EXERCISE

Select the correct answer of the following questions.

1) A water wave moves in two dimensions from the source point and at a far distance the curvature of the wave front becomes plane. As the wave proceeds the energy carried by the wave.

a. Decreases b. Increases
c. Remains constant d. It needs some more information

2) When a wave goes from one medium to another medium, which one of the following characteristics of the wave remains constant

a. Velocity b. Frequency c. Wave length d. Phase

3) When a transverse wave is reflected from the boundary of a denser to a rarer medium, it under goes a phase change of

a. 0 b. $\frac{\pi}{2}$ c. π d. 2π

4) If the tension in the string is doubled and its mass per unit length is reduced to half. Then the speed of transverse wave on it is

a. Doubled b. Halved c. Constant d. One fourth

5) Which one of the following properties is not exhibited by the longitudinal waves?

a. Reflection b. Interference c. Diffraction d. Polarization

6) A sounding source and a listener are both at rest relative to each other. If wind blows from the listener towards the source, then which one of the following of sound will change?

a. Frequency b. Speed
c. Both frequency and speed d. Wavelength

7) Which one of the following factors has no effect on the speed of sound in gas?

a. Humidity b. Pressure c. Temperature d. Density

8) When sound waves travel from air to water which of these remain constant?

a. Velocity b. Frequency c. Wavelength d. All the above

9) There is no net transfer of energy by particles of medium in.

a. Longitudinal wave b. Transverse wave
c. Progressive wave d. Stationary wave

10) Which one of the following could be the frequency of ultraviolet radiation?

a. 1.0×10^{14} Hz b. 1.0×10^{6} Hz c. 1.0×10^{9} Hz d. 1.0×10^{18} Hz

11) When a stationary wave is formed then its frequency is

a. Same as that of the individual waves b. Twice that of the individual waves
c. Half that of the individual waves d. Four of the individual waves

a. Triple that of the individual waves

12. Which of the following changes of an ambulance in a stationary wave?

a. Density only b. Pressure only
c. Both pressure and density d. Neither density nor pressure

13. A sound source is moving towards stationary listener with $1/10^{th}$ of the speed of sound. The ratio of apparent of real frequency is

a. $\frac{10}{11}$ b. $\frac{11}{10}$ c. $\frac{1}{10}$ d. $\frac{10}{9}$

Answers:

1.	(c)	**2.**	(c)	**3.**	(c)	**4.**	(c)	**5.**	(d)
6.	(d)	**7.**	(c)	**8.**	(b)	**9.**	(c)	**10.**	(d)
11.	(c)	**12.**	(c)	**13.**	(d)				

Write the short answer of the following:

1) What is the difference between progressive and stationary waves?

Answer

Progressive waves:

Those waves which transmit energy from one point to another point are called progressive waves. Many vibrating objects act as sources for the generations of waves. When an object vibrates, it does work on the particles of the medium and imparts energy, due to which particles of the medium start vibration. As a result energy is transferred from one place to another place without the transportation of material object.

- For example, sound waves can originate from a vibrating tuning fork and electromagnetic waves can originate from vibrating atoms.
- In case of progressive waves principle of superposition may or may not be applied.

Standing waves:

When two or more than two waves having the same amplitude & frequency traveling with the same speed in opposite direction along a line are superposed, a wave is obtained is called stationary wave or standing wave. These waves can be set up in any medium which do not transmit energy from one place to another place. Since the wave forms does not move in the direction of either the incident waves or the reflected waves.

That's why it is called stationary or standing wave.

To produce stationary waves superposition principle must be applied.

2) Clearly explain the difference between longitudinal & transverse wave.

Answer

Longitudinal waves:

Those waves in which the particles of the medium have displacements along the direction of propagation of waves, are called longitudinal waves. Generally longitudinal waves require a material medium for their propagation.

- For example, sound waves are longitudinal waves which cannot travel through vacuum.

Transverse waves:

Those waves in which the particles of the medium have displacement perpendicular to the direction of propagation of waves are called transverse

waves. Transverse waves may or may not require a material medium for their propagation.

For example, transverse waves in water certainly require medium while electromagnetic waves do not require material medium for their propagation.

3) A careful student says that he can predict the frequency of mass spring system even though he knows that how far the spring stretches when the mass is hung from it. How he justified himself?

Answer

Since the frequency of mass spring system is given by the formula

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad \text{------(1)}$$

Where 'k' is spring constant & m is mass attached to the spring. Knowing the values of 'k' & 'm' one can calculate the frequency of mass spring system. If the student does not know even that how far the spring stretches, when the mass is hung from it he can predict the frequency of oscillation. Because frequency is independent of the amplitude of vibration.

4) Is there a transfer of energy through a medium when a stationary wave is produced in it? Explain.

Answer

In stationary waves energy is confined between nodes. Since nodes always remain at rest so energy cannot flow past these points. Hence energy remains standing in the medium between nodes, although energy remains standing in

the medium between nodes, although energy alternates between potential and kinetic terms.

5) Two wave pulses travelling in opposite direction completely cancel each other as they pass. What happens to the energy possessed by the waves?

Answer

Energy in a wave moves because of the motion of the particles of the medium. When two wave pulses travelling in opposite direction completely cancel each other, results standing waves. The nodes always remain at rest so energy cannot flow these points. Hence energy remains standing in the medium between nodes although it alternates between potential and kinetic terms.

When the +ve nodes are at of their extreme displacements. The energy stored is wholly potential and when they are simultaneously passing through the equilibrium position, the energy is wholly kinetic.

6) What are the conditions of constructive and destructive interference?

Answer

- **Condition for constructive interference:**

For constructive interference the waves must be in phase. The path difference between the waves must be either zero or integral multiple of wave length 'λ' i.e.

$$\Delta = n\lambda \quad \text{where } n=0, \pm1, \pm2, \ldots\ldots$$

- **Condition for destructive interference:**

For destructive interference the two waves must be out of phase by 180° & the path difference between the waves must be half integral multiple of wave length 'λ' i.e.

$$\Delta = \left(n+\frac{1}{2}\right)\lambda$$

or

$$\Delta = \left(2n+1\right)\frac{\lambda}{2} \quad \text{where } n=0, \pm1, \pm2, \ldots\ldots$$

7) How might one can locate the position of nodes & anti nodes in vibrating string?

Answer

In a vibrating string the points which do not vibrate at all are called nodes, so one can locate the position of nodes on a string where there is zero displacement. But those points which have maximum amplitude of oscillation between nodes are called antinodes. So, one can locate the position of antinodes on a vibrating string where the amplitude of oscillation is maximum, as known in fig.

8) Is it possible for an object which is vibrating transversely to produce sound waves?

Answer

No, it is not possible for an object which is vibrating transversely to produce sound waves, because sound waves are longitudinal or compressional waves in nature which can only be produced when the object is vibrating longitudinally.

9) Why does a sound wave travel faster in solid than in gases?

Answer

The speed of sound is given by the formula

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

The speed of sound is much higher in solids than in gases, because the molecules in a solid are closer than in gas and hence, respond more quickly to a disturbance due to larger elastic modulus.

- Sound travel more slowly in gases than in solids because gases are more compressible & hence have a smaller elastic modulus.

10) Why does the speed of sound wave in gas change with temperature?

Answer

Since gases expand on heating so density of the gases decreases and contract on cooling, so density of the gases increases.

As speed of sound in gases is given as

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad \text{------(1)}$$

From the above relation it is clear that with rise in temperature, density of a gas decreases & speed of sound increases. But with the fall in temperature density of a gas increases & hence speed of sound decreases. That's why speed of sound waves in a gas changes with rise & fall in temperature.

11) Is it possible for two astronauts to talk directly to one another even if they remove their helmets?

Answer

Since sound waves are mechanical waves, which require medium for their propagation. So, in vacuum sound waves cannot travel. That's why it is not possible for two astronauts to talk directly to one another.

12) Estimate the frequencies at which a test tube 15 cm long resonates when you blow across its top.

Answer

As the test tube is closed at one end & open at the other, so it will act like resonance tube. Since the expression for frequency of 1st harmonic is given as

$$f = \frac{v}{4l} \quad \text{------(1)}$$

$$v = 320 \text{ m/s and } l = 15 \text{ cm} = 0.15 \text{ m}$$

So,

$$f = \frac{320 \text{ m/s}}{4 \times 0.15 \text{ m}}$$

$$f = 533.3 \text{ Hz}$$

Numerical Problems

1. What are the wavelengths of television station which transmits vision on 500 MHz and sound on 505 MH respectively? C = 3x10⁸ ms⁻¹

Data:

Frequency of which television transmits vision f_v=500 MHz = 500 x 10⁶ Hz

Frequency of which television transmits sound f_s=505 MHz = 505 x 10⁶ Hz

i) Wavelength of which television transmit vision λ_v=?

ii) Wavelength of which television transmit sound λ_s=?

Solution

Since

$$C = f\lambda$$

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

$$\lambda_v = \frac{C}{f_v}$$

Putting values

$$\lambda_v = \frac{3 \times 10^8 \text{ m/s}}{500 \times 10^6 \text{ Hz}}$$

$$\boxed{\lambda_v = 0.6\text{m}}$$

$$\lambda_s = \frac{C}{f_s}$$

Putting values

$$\lambda_s = \frac{3 \times 10^8 \text{ m/s}}{505 \times 10^6 \text{ Hz}}$$

$$\boxed{\lambda_s = 0.594\text{m}}$$

2. A person on sea shore observes that 48 waves reach the shore in one minute. If the wave length of the wave is 10m, then find its speed.

Data:

No. of waves n = 48

Time taken by waves t = 60 sec

Frequency of the wave f = 48/60 = 0.8 Hz

Wave length λ = 10 m

Speed of the wave v = ?

Solution

As

$$v = f\lambda$$

$$v = 0.8 \text{ Hz} \times 10 \text{ m}$$

$$\boxed{v = 8 \text{ m/s}}$$

3. In a ripple tank 500 waves passes through a certain point in 10 sec. If the speed of the wave is 3.5 m/s, then find the wave length of the wave.

Data:

No. of waves n = 500

Time taken by waves t = 10 sec

Frequency of waves f = $\frac{500}{10}$ = 50 Hz

Speed of the waves v = 3.5 m/s

Wave length of the waves λ = ?

Solution

As v = fλ

$$\Rightarrow \quad \lambda = \frac{v}{f}$$

$$\Rightarrow \quad \lambda = \frac{3.5 \text{ m/s}}{50\text{Hz}}$$

$$\Rightarrow \quad \lambda = 7\text{cm}$$

4. A string of guitar 1.3 m long vibrates with 4 nodes. 2 of them at the two ends. find the wave length & speed of the wave in the string if it vibrates at 500 Hz.

Data:

The total length of string = 1.3 m

No. of nodes in the string n = 4

Frequency of vibration f= 500 Hz

Wave length of vibration λ = ?

Speed of vibrations = ?

Solution

Since the string of a guitar vibrates with 4 nodes as shown in fig.

i) Relation between length & wave length is given as

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

$$\Rightarrow \quad \lambda = \frac{4}{3} \times 1.3$$

$$\Rightarrow \quad \lambda = 0.87 \text{ m}$$

ii) Since v = fλ

v = 500 Hz x 0.65 m

$$\boxed{v = 325 \text{ m/s}}$$

5. Find the speed of sound in Helium gas at 27°C.

γ = 1.66 and R=8334 J/k mol.

Data:

Speed of sound in Helium gas v = ?

Temperature T = (27°C+273)k = 300 k

γ =1.66

R = 8334 J/k mol.

Atomic mass of Helium M = 4 kg

Solution

As

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

$$v = \sqrt{\frac{1.6 \times 8334 \times 300}{4}}$$

$$v = 1018.4 \text{ m/s}$$

6. The speed of sound in air at 0°C is 332 m/s. What will be the speed of sound at 22°C?

Data:

The speed of sound in air at 0°C v_0 = 332 m/s

The speed of sound in air at 22°C v_t = ?

Since

$$\frac{v_t}{v_0} = \sqrt{\frac{T_t}{T_0}}$$

$$v_t = v_0\sqrt{\frac{T_t}{T_0}} \quad \text{———(1)}$$

$$v_0 = 332 \text{ m/s}$$

$$v_t = \boxed{\sqrt{343.2} \text{ m/s}}$$

7. Two tuning forks P & Q give 4 beats per second. On loading Q slightly with wax, we get 3 beats per second. What is the frequency of Q before and after loading if the frequency of P is 512 Hz?

Data:

Number of beats per second of tuning forks before loading P & QN1 = 4

Number of beats per second of tuning forks when Q is loaded with wax N_2 = 3

Frequency of 'Q' before and after loading f_1 & f_2 = ?

Frequency of P f_p = 512 Hz

Solution

i) Frequency of 'Q' before loading

$$N_1 = f_p - f_q$$

$$\Rightarrow \quad 4 = f_p - 512$$

$$\boxed{f_q = 516 \text{ Hz}}$$

ii) Frequency of 'Q' after loading

$$N_2 = f_p - f_q$$

$$\Rightarrow \quad 4 = f_p - 512$$

$$\boxed{f_q = 516 \text{ Hz}}$$

8. On a sunny day, the speed of sound in the air is 340 m/s. 2 tuning forks A & B are sounded simultaneously. the wave length of the sound emitted are 1.5 m and 1.68 m respectively. How many beats will produce per second?

Data:

Speed of sound in air V = 340 m/s

The wave length emitted by fork A λ_A = 1.5 m

The wave length emitted by fork B λ_B = 1.68 m

Number of beats per second N = ?

Solution

Frequency emitted by fork A 'f_A' is $f_A = \frac{v}{\lambda_A}$

$$f_A = 226.6 \text{ Hz}$$

Frequency emitted by fork B 'f_B' is $f_B = \frac{v}{\lambda_B}$

$$f_B = 202.3 \text{ Hz}$$

Since number of beats per second is given as

$$N = f_A - f_B$$

$$N = 226.6 - 202.3$$

$$\boxed{N = 24 \text{ approximately}}$$

9. A sound source vibrates at 200 Hz and is recording from a stationary observer at 18 m/s. If the speed of sound is 331 m/s then what frequency does the observer hear?

Data:

Frequency of source f = 200 Hz

Speed of source moving away from the observer v_s =18 m/s

Speed of sound v = 331 m/s

The frequency observed by observer F = ?

Solution

Since

$$F = \left(\frac{v}{v + v_s}\right) f$$

$$F = \left(\frac{331}{18 + 331}\right) \times 2000$$

$$\boxed{F = 189.68 \text{ Hz}}$$

10. The first overtone of an open organ pipe has the same frequency as the first overtone of a closed pipe 3.6 m in length. What is the length of the open organ pipe?

Solution

Since the first overtone of an open organ pipe $L_1 = \frac{v}{2L_1}$ ——— (1)

& the first overtone of a closed organ pipe $L_2 = \frac{v}{4L_2}$ ——— (2)

Length of closed organ pipe L_2 = 3.6 m

Length of open organ pipe L_1 = ?

According to the given condition

$$L_1 = \frac{v}{2L_1}$$

$$L_1 = \frac{4 \times 3.6}{2}$$

$$\boxed{L_1 = 4.8 \text{ m}}$$

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Objective Type Questions & Answers

Select the best answer for the following MCQs:

1) The waves in which the particles of the medium vibrate at right angle to the direction of the wave motion are called,

(a) compressional waves (b) longitudinal waves
(c) electromagnetic waves (d) transverse waves

2) Waves formed on the surface of water,

(a) stationary waves (b) transverse waves
(c) longitudinal waves (d) electromagnetic waves

3) The waves which do not require any medium for their propagation are called,

(a) sound waves (b) water waves
(c) transverse waves (d) electromagnetic waves

4) Crest and trough are formed in,

(a) compressional waves (b) stationary waves
(c) longitudinal waves (d) transverse waves

5) The speed of the waves in terms of frequency f and wavelength λ is given by,

(a) $v = f\lambda$ (b) $v = \frac{\lambda}{f}$ c. $v = \frac{f}{\lambda}$ d. $v = \frac{f^2}{\lambda}$

6) The distance between two consecutive nodes is,

(a) λ (b) 2λ c. $\frac{\lambda}{2}$ d. $\frac{\lambda}{4}$

7) The distance between a node and the next antinode is.

(a) λ (b) 2λ c. $\frac{\lambda}{2}$ d. $\frac{\lambda}{4}$

8) The distance between a crest and a trough is equal to,

(a) λ (b) 2λ c. $\frac{\lambda}{2}$ d. $\frac{\lambda}{4}$

9) Sound waves in air are,

(a) longitudinal waves (b) transverse waves
(c) matter waves (d) electromagnetic waves

10) The velocity of sound in vacuum is,

(a) 300 ms^{-1} (b) 332 ms^{-1} (c) zero ms^{-1} (d) 280 ms^{-1}

11) Increase in velocity of sound in air due to increase in temperature by 1°C is,

(a) 0.61 ms^{-1} (b) 1.61 ms^{-1} (c) 2ms^{-1} (d) 61 ms^{-1}

12) When sound waves enter in different medium, the quantity that remains unchanged is,

(a) speed (b) intensity (c) frequency (d) wavelength

13) Sound of frequencies higher than 20,000 hertz are,

(a) supersonics (b) audible (c) ultrasonic (d) none of these

14) Two tuning forks of frequencies 260 hertz and 256 hertz are sounded together, the number of beats/secs is,

(a) zero (b) 2 (c) 4 (d) 256

15) Doppler effect applies to,

(a) sound waves (b) light waves
(c) both sound and light waves (d) none of these

16) Radar is a device which transmits and receives,

(a) heat waves (b) electromagnetic waves
(c) radio waves (d) matter waves

17) The stationary waves are produced when two identical waves are moving on the string along,

(a) same direction (b) opposite direction
(c) perpendicular direction (d) none of these

18) When the bob of the simple pendulum is at the mean position, the value of the P.E. is,

(a) zero (b) minimum (c) maximum (d) infinite

19) The phenomenon of interference comes out because waves obey,

(a) law of conservation of energy (b) 1st law of thermodynamics
(c) the inverse square law (d) the principle of superposition of waves

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