\right)\right]$

(D) $y = 0.2 \sin\left[\pi\left(6t + \frac{x}{60}\right)\right]$

32. If a wave enters from air to water, then what remains unchanged?

(A) Frequency

(B) Amplitude

(C) Velocity

(D) Wavelength

33. A source of sound is travelling towards a stationary observer. The frequency of sound heard by the observer is three times the original frequency. The velocity of sound is v m/sec. The speed of source will be

(A) $\frac{2}{3}$ v (B) v

(C) $\frac{3}{2}$ (D) 3v

34. One beat means that the intensity of sound should be _______. **[Mar 10]**

(A) once maximum

(B) once minimum

(C) once maximum and once minimum

(D) twice maximum and twice minimum

35. The path difference between the two waves

$y_1 = a_1 \sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$ and

$y_2 = a_2 \cos\left(\omega t - \frac{2\pi x}{\lambda} + \delta\right)$ is

(A) $\frac{\lambda}{2\pi}\delta$ (B) $\frac{\lambda}{2\pi}(\delta + \pi/2)$

(C) $\frac{2\pi}{\lambda}(\delta - \pi/2)$ (D) $\frac{2\pi}{\lambda}\delta$

36. Two tuning forks A and B give 4 beats per second when sounded together. The frequency of A is 320 Hz. When some wax is added to B and it is sounded with A, 4 beats per second are again heard. The frequency of B is

(A) 312 Hz (B) 316 Hz

(C) 324 Hz (D) 328 Hz

37. The equation of a simple harmonic progressive wave travelling along negative direction of x-axis is [Oct **10**]

(A) $Y = a \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

(B) $Y = a \sin \frac{2\pi}{\lambda}(vt - x)$

(C) $Y = a \sin \pi\left(nt + \frac{x}{\lambda}\right)$

(D) $Y = a \sin 2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right)$

38. The phase difference between two points separated by 0.8 m in a wave of frequency 120 Hz is 90°. The wave velocity is

(A) 192 m/s (B) 384 m/s

(C) 38.4 m/s (D) 19.2 m/s

39. A transverse wave is reflected from rigid support. The change of phase after reflection will be

(A) p (B) p/2

(C) 0 (D) p/4

40. In reflection of sound waves from rarer medium, there is phase change of _____

[Mar **08]**

(A) 0 rad (B) $\frac{p}{4}$rad

(C) $\frac{p}{2}$rad (D) p rad

41. In a sinusoidal wave, the time required for a particular point to move from maximum displacement to zero displacement is 0.17 sec. The frequency of the wave is

(A) 1.47 Hz (B) 0.36 Hz

(C) 0.73 Hz (D) 2.94 Hz

42. If the phase difference between two points is 60°, on a wave of velocity 360 m/s and frequency 500 Hz, then path difference between the two points is

(A) 1 cm (B) 6 cm

(C) 12 cm (D) 24 cm

43. The angle between paticle velocity and wave velocity in transverse wave is _____ .

[Mar 11]

(A) zero rad (B) $\frac{p}{2}$rad

(C) $\frac{p}{4}$rad (D) p rad

44. A wave is represented by the equation $y = 0.5 \sin(10t + x)$ m. It is a travelling wave propagating along negative direction of X-axis with velocity

(A) 10 m/s (B) 20 m/s

(C) 5 m/s (D) 15 m/s

45. Two identical strings of different materials are stretched under the same tension. Velocity of the transverse waves in the strings are

(A) same.

(B) proportional to their densities.

(C) different.

(D) inversely proportional to their densities.

46. For the phenomenon of interference, the necessary conditions are

(A) The two sources must he of same frequency.

(B) The, two sources must have same amplitude.

(C) The two sources must be in the same phase.

(D) All the above three conditions are necessary.

47. Apparent frequency of the sound heard by a listener is less than the actual frequency of sound emitted by source. In this case:

[Oct 13]

(A) listener moves towards source.

(B) source moves towards listener.

(C) listener moves away from the source.

(D) source and listener move towards each other.

48. Mechanical waves on the surface of a liquid are

(A) transverse

(B) longitudinal

(C) torsional

(D) both transverse and longitudinal

49. When a transverse wave on a string is reflected from the free end, the phase change produced is ______. [Feb **2013]**

(A) zero rad (B) $\frac{p}{2}$rad

(C) $\frac{3p}{4}$rad (D) p rad

50. In case of the longitudinal mechanical wave in air what is the phase difference between the pressure wave and the displacement Wave ?

(A) 0° (B) 45°
(C) 90° (D) 180°

51. What is the nature of motion of the water particles: when ripples propagate on its surface?
(A) Straight line (B) Circular
(C) Parabolic (D) Elliptical

52. Wavelength of the wave is the distance between two particles of the medium having a phase difference of
(A) p/2 (B) 2p
(C) 3p/4 (D) zero

53. A transverse wave passes through a string with the equation y = 10 sin p(0.02x – 2.00t), where x is in metre and t in seconds. The maximum velocity of the particles in wave motion is
(A) 63 (B) 100
(C) 78 (D) 121

54. By Quinke's tube experiment, ... of two sound waves can be demonstrated,
[Oct 11]
(A) super position
(B) refraction
(C) reflection
(D) reflection and refraction

55. With the propagation of a longitudinal wave through a material medium, the quantities transmitted in the propagation direction are
(A) energy, momentum and mass
(B) energy
(C) energy and mass
(D) energy and linear momentum

56. The phenomenon of beats is due to
(A) superposition of incoherent waves.
(B) superposition of coherent waves.
(C) reflection.
(D) refraction.

57. The equation of a sound wave travelling along negative X-axis is
y = 0.04 sinrc (500t + 1.5 x) metre. Its amplitude is
(A) 0.4 m (B) 0.04 m
(C) 4 m (D) 40 m

58. A tuning fork makes 256 vibrations per second in air. When velocity of sound is 330 m/sec, then wavelength of the tone emitted is
(A) 0.56 m (B) 0.89 m
(C) 1.11m (D) 1.29 m

59. Phenomenon of beats is audible if the difference in the frequencies of the sound wave is
(A) very large (B) zero
(C) more than 20 (D) less than 20

60. Two sound waves of equation

$y_1 = 3 \sin (200\ pt - \frac{2px}{4.9})$ cm and

$y_2 = 3 \sin (200\ pt - \frac{2px}{4.9})$ superimpose each

other at a point. Number of beats produced per second will be
(A) 10 (B) 20
(C) 5 (D) 15

61. When transverse wave is propagated through the medium, the successive particles A and B are on trough, then the phase difference between A and B in radian is .
[Mar 12]
(A) p (B) 2p
(C) 3p (D) 4p

62. Two waves of wavelength 2 m and 2.02 m respectively, moving with the same velocity superimpose to produce 2 beats per second. The velocity of the wave is
(A) 42.2 m/s (B) 420 m/s
(C) 404 m/s (D) 40.6 m/s

63. A source X of unknown frequency produces 8 beats per second with a source of 250 Hz and 12 beats per second with a source of 270 Hz. The frequency of the source X is
(A) 242 Hz (B) 258 Hz
(C) 282 Hz (D) 262 Hz

64. Two tuning forks of frequency 256 and 258 vibrations per second are sounded together, then time interval between consecutive maxima heard by the observer is
(A) 2 s (B) 0.5 s
(C) 250 s (D) 252 s

65. Two tuning forks X and Y are sounded together and 6 beats are produced per second. The frequency of X is 512 Hz. When Y is filed and the two forks are sounded again together, 6 beats per second are heard again. The frequency of Y before and after filing are respectively,

(A) 506 Hz and 512 Hz
(B) 512 Hz and 506 Hz
(C) 510 Hz and 516 Hz
(D) 516 Hz and 510 Hz

66. 20 tuning forks are so arranged in series that each fork gives 4 beats per second with the previous one. The frequency of the 20' fork is 3 times that of the first. What is the frequency of the first tuning fork?

(A) 38 Hz (B) 40 Hz
(C) 57 Hz (D) 60 Hz

67. When both source and listener approach each other with a velocity equal to half the velocity of sound, the change in frequency of the sound as detected by the listener is

(A) zero (B) 25%
(C) 50% (D) 200%

68. Doppler effect is not applicable when ____ [Feb 2013 old course]

(A) the source and observer are moving towards each other.
(B) there is relative motion between source and observer.
(C) the source is at rest and observer is moving.
(D) source and observer are moving in the same direction with the same speed

ANSWERS

Section A

1. i. 0.01 m
   ii. 50 Hz,
   iii. 40 m/s
2. 352 m/s
3. i. 412.1 Hz
   ii. 388.6 Hz
4. 1889 Hz
5. 0
6. i. 500 Hz
   ii. 35 cm
   iii 0.002 s
7. 28 Hz
8. i. 0.001 m
   ii. 0.005 s
   iii. 200 Hz
   iv. 0.05 m
9. i. 160 Hz
   ii. 124 Hz
10. 100 Hz, 200 Hz
11. 252 Hz

Section C

1. 340 ms^{-1}, 684 Hz
2. 025 m, $\frac{5p}{6}$ radian
3. $0.02\sin\frac{2p}{0.05}\left(t \pm \frac{x}{10}\right)m$
4. 5.25 m
5. 0
6. 360 Hz, 180 Hz
7. 0.05 m
8. 369 m/s
9. 0
   i. p/2 rad ii. 2p rad
10. i. 2 m ii. 25 Hz
    iii. 1000 m/s
11. i. 0.8 m ii. 40 m/s
12. 0.1 s, 34 m, 340 m/s
13. 314 Hz
14. i. 10 Hz ii. 1 m
    iii. 10 m/s

15. 0, 2π radian
16. 320 m/s
17. $\frac{\pi}{2}$ radian

    2
18. 280 m/s, 620 Hz
19. $0.05 \sin 2\pi \left(\frac{t}{0.04} - \frac{x}{0.5}\right)$ m
20. i. 2.2 m

    ii. 5 beats/s
21. 100 Hz, 150 Hz
22. 332 m/s
23. 0.1 m, 100 Hz, 5 i
24. 496 Hz, 248 Hz, 336 Hz

24. 496 Hz, 248 Hz, 336 Hz

Section D

1. (D)	2. (B)	3. (A)	4. (A)
5. (C)	6. (D)	7. (B)	8. (C)
9. (A)	10. (B)	11. (A)	12. (B)
13. (C)	14. (C)	15. (C)	16. (A)
17. (D)	18. (C)	19. (A)	20. (C)
21. (C)	22. (C)	23. (A)	24. (D)
25. (B)	26. (A)	27. (B)	28. (B)
29. (B)	30. (C)	31. (A)	32. (A)
33. (A)	34. (C)	35. (B)	36. (C)
37. (D)	38. (B)	39. (A)	40. (A)
41. (A)	42. (C)	43. (B)	44. (A)
45. (C)	46. (A)	47. (C)	48. (D)
49. (A)	50. (C)	51. (D)	52. (B)
53. (A)	54. (A)	55. (D)	56. (B)
57. (B)	58. (D)	59. (D)	60. (C)
61. (B)	62. (C)	63. (B)	64. (B)
65. (A)	66. (A)	67. (D)	68. (D)