

Waves

Answers

Module 1 Propagation of Waves

A.15.1.1 (C)

Light waves, X-ray and radio waves are electromagnetic in nature with an electric field and a magnetic field oscillating in two mutually perpendicular planes and propagating along the third mutually perpendicular direction. So, light waves, X-ray and radio waves are transverse in nature. Hence, the option (C). The sound wave is longitudinal in nature.

A.15.1.2 (D)

The bulk modulus = P , out of which P occurs as the bulk stress. So it represents elasticity. ρ , being the density, represents the inertia. Hence the option (D).

A.15.1.3 (B)

The prongs (when excited) either approach to or recede away from each other. Hence, the prongs execute transverse vibration. When they approach, the stem moves down, and when the prongs recede away from each other the stem moves up. So, the stem executes longitudinal vibration. Hence the option (B).

A.15.1.4 (B)

The velocity of propagation of a progressive wave does not depend on the amplitude of vibration. Hence the option (B)

A.15.1.5 (B)

Phase Diff = $\frac{2\pi x}{\lambda} = \frac{2\pi}{28} \times 14 = \pi$, Hence the option (B)

A.15.1.6 (C)

At a particular time, the points which are equidistant from the line are at the same phase. They all lie on a cylinder with the linear source as its axis. Hence the option (C)

A.15.1.7 (D)

We know, $y = a \sin \frac{2\pi}{\lambda}(vt - x)$

$$\text{Particle velocity} = \frac{\partial y}{\partial t} = \frac{2\pi av}{\lambda} \cos \frac{2\pi}{\lambda} (vt - x)$$

$$\text{maximum particle velocity} = \frac{2\pi av}{\lambda} = 2v$$

$$\therefore a = \frac{\lambda}{\pi} \text{ Hence, (D)}$$

A.15.1.8 (C)

Just a look at the expression $y = a \sin \frac{2\pi}{\lambda} (vt - x)$ shows that the phase $(vt - x)$ depends on both the velocity and the position. Hence the option (C).

Like any other mechanical system, the differential equation of a simple pendulum is of second order. Its solution is obtained by two integrations. The first integration yields the velocity and the second yields the position. Both are required for the determination of phase. Hence phase depends on both velocity and position i.e., displacement. Hence the option (C).

Note: The expression for phase is $(\omega t + \delta)$, and so it apparently seems that phase does not depend on either velocity and displacement. But it has to be noted that the physical meaning of ' ω ' appears through the combined analysis of displacement vs. time graph and velocity-time equation. (I think this explanation is not needed, so drop)

A.15.1.9 (C)

$$x_1 = a_1 \cos (\omega t + \delta)$$

$$x_2 = a_2 \cos \omega t$$

$$x = x_1 + x_2$$

$$= a_1 \cos \omega t \cos \delta - a_1 \sin \delta \sin \omega t + a_2 \cos \omega t$$

$$= A \cos (\omega t + \varepsilon),$$

where

$$A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2 \cos \delta}$$

$$\varepsilon = \tan^{-1} \left(\frac{a_1 \sin \delta}{a_1 \cos \delta + a_2} \right)$$

$$A_{\max} = \sqrt{a_1^2 + a_2^2 + 2a_1a_2}, \text{ Where } \cos \delta = 1$$

$$\therefore A_{max} = a_1 + a_2$$

Hence, (C)

A.15.1.10 (B)

$$y = a \sin k(vt - x)$$

$(vt - x)$ Has the dimension of length. The argument of the sine function should be essentially dimensionless. So k must have the dimension of reciprocal of length. Hence, the option(B).

Module 2 Stationary Waves

A.15.2.1 (C)

The reflected wave always travels in a direction opposite to the original wave. When reflection takes place from a rarer to a denser medium, there is a phase change of 180° , but when the reflection is from a denser to a rarer medium, there is no change in phase.

Hence (P) and (R) are correct, So (C) is the right option.

A.15.2.2 (B)

In a progressive wave continuous transfer of energy takes place from one particle to the next. Hence (P) is correct. In a stationary wave 'nodes' and 'antinodes' are permanent points respectively of minimum (zero) and maximum displacement. So there is no transfer of energy across the 'node' points. Hence (R) is also correct. So, (B) is the right option.

A.15.2.3 (D)

Nodes are permanent points of minimum displacement and so maximum change of density takes place there, and the velocity of particles is zero. No change of density takes at the antinodes, the permanent positions of maximum displacement. So velocity of particles is maximum there.

Hence, (D) is the right option.

A.15.2.4 (C)

The equation of a stationary wave is given by,

$$y = 2a \cos kx \sin \omega t$$

Comparing with the given equation

$$\text{Here, } k = \frac{2\pi}{\lambda} = 4 \text{ cm}^{-1}, \quad \omega = \frac{2\pi v}{\lambda} = 20 \text{ s}^{-1}$$

$$v = \frac{\omega}{k} = \frac{20 \text{ s}^{-1}}{4 \text{ cm}^{-1}} = 5 \text{ cm s}^{-1}$$

So, (C) is the right option.

A.15.2.5 (B)

$$y_1 = 2 \sin (4\pi t - \pi x)$$

$$y_2 = 2 \sin (4\pi t + \pi x)$$

$$y = y_1 + y_2 = 2.2 \sin 4\pi t \cos \pi x$$

$$= 4 \sin 4\pi t \cos \pi x$$

Hence, (B) is the right option.

A.15.2.6 (A)

Third Harmonic

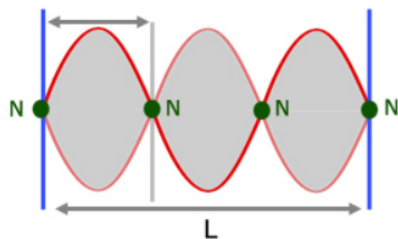


Fig. A.15.2.1

There will be three loops in the third harmonic (Fig. A.15.2.1), and so the segments will be $\frac{120}{3} = 40$ cm long.

Therefore, nodes at 0, 40, 80, 120 cm. So, (A) is the correct option.

A.15.2.7 (A)

$$n = \frac{1}{2l} \sqrt{\frac{T}{m}} = \frac{1}{2l} \sqrt{\frac{T}{\frac{\pi r^2 l \rho}{l}}}$$

$$\therefore n = \frac{1}{2lr} \sqrt{\frac{T}{\pi \rho}}$$

$$x = \frac{n_2}{n_1} = \sqrt{\frac{T_2}{T_1}} \cdot \sqrt{\frac{\rho_1}{\rho_2}} = \sqrt{2 \cdot \frac{1}{8}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

So, (A) is the correct option.

A.15.2.8 (C)

For the second harmonic, $\frac{3\lambda_2}{4} = l$

$$\therefore \lambda_2 = \frac{4l}{3}$$

$$\therefore v_2 = \frac{v}{\frac{4l}{3}} = \frac{3v}{4l} \text{ (where } v = \text{velocity of sound)}$$

$$\therefore v_2 = \frac{3}{4} \cdot \frac{340 \times 100}{68} = 375 \text{ Hz}$$

So, (C) is the right option.

A.15.2.9 (C)

For first resonance, $v_1 = \frac{v}{4l_1}$

For second resonance, $v_2 = \frac{3v}{4l_2}$

$$\therefore 2v = 4(l_2 - l_1)$$

Or,

$$v = 2v_2(l_2 - l_1)$$

Or,

$$v = \frac{v}{2(l_2 - l_1)} = \frac{345 \times 100}{2(70 - 24)} = 375 \text{ Hz}$$

Hence (C) is the right option.

A.15.2.10 (B)

$$y = 2a \cos kx \sin \omega t$$

Displacement at A $y = 2a \cos \frac{2\pi}{\lambda} x \sin \omega t$

Displacement at B, $= y\left(x + \frac{\lambda}{2}\right) = 2a \cos \frac{2\pi}{\lambda} \left(x + \frac{\lambda}{2}\right) \sin \omega t = 2a \cos\left(\frac{2\pi x}{\lambda} + \pi\right) \sin \omega t$

$$\therefore y\left(x + \frac{\lambda}{2}\right) = 2a \cos \frac{2\pi x}{\lambda} \sin \omega t = -y$$

Displacement at C $= y\left(x + \frac{\lambda}{2} + \frac{\lambda}{2}\right) = y(x + \lambda)$

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

$$= 2a \cos \left(\frac{2\pi x}{\lambda} + 2\pi\right) \sin \omega t$$

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

Hence (B)

Module 3 Beats and Doppler Effect

A 15.3.1 (D)

The crux of the matter is the word 'transient'. In all the given cases, beats will be produced. But beat frequency will be a variant for a brief moment of time when the forced system approaches the frequency of the driving system while executing forced vibration. Hence (D)

A. 15.3.2 (B)

$$\Delta v = \frac{v}{2} \left[\frac{1}{l} - \frac{1}{(1.01)l} \right] = \frac{v}{2l} \times \frac{.01}{1.01} = \frac{v}{2l} \times \frac{1}{101} = \frac{1}{0.202}$$

$$\therefore \frac{v}{2l} = \frac{101 \times 1000}{202} = 500$$

$$\therefore l = \frac{v}{1000} = 0.34 \text{ m} = 34 \text{ cm.}$$

Hence, **(B)**

A. 15.3.3 (C)

$$\frac{3v}{4l} - \frac{v}{4l} = 4$$

$$\therefore \frac{2v}{4l} = 4$$

$$\therefore v = 8l \text{ Hence the option (C).}$$

A.15.3.4 (B)

$$\frac{1}{2l} \sqrt{\frac{T}{m}} (1.2 - 1) = 2$$

$$\therefore \frac{1}{2l} \sqrt{\frac{T}{m}} = \frac{2}{0.2} = 10 \text{ Hz,}$$

Hence **(B)** is the correct option.

A. 15.3.5 (D)

$$v_1 - v_2 = \frac{1}{1} = 1 \text{ Hz}$$

$$v_2 - v_3 = \frac{1}{0.5} = 2 \text{ Hz}$$

$$v_3 - v_4 = \frac{1}{0.33} = 3 \text{ Hz}$$

$$v_4 - v_5 = \frac{1}{0.25} = 4 \text{ Hz}$$

$$\therefore v_1 - v_5 = (v_1 - v_2) + (v_2 - v_3) + (v_3 - v_4) + (v_4 - v_5)$$

$$= 1 + 2 + 3 + 4$$

$$= 10 \text{ Hz.}$$

Hence (D) is the correct option.

A. 15.3.6 (D)

$$\text{Number of buses crossing the person /hour} = n' = \left(\frac{v}{v-v_s} \right) n_0 = 4 \left(\frac{10}{10-5} \right) = 4 \times 2 = 8$$

Hence (D.) is the correct option.

A. 15.3.7 (A)

$$n' = \frac{v+v_0}{v-v_s} n = \frac{320+10}{320-10} \times 500 = \frac{33}{31} \times 500 \text{ Hz.}$$

Hence (A.) is the correct option.

A. 15.3.8 (B)

$$n' = \frac{v-v_0}{v+v_s} n = \frac{330-10}{330+10} \times 600 = \frac{32}{34} \times 600 = \frac{16}{17} \times 600 \text{ Hz.}$$

Hence (B.) is the correct option.

A. 15.3.9 (D)

$$n_D = \frac{v}{v+v_s}, n_R = \frac{v}{v-v_s}$$

$$\therefore \frac{1}{T} = n_R - n_D = nv \left(\frac{1}{v-v_s} - \frac{1}{v+v_s} \right) = nv \cdot \frac{2v_s}{v^2 - v_s^2} = nv \cdot \frac{2v_s}{v^2} \quad (\because v \gg v_s)$$

$$\therefore \frac{1}{T} = \frac{2nv_s}{v} \text{ or } v_s = \frac{v}{2nT}.$$

Hence (D) is the correct option.

A. 15.3.10 (D)

$$v = \frac{\Delta\lambda}{\lambda} c, \therefore \Delta\lambda = \frac{\lambda v}{c} = 6000 \text{ \AA} \times \frac{6 \times 10^6}{3 \times 10^8}$$

$$\therefore \text{The apparent wavelength} = 6120 \text{ \AA}$$

Hence (D) is the correct option.



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