

# A. Waves

## Chapter 1: Wave Motion

### Short Answer Questions

1. **2076 Set B Q.No. 3a** Can longitudinal wave be polarized? Explain. [2]

Ans. Polarization is the phenomenon of restriction of wave to vibrate in a single direction. The transverse wave vibrates in all directions and we can cut off other directions restricting vibration in a single direction. The longitudinal waves vibrate in a single direction (in the direction of propagation of wave) i.e. this wave is already polarized. Due to this reason, longitudinal waves can not be polarized.

2. **2076 Set C Q.No. 3a** How are stationary waves formed? [2]

Ans. **Stationary (or standing) wave:** when two progressive waves of the same wavelength and amplitude travelling with the same speed through a medium in opposite directions and superimpose upon each other, they give rise to a wave which is called stationary wave.

In stationary wave, there are certain points where the amplitude of vibration is always zero. These points are known as nodes.

Midway between these nodes, there are other points where amplitude of vibration is maximum. These points are known as antinodes. The formation of stationary wave along with nodes and antinodes is shown in figure.

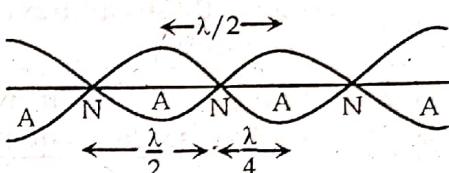


Fig: Stationary wave

3. **2075 GIE Q.No. 3a** **2072 Set D Q.No. 3a** Distinguish between progressive waves and stationary waves. [2]

Ans. Differences between progressive wave and stationary wave are:

Progressive waves	Stationary waves
▪ The disturbance travels in forward direction.	▪ The disturbances are confined to a particular region.
▪ The amplitude of vibration of each particle is same.	▪ The amplitude is zero at nodes and maximum at antinodes.
▪ Energy is transferred forward along the waves.	▪ There is no transfer of energy in the medium.
▪ No particles in the medium are permanently at rest but momentarily at rest at the extreme positions.	▪ Particles at the nodes are permanently at rest.

4. **2075 Set A Q.No. 3a** We can't hear echo in a small room. Why? [2]

Ans. The minimum distance between the listener and the wall (reflecting surface) must be 17m to hear an echo. If a room is small, this requirement is not fulfilled. Due to persistence of hearing (0.1Sec), our ears cannot detect the repeated sounds i.e. we cannot hear echo.

5. **2075 Set B Q.No. 3a** Frequency is the most fundamental property of a wave. Why? [2]

Ans. The frequency is the most fundamental property of a wave as it is determined from the wave source. In a wave motion, its velocity and wavelength may change with the medium in which it passes but frequency does not change. Due to this reason, frequency of a wave is taken as empirical parameter.

6. **2073 Supp Q.No. 3a** **2058 Q.No. 1 c** If you are walking on the moon surface, can you hear the cracking sound behind you? Explain. [2]

Ans. Sound wave is a mechanical wave so it requires a medium for propagation but there is no atmosphere i.e. medium on the moon surface. There is lack of atmosphere on the moon because of its weak gravity. So, due to lack of medium (i.e. atmosphere), the propagation of sound waves on moon

surface is not possible. That is why we cannot hear the cracking sound behind us on the surface of moon.

7. [2069 Q.No. 3b] A radio station broadcasts at 800 KHz. If the radio waves (em-waves) travel with a speed of  $3 \times 10^8$  m/s, what will be the wavelength of the wave? [2]

Frequency ( $f$ ) = 800 KHz =  $800 \times 10^3$  Hz

Wavelength ( $\lambda$ ) = ?

Speed ( $c$ ) =  $3 \times 10^8$  m/s

We have,

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{ m/s}}{800 \times 10^3} = 375 \text{ m}$$

8. [2069 (Set A) Old Q.No. 1d] Why echo cannot be heard in a small room? [2]

Ans. Please refer to [2075 Set A Q.No. 3a]

9. [2068 Can. Q.No. 3a] Distinguish between light waves and sound waves. [2]

Ans. The main differences between sound waves and light waves are:

Light waves	Sound waves
1. Light waves are electromagnetic waves because these can travel in medium as well as in vacuum.	1. Sound waves are mechanical waves because they travel only in medium.
2. The speed of light wave is greater i.e. $3 \times 10^8$ m/sec in vacuum or air.	2. The speed of sound wave is smaller i.e. 330m/sec at $0^\circ\text{C}$ in air.
3. They are transverse wave.	3. They are longitudinal wave.
4. Their wavelength is short.	4. Their wavelength is long.
5. Light wave can be polarized.	5. Sound wave can not be polarized.

10. [2067 Sup Q.No. 3b] Longitudinal waves cannot be polarized. Why? [2]

Ans. Please refer to [2076 Set B Q.No. 3a]

11. [2063 Q.No. 1c] Which types of wave propagate in liquid, explain. [2]

Ans. For the propagation of transverse wave, the modulus of rigidity of the medium is responsible and for the propagation of longitudinal wave, the bulk modulus of elasticity is responsible. A solid has both modulus of rigidity and bulk modulus but liquids have only bulk modulus. Hence only longitudinal wave can propagate inside the liquid.

12. [2062 Q.No. 2c] Do sound waves undergo reflection, refraction and polarization phenomena? Explain. [2]

Ans. Yes, sound waves undergo reflection and refraction phenomenon. Sound waves are reflected from surfaces like walls, ground, big halls etc while striking on them. During night hearing of sound is clearer than at day time due to the refraction of sound. But sound wave does not undergo polarization phenomenon because it is a longitudinal wave, and only transverse wave undergoes the phenomenon of polarization.

13. [2055 Q.No. 1b] How are stationary waves formed?

Ans. Please refer to [2076 Set C Q.No. 3a]

### Long Answer Questions

14. [2074 Set B Q.No. 7a] [2070 Set D Q.No. 7a] How is a progressive wave different from a stationary wave? Derive an equation for a progressive wave. [4]

Ans. **Progressive wave:** A wave that travels from one region of medium to another region carrying energy in the form of crest and trough or compression and rarefaction is called the progressive wave. Both transverse and longitudinal waves are progressive waves. E.g., water wave, sound wave, light wave etc. are progressive waves. The motion of progressive wave is given below.

**Equation of progressive wave:** Let us consider a wave is travelling from left to right as shown in figure, the displacement of the vibrating particle in the medium is given by,

$$y = a \sin \omega t \quad \dots (i)$$

where  $a$  is amplitude,  $t$  is time and  $\omega = 2\pi f$  and  $f$  is frequency of vibration. If  $\phi$  be the phase angle of the particle  $P$  at distance  $x$  from  $O$ , then the displacement equation given by

$$y = a \sin(\omega t - \phi) \dots (ii)$$

Since, for a path diff.  $\lambda$ , phase diff. is  $2\pi$ .

And for a path diff.  $x$ , phase diff. is  $\frac{2\pi}{\lambda} x$ .

$$\text{i.e., } \phi = \frac{2\pi}{\lambda} x$$

$$y = a \sin(\omega t - \frac{2\pi}{\lambda} x)$$

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

$$y = a \sin(\omega t - kx) \dots (i) \quad [ \because k = \frac{2\pi}{\lambda}, \text{ a wave number or wave vector} ]$$

If the wave is travelling from right to left, then the displacement of the particle is given by,

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

These equations (i) and (ii) are the plane progressive wave equations.

15. **2072 Set C Q.No. 7a** What is a wave motion? Derive progressive wave equation in a medium. [4]

☛ Please refer to **2074 Set B Q.No. 7a**

16. **2072 Set E Q.No. 7a** **2066 Supp Q.No. 5a** Define progressive waves. Derive an equation to represent this wave. [4]

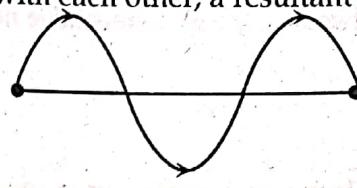
☛ Please refer to **2074 Set B Q.No. 7a**

17. **2070 Sup (Set A) Q.No. 7 b** **2068 Q.No. 7 b** What is the principle of superposition of waves? Discuss the result of superposing two waves of equal amplitude and same frequency travelling in opposite direction. [4]

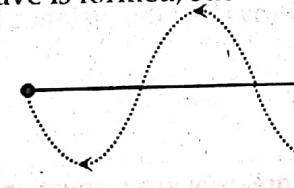
☛ Principle of Superposition of Waves: It states that if two or more progressive waves traveling together in a medium, converges to a point, the resulting displacement of the particle at that point is equal to the algebraic (vector) sum of individual displacements of the waves. Let  $y_1, y_2, y_3, \dots, y_n$  be the displacement at a point due to individual waves then the resultant displacement,  $y$  at the same time when the waves superpose to each other is given by

$$y = y_1 + y_2 + y_3 + \dots + y_n$$

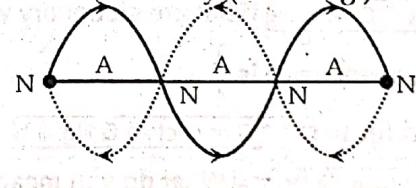
**Stationary (or standing) wave:** Whenever two progressive waves of the same (or nearly same) wavelength and amplitude travel in opposite directions with the same speed in a medium superpose with each other; a resultant wave is formed, such a wave is called stationary (Standing) wave.



(i)  
Original Wave



(ii)  
Reflection Wave



(iii)  
Stationary Wave

Fig: Formation of Stationary Wave

Let us consider a progressive wave of wavelength  $\lambda$  is travelling to right as in fig(i) strikes to a pole or reflector and a reflecting wave is formed which propagate in opposite direction as in fig(ii). When these two waves combine with each other in a medium, another resultant wave is formed which is called stationary wave as fig(iii).

This wave is called stationary wave because there is no flow of energy along the wave. When a stationary wave is formed due to the superposition of two waves, the points of maximum and zero amplitude are resulted alternatively in the space. The points where the amplitude of vibration is maximum are called anti-nodes and those where the amplitude is zero are called nodes. The distance

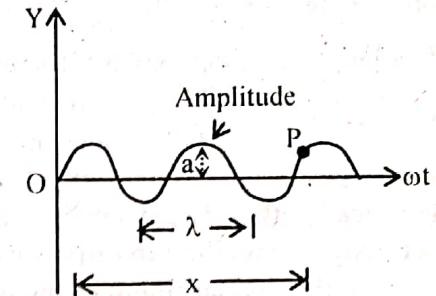


Fig: Progressive Wave

between two consecutive nodes or antinodes is equal to half of the wavelength i.e.  $\frac{1}{2}\lambda$ , where  $\lambda$  is wavelength of a wave. Also, the distance between adjacent node and antinode is equal to one quarter of wavelength i.e.  $\frac{1}{4}\lambda$ .

**Stationary wave equation:** Stationary wave equation can be obtained by opposite adding vectorically the displacements of two waves of equal amplitude, frequency (or period) and wavelength travelling in opposite directions.

Let  $y_1$  be the displacement of the wave travelling to the positive x-direction,

$$y_1 = a \sin(\omega t - kx) \quad \dots \text{(i)}$$

And,  $y_2$  be the displacement of the wave travelling to the negative x-direction.

$$y_2 = a \sin(\omega t + kx) \quad \dots \text{(ii)}$$

By using the principle of superposition of waves, the resultant displacement  $y$  is given by

$$y = y_1 + y_2$$

$$= a \sin(\omega t - kx) + a \sin(\omega t + kx)$$

$$= a [\sin(\omega t - kx) + \sin(\omega t + kx)]$$

$$= a [\sin \omega t \cos kx - \cos \omega t \sin kx + \sin \omega t \cos kx + \cos \omega t \sin kx]$$

$$= 2a \sin \omega t \cos kx = 2a \sin \frac{2\pi}{T} t \cos \frac{2\pi}{\lambda} x$$

$$y = A \sin \frac{2\pi}{T} t \cos \frac{2\pi}{\lambda} x \quad \dots \text{(iii)}$$

where,  $A = 2a \cos \frac{2\pi x}{\lambda}$  be the amplitude of resultant wave.

Equation (iii) is the equation of stationary wave equation.

**Case I:** For  $x = 0, \frac{\lambda}{2}, \frac{2\lambda}{2}, \frac{3\lambda}{2}, \dots$

then,  $A = 2a$  is maximum amplitude.

Thus, these points are antinodes.

**Case II:** For  $x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}, \dots$

then,  $A = 0$  is minimum or zero amplitude.

Thus, these points are nodes.

- Distance between two consecutive nodes or antinodes is  $\frac{\lambda}{2}$  and distance between any two consecutive nodes and antinodes is  $\frac{\lambda}{4}$ .

18. **2070 Set C Q.No. 7 a** What are stationary waves? Prove that the distance between any two consecutive nodes in a stationary wave is  $\frac{\lambda}{2}$ . [4]

19. **2068 Old Can. Q.No. 5a** What do you mean by progressive wave equation? Derive progressive wave equation in terms of its wave vector and displacement. [1+3]

20. **2063 Q.No. 6 a** State and explain the stationary wave. [4]

21. **2061 Q.No. 5 a** Use the principle of superposition of two waves to find the position of nodes and antinodes in a standing wave. [4]

22. Please refer to **2070 Sup (Set A) Q.No. 7 b** [4]

### Numerical Problems

22. [2053 Q.No. 3 OR] A wave has the equation (x in metres and t in seconds)  $y = 0.02 \sin(30t - 4x)$ . Find

i. Its frequency, speed and wave length.

ii. The equation of wave with double the amplitude but travelling in the opposite direction.

[4]

#### Solution

Given,

The given equation is

$$y = 0.02 \sin(30t - 4x)$$

Comparing this equation with the standard wave equation,

$$y = a \sin(\omega t - kx), \text{ where } k = \frac{2\pi}{\lambda}, \text{ we have}$$

$$\omega = 30$$

$$\text{or, } 2\pi f = 30$$

$$\text{or, } f = \frac{30}{2\pi} = \frac{15}{\pi}$$

$$\therefore \text{Frequency, } f = \frac{15}{\pi} = 4.77 \text{ Hz}$$

$$k = 4$$

$$\text{or, } \frac{2\pi}{\lambda} = 4$$

$$\text{or, } \lambda = \frac{2\pi}{4} = \frac{\pi}{2}$$

$$\therefore \text{Wavelength, } \lambda = \frac{\pi}{2} = 1.571 \text{ m}$$

and Speed,  $v = ?$

We know that,

$$\text{Speed, } v = \lambda f = \frac{\pi}{2} \times \frac{15}{\pi} = 7.5 \text{ ms}^{-1}$$

Hence, frequency,  $f = 4.77 \text{ Hz}$

Speed,  $v = 7.5 \text{ ms}^{-1}$

and wavelength,  $\lambda = 1.571 \text{ m}$

The equation of the wave moving in opposite direction and double the amplitude is  $y = 0.04 \sin(30t + 4x)$ .

