Topic 11 : Wave Motion Tutorial Solutions (2025)

1. **(i)** Displacement: The distance in a specific direction from the equilibrium position of the simple harmonic motion.

(ii) Amplitude: Maximum displacement from the equilibrium point in either direction.

(iii) Wavelength: The shortest distance between two points on a *progressive wave* which are vibrating in phase.

(iv) Frequency: Number of oscillations *per unit time* of a particle in a wave.

(v) Period: Time taken for a particle in the wave to undergo one complete oscillation.

(vi) Phase difference: A measure of how much one wave is out of step with another. It is measured in either degrees or radians.

(b) One wavelength λ is equal to the distance travelled by the wave energy during one complete oscillation of the source.

The distance travelled by the wave energy during n complete oscillation of the source = $n\lambda$

Speed is the distance travelled per unit time by the wave energy

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

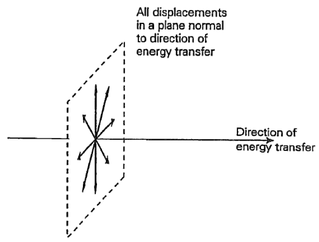
Frequency is number of oscillations *per unit time* i.e. $f = \dfrac{n}{t}$

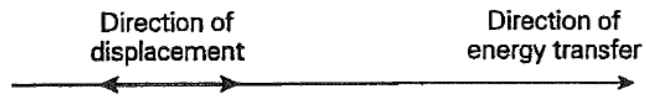
Therefore speed $v = f\lambda$

(c) Progressive wave: A progressive wave transfers energy from one point to another by means of oscillations.

Intensity of a wave: Wave energy incident per unit time per unit area *normal* to the direction of energy transfer.

(d) Transverse wave: Waves in which the oscillation of the particles in the wave is perpendicular to the direction of transfer of energy of the wave.

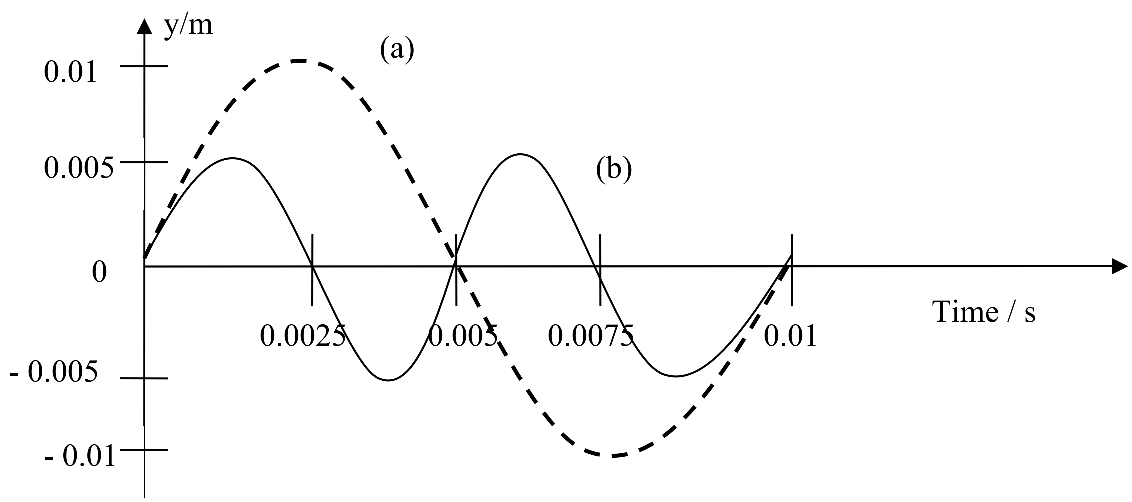




Longitudinal wave: Oscillations of the particles in the wave are along the direction of transfer of energy of the wave.

2. (a) $f = \frac{1}{T}$ = 100 Hz, T = 0.01 s

(b) $f = \frac{1}{T}$ = 200 Hz, T = 0.005 s

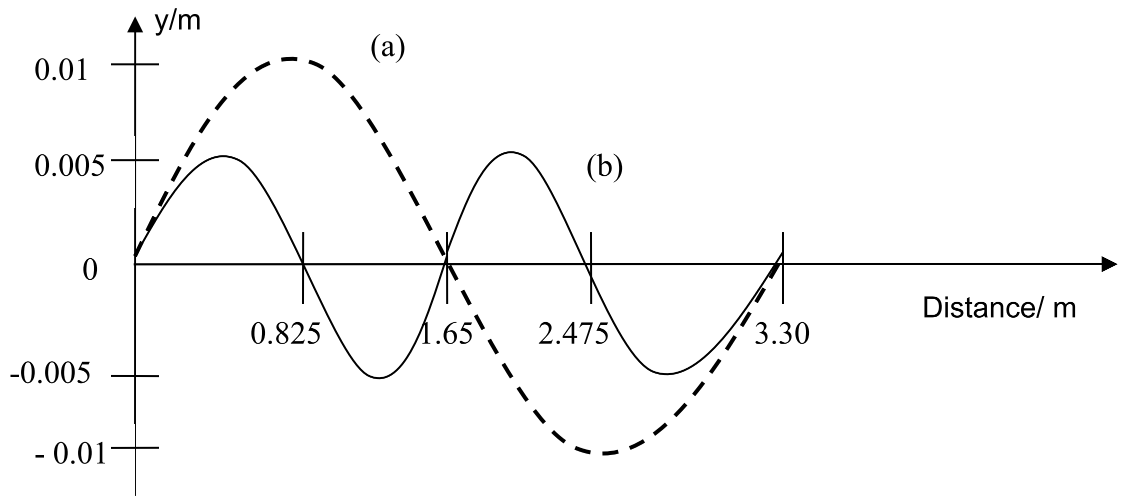


(c) For wave 1, v = f λ

λ = 330/100 = 3.3 m

For wave 2, v = f λ

λ = 330/200 = 1.65 m



(d) Sound wave. *Horizontal* displacement-distance graph.

3. v = f λ $\Rightarrow f = \dfrac{v}{\lambda}$

Minimum f = $\dfrac{3.0\times10^{8}}{700\times10^{-9}} = 4.3\times10^{14}\,Hz$ (red)

Maximum f = $\dfrac{3.0\times10^{8}}{400\times10^{-9}} = 7.5\times10^{14}\,Hz$ (violet)

4. Answer: 50 mm outwards

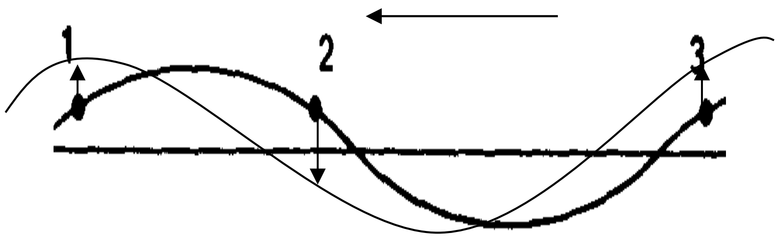
Diameter of bowl = 400 mm
Radius of bowl = 200 mm

Since the wave travel 250 mm in 1 second, it will travel 200 mm inward, then the remaining 50 mm outwards.

5. P gives the period T of the motion and Q the wavelength λ.

v = f λ => $v = \dfrac{\lambda}{T} = \dfrac{Q}{P}$

6. Draw a graph moments after.



7. (a) False. Speed at P is a minimum (zero)

(b) False. This graph is not that of a stationary wave. It will follow an oscillatory motion.

(c) False. Energy of R is entirely potential energy.

(d) False. Energy of S is entirely kinetic energy.

8. (a) Ans: C

$I \propto \frac{1}{r^2}$ By similar triangle, r is 8 times, I will be $\frac{1}{64}$

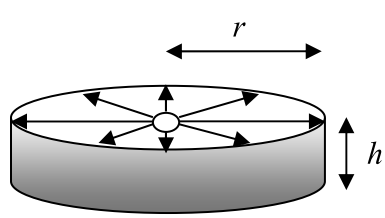
$I \propto A^2$ Since I is $\frac{1}{64}$, then A is $\frac{1}{8}$

(b) Ans: D

$\boldsymbol{I} = \frac{P}{A} = \frac{P}{2\pi rh}$ where h is the depth of pond

$\boldsymbol{I} \propto \frac{1}{r}$

$\boldsymbol{I} \propto A^2$



$\mathbf{A^2} \propto \frac{1}{r}$

$\boldsymbol{A} \propto \frac{1}{\sqrt{r}}$

Note: For a pond, it is a 2D distribution of wave energy, thus the usual 3D distribution $\boldsymbol{I} \propto \frac{1}{r^2}$ cannot be used.

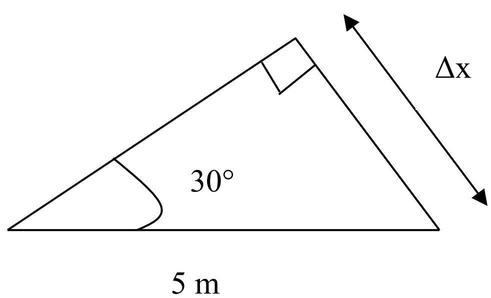
9. Energy is spread over a longer wavefront. Intensity drops. Since Intensity is proportional to square of amplitude, the amplitude drops too.

10. (0.25I, f, 0.50λ) as the frequency is constant as the wave travels from one medium to another.

11.

$$\frac{\frac{\pi}{4}}{2\pi} = \frac{\Delta x}{1.00} \rightarrow \Delta x = 0.125 \text{ m}$$

12. Let Δx be the path difference between the two points 5 m apart along the wall.



$$\sin 30° = \frac{\Delta x}{5} \Rightarrow \Delta x = 2.5m$$

$$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda} \Rightarrow \frac{\Delta\phi}{2\pi} = \frac{2.5}{10} \rightarrow \Delta\phi = 0.5\pi \quad rad$$

13. (a) (i) Period, T = 1.25 ms = 1.25 x 10^{-3} s

$f = \frac{1}{T}$ = 800 Hz

Wavelength, λ = 0.40 m

Velocity, v = f λ = 800 x 0.40 = 320 ms^{-1}

(ii) $$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda} \Rightarrow \frac{\Delta\phi}{2\pi} = \frac{0.9}{0.4} \rightarrow \Delta\phi = \frac{9}{4} \times 2\pi = \frac{9\pi}{2} \text{ rad}$$

$$\Delta\phi = \frac{\pi}{2} rad \quad \text{(round to between 0 rad and } 2\pi \text{ rad)}$$

(iii) $$\frac{Amplitude \quad at \quad P}{Amplitude \quad at \quad Q} = \frac{2mm}{0.5mm} = 4$$

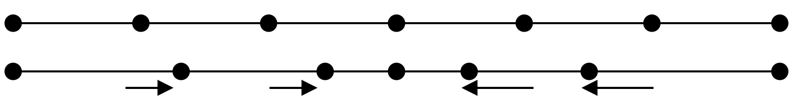
(iv) $$\frac{Intensity \;\; at \;\; P}{Intensity \;\; at \;\; Q} = \frac{(A_p)^2}{(A_Q)^2} = 4^2 = 16$$

(b) With the speed being 320ms^{-1}, it is probably a sound wave

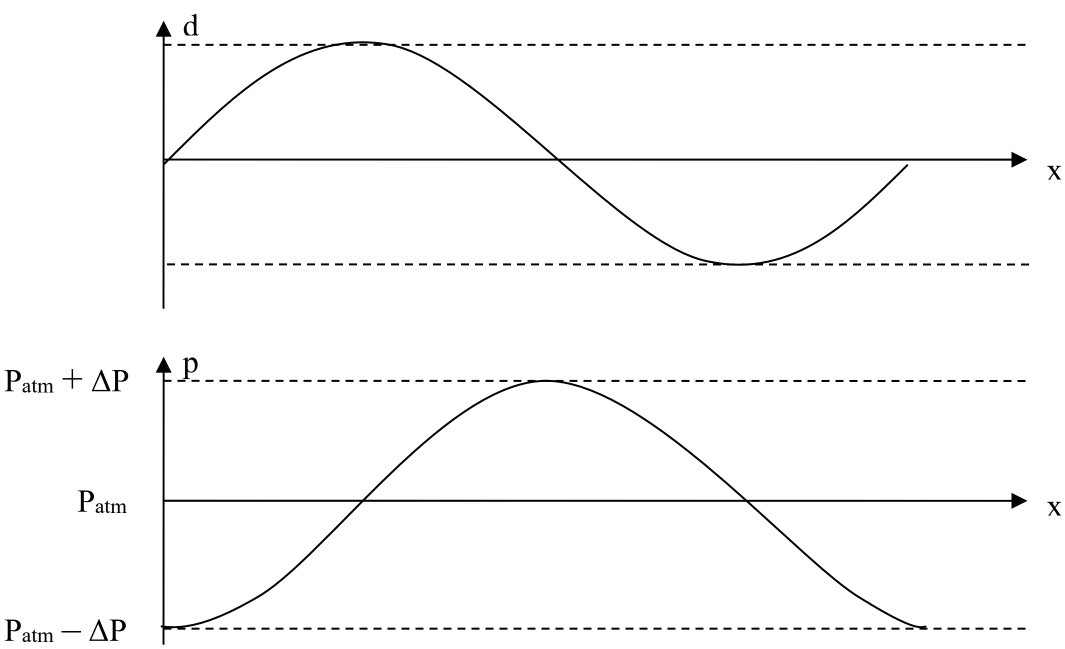
(c) (i) A microphone and a suitably adjusted Cathode Ray Oscilloscope (CRO) placed at position *P* could detect the 800 Hz 320 ms^{-1} sound waves from an appropriate source and produce a display similar to that graph.

(ii) The same method cannot be used directly to obtain the 2nd graph. However, we can use several microphones and place them at several specified positions, at various distances *x* from the source. These are connected the CRO and provide the displacement *y* of the point it is placed at, at the time *t* = 0 s. By manually plotting displacement *y* against distance *x* and joining these points in a curve, we can get the graph as seen.

14. (a)



(b)



(c) $\frac{\pi}{2}$ rad out of phase

15. For the intensity of the emergent light to be a minimum (zero), the polarizing axis of P_3 should be perpendicular to P_2. Hence,

$\theta = 30° + 90° = 120°$ or $\theta = 30° + 270° = 300°$

16. **(a) (i)** Monochromatic: only one wavelength (color)

(ii) Plane-polarized: If the oscillations in a wave are confined to one direction only, in a plane normal to the direction of transfer of energy of the wave, the wave is said to be polarised in that direction.

(b) $s = r\,\theta$

$s = (6.0)(1.2 \times 10^{-3}) = 7.2 \times 10^{-3}$ m

(c) Rotate a Polaroid between the beam and a receiver through 180°. If there is an angle where the receiver detects no laser beam, the beam is plane polarized.

17. **(a)** $\lambda = \dfrac{c}{f} = \dfrac{3.0\times10^{8}}{9.0\times10^{7}} = 3.33$ m

$d = \dfrac{\lambda}{2} = 1.67$ m

(b) rate $= \dfrac{\text{speed of detector}}{\text{internodal distance}} = \dfrac{10}{1.67} = 6$ nodes per second

18. Let I_1, I_2 and I_3 be the intensity after passing through polarisers 1, 2, and 3 respectively.

$I_2 = I_1\cos^2 45°$

$I_3 = I_2\cos^2 45°$

$= I_1\cos^4 45°$

$\neq 0$