

Waves — Assignment 2

Class 11 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
 (2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
 (3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Wave Motion and Its Types

2 Mark Questions

1. Distinguish between transverse and longitudinal waves with respect to particle displacement.
2. Explain why sound cannot travel in vacuum but light can.

3 Mark Questions

1. A wave travels the length of a 20 m string in 5 s. If consecutive crests are 0.4 m apart, find the frequency and period of the wave.

Characteristics of a Wave

2 Mark Questions

1. A tuning fork of frequency 512 Hz produces a wave in air with speed 345 m/s. Find the wavelength.

3 Mark Questions

1. A source emits a wave of frequency 500 Hz. If the wave speed in the medium is 1500 m/s, find the wavelength and the time period, and state how far the wavefront travels in 2 s.

The Speed of Sound

2 Mark Questions

1. The speed of sound in air at 0°C is 331 m/s. Estimate its speed at 20°C .

3 Mark Questions

1. Show that the speed of sound in a gas is proportional to the square root of its absolute temperature.

Progressive Waves and Superposition

2 Mark Questions

1. Show that the wave speed $v = \omega/k$ follows from the constancy of the phase.

3 Mark Questions

1. A progressive wave is described by $y = 0.05 \sin \pi(200t - 2x)$ m. Find its (a) frequency, (b) wavelength and (c) speed of propagation.

Reflection and Standing Waves

2 Mark Questions

1. Show that consecutive nodes (or antinodes) of a stationary wave are $\lambda/2$ apart.

3 Mark Questions

1. Two waves $y_1 = A \sin(kx - \omega t)$ and $y_2 = A \sin(kx + \omega t)$ superpose on a string. Obtain the resultant wave and identify the positions of nodes and antinodes.

Standing Waves in Strings and Organ Pipes**2 Mark Questions**

1. A string of length 1 m has a fundamental frequency of 110 Hz. Find its wavelength and the speed of waves on the string.

3 Mark Questions

1. A stretched wire of length 0.90 m and mass 3.6×10^{-3} kg is under a tension of 90 N. Calculate its fundamental frequency and the frequencies of its first three harmonics.

Beats**2 Mark Questions**

1. Two tuning forks A (300 Hz) and B produce 4 beats per second. What are the possible frequencies of B?

3 Mark Questions

1. A fork of unknown frequency produces 5 beats/s with a 256 Hz fork. When the unknown fork is slightly loaded with wax, the beats drop to 3 beats/s. Find the unknown frequency and justify your answer.

The Doppler Effect**2 Mark Questions**

1. A whistle of frequency 400 Hz is sounded by a train moving at 30 m/s. For a stationary observer towards whom the train moves, find the apparent frequency. (Speed of sound = 330 m/s.)

3 Mark Questions

1. A source of sound of frequency 500 Hz moves towards a stationary observer at 20 m/s while the observer walks towards the source at 5 m/s. Find the apparent frequency heard. (Speed of sound = 340 m/s.)

Part B — Integrated problems (multi-topic)

1. A string of length 20 m fixed at both ends has a linear density of 4×10^{-3} kg/m and is under a tension of 90 N. Find (i) the speed of transverse waves on the string and (ii) its fundamental and third-harmonic frequencies.
2. A whistle of frequency 400 Hz is sounded by a train moving at 30 m/s. Find the apparent frequency heard by a stationary observer (a) towards whom the train approaches and (b) from whom it recedes. (Speed of sound = 330 m/s.)
3. An observer moves away from a stationary source of sound of frequency 400 Hz at a speed of 10 m/s. Find the apparent frequency heard. (Speed of sound = 330 m/s.)
4. A closed organ pipe has a fundamental frequency of 220 Hz. Find its length and the frequency of the next higher harmonic it can produce. (Speed of sound = 330 m/s.)

5. Two waves $y_1 = 0.04 \sin(2\pi x - 100\pi t)$ m and $y_2 = 0.04 \sin(2\pi x + 100\pi t)$ m superpose on a string. Obtain the resultant equation of the standing wave and locate the first two nodes.

Answer Key

Wave Motion and Its Types

2M(0): Transverse — particles vibrate perpendicular to the direction of propagation; longitudinal — particles vibrate parallel to it. 2M(1): Sound is a mechanical wave and needs a material medium; light is electromagnetic and needs none, so it can travel through vacuum. 3M(0): $v = 20/5 = 4$ m/s; $\lambda = 0.4$ m $\Rightarrow v/\lambda = 4/0.4 = 10$ Hz; $T = 1/f = 0.1$ s.

Characteristics of a Wave

2M(1): $\lambda = v/f = 345/512 \approx 0.674$ m. 3M(0): $\lambda = v/f = 1500/500 = 3$ m; $T = 1/f = 2 \times 10^{-3}$ s; the wavefront travels $1500 \times 2 = 3000$ m in 2 s.

The Speed of Sound

2M(1): $v = 331\sqrt{(293/273)} \approx 343$ m/s ($\approx 331 + 0.6 \times 20$). 3M(2): $v = \sqrt{(\gamma P/\rho)}$ and $P = \rho RT/M \Rightarrow v = \sqrt{(\gamma RT/M)} \propto \sqrt{T}$ at constant M — the speed of sound is proportional to the square root of the absolute temperature.

Progressive Waves and Superposition

2M(1): the phase $\phi = \omega t - kx$ is constant for a point on the wavefront, so $d\phi/dt = \omega - k(dx/dt) = 0 \Rightarrow dx/dt = \omega/k$. 3M(0): $y = 0.05 \sin(200\pi t - 2\pi x)$: (a) $\omega = 200\pi \Rightarrow f = 100$ Hz; (b) $k = 2\pi \Rightarrow \lambda = 1$ m; (c) $v = f\lambda = 100$ m/s.

Reflection and Standing Waves

2M(0): The standing wave has nodes where $\sin kx = 0$, i.e. $x = 0, \lambda/2, \lambda, \dots$, so consecutive nodes are $\lambda/2$ apart (antinodes likewise). 3M(1): $y = y_1 + y_2 = 2A \sin kx \cos \omega t = 2A \sin(2\pi x/\lambda) \cos(2\pi ft)$; nodes at $x = n\lambda/2$, antinodes at $x = (2n+1)\lambda/4$.

Standing Waves in Strings and Organ Pipes

2M(1): $\lambda_1 = 2L = 2$ m $\Rightarrow f_1\lambda_1 = 110 \times 2 = 220$ m/s. 3M(1): $\mu = 3.6 \times 10^{-3}/0.90 = 4 \times 10^{-3}$ kg/m; $v = \sqrt{(T/\mu)} = \sqrt{(90/4 \times 10^{-3})} = 150$ m/s; $f_1 = v/2L = 150/1.8 \approx 83.3$ Hz; $f_2 = 2f_1 \approx 166.7$ Hz, $f_3 = 3f_1 = 250$ Hz.

Beats

2M(1): $f_B = 300 \pm 4$ Hz is 296 Hz or 304 Hz. 3M(1): $f = 256 \pm 5 = 251$ Hz or 261 Hz; loading with wax lowers the frequency and the beats drop to 3 (moving closer to 256), so the unknown fork is 261 Hz.

The Doppler Effect

2M(1): $f' = f_v/(v - v_s) = 400 \times 330/(330 - 30) = 400 \times 330/300 = 440$ Hz. 3M(1): $f' = f(v + v_o)/(v - v_s) = 500 \times (340 + 5)/(340 - 20) = 500 \times 345/320 \approx 539$ Hz.

Integrated problems

1: $v = \sqrt{(T/\mu)} = \sqrt{(90/4 \times 10^{-3})} = 150$ m/s; $f_1 = v/2L = 150/40 = 3.75$ Hz; $f_3 = 3f_1 = 11.25$ Hz. 2: (a) $400 \times 330/300 = 440$ Hz; (b) $400 \times 330/360 \approx 367$ Hz. 3: $f' = f(v - v_o)/v = 400 \times (330 - 10)/330 \approx 388$ Hz. 4: $L = v/4f_1 = 330/880 = 0.375$ m; next higher = 3rd harmonic = 660 Hz. 5: $y = 0.08 \sin(2\pi x) \cos(100\pi t)$; $\lambda = 1$ m, so nodes ($\sin 2\pi x = 0$) at $x = 0$ and 0.5 m.