



Attempt questions first; check the separate key afterward. Take sound speed = 340 m/s where needed. Neglect pipe end corrections.

A. Very short answers - 1 mark each

1. Distinguish transverse and longitudinal waves with examples.
2. Define wavelength and wave number.
3. Can mechanical waves travel through a vacuum? Explain.
4. What travels along a wave: matter, energy or both?
5. Define a node and an antinode.
6. What is the fundamental frequency?
7. What are beats?
8. What phase change occurs when a transverse string wave reflects at a fixed end?

B. Short answers / practice - 2 marks each

9. Write the relation between wave speed, frequency and wavelength.
10. For $y = 0.02 \sin(4\pi x - 200\pi t)$ m, with x in m and t in s, find amplitude, wavelength, frequency and propagation direction.
11. How does wave speed on a stretched string change if tension is quadrupled at constant linear density?
12. Why can sound in air be longitudinal but not transverse?
13. State the principle of superposition of waves.
14. Distinguish progressive and standing waves using two features.
15. Two tuning forks of frequencies 256 Hz and 260 Hz sound together. Find beat frequency and time between successive loud sounds.
16. Why does a pipe closed at one end have only odd harmonics in the ideal model?

C. Application / reasoning - 3 marks each

17. A string of mass 4 g and length 1 m is under 100 N tension. Find transverse-wave speed and fundamental frequency when fixed at both ends.
18. A wave has frequency 50 Hz and speed 200 m/s. Find wavelength and phase difference between points 0.5 m apart at the same instant.
19. Write the equation of a wave of amplitude 2 cm, wavelength 0.8 m and frequency 5 Hz moving along $+x$. Take $y = 0$ at $x = t = 0$ with initial downward motion.

20. An open pipe is 0.85 m long. Find its first three natural frequencies for sound speed 340 m/s, neglecting end correction.

21. A pipe closed at one end is 0.85 m long. Find its first three natural frequencies for sound speed 340 m/s, neglecting end correction.

22. A string fixed at both ends is 1.2 m long and vibrates in its third harmonic. Find wavelength and node/antinode positions measured from one end.

23. Two forks produce 5 beats/s. One has frequency 300 Hz. After wax is added to the other, beat frequency becomes 3 Hz. Find its original frequency and explain.

24. Explain reflection of sound at open and closed pipe ends in terms of displacement nodes and antinodes.

25. An ideal gas at 300 K carries sound at 340 m/s. Find sound speed at 432 K, assuming unchanged composition and γ .

D. Extended practice - 5 marks each

26. Derive the equation of a sinusoidal progressive wave. Explain each parameter and distinguish particle velocity from wave velocity.
27. Superpose two identical waves travelling in opposite directions to obtain a standing wave. Derive node and antinode positions and their spacings.
28. Derive allowed frequencies of a string fixed at both ends. Explain fundamental and harmonics with labelled sketches of the first three modes.
29. Derive allowed frequencies for open and one-end-closed organ pipes. Compare fundamentals for equal lengths and identify displacement/pressure nodes.
30. Derive the beat-frequency formula by superposing two equal-amplitude waves of nearly equal frequencies. Explain loudness maxima, minima and the condition for distinct beats.

ANSWER KEY - Numerical / closed questions

- 3) No; a material medium is required. 8) π radians.
10) 0.02 m; 0.5 m; 100 Hz; $+x$. 11) It doubles. 15) 4 Hz; 0.25 s. 17) 158.1 m/s; 79.06 Hz. 18) 4 m; $\pi/4$.
19) $y = 0.02 \sin(2.5\pi x - 10\pi t)$ m. 20) 200, 400, 600 Hz.
21) 100, 300, 500 Hz. 22) $\lambda = 0.8$ m; nodes 0, 0.4, 0.8, 1.2 m; antinodes 0.2, 0.6, 1.0 m. 23) 305 Hz, assuming wax lowers frequency without crossing 300 Hz. 25) 408 m/s.