PHYSICS – CLASS XI

Chapter 14 : Waves

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown in brackets. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(b)	(b)	(c)	(a)	inverted	5 m s^{-1}	zero	660 Hz

SECTION A

1. **Ans: (b) 5 Hz.** **(1)**

From the graph, λ = 4 m (the wave repeats after 4 m). $\nu = v/\lambda = 20/4 =$ **5 Hz**.

2. **Ans: (b) longitudinal.** **(1)**

The air layers move to and fro along the direction of propagation (the pipe axis), forming compressions and rarefactions: a **longitudinal** wave.

3. **Ans: (c) third harmonic.** **(1)**

The pattern has three loops between the fixed ends, so $L = 3(\lambda/2)$: the **third harmonic**.

4. **Ans: (a).** **(1)**

Transverse waves need shear (rigidity) in the medium; gases cannot sustain shear stress, so R explains A.

5. **Ans: Inverted.** **(1)**

At a rigid boundary the reflected pulse suffers a phase change of π, so it returns **inverted**.

6. **Ans: 5 m s^{-1}.** **(1)**

$k = 2$ m^{-1}, ω = 10 rad s^{-1}: $v = \omega/k = 10/2 =$ **5 m s^{-1}** (towards $+x$).

7. **Ans: Zero.** **(1)**

$A(\varphi) = 2a\cos(\varphi/2) = 2a\cos(\pi/2) =$ **0**: destructive interference.

8. **Ans: 660 Hz.** **(1)**

$v = \nu\lambda \rightarrow \nu = 330/0.5 =$ **660 Hz**.

SECTION B

9. **(i)** λ = v/ν = 100/50 = **2 m**. (1) **(2)**

(ii) $k = 2\pi/\lambda = \pi$ rad m^{-1} and $\omega = 2\pi\nu = 100\pi$ rad s^{-1}. So **$y = 0.02\sin(\pi x - 100\pi t)$** (SI). (1)

10. **(i)** $v = \sqrt{(Y/\rho)} = \sqrt{(2 \times 10^{11}/8 \times 10^{3})} = \sqrt{(2.5 \times 10^{7})} = \sqrt{(25 \times 10^{6})} =$ **5000 m s^{-1}**. (1) **(2)**

(ii) $t = L/v = 10/5000 =$ **2×10^{-3} s**. (1)

11. Take a point of constant phase: $kx - \omega t$ = constant. (1) **(2)**
Differentiating, $k\,\mathrm{d}x - \omega\,\mathrm{d}t = 0$, so the speed of this point (and of the wave) is $v = \mathrm{d}x/\mathrm{d}t = \boldsymbol{\omega/k}$. (1)

OR

Wrong assumption: Newton assumed that the pressure changes in the sound wave are **isothermal**. They are so rapid that there is no time for heat flow, so they are **adiabatic**. (1)
Laplace's formula: $v = \sqrt{(\gamma P/\rho)}$ ($\gamma = C_p/C_v = 7/5$ for air), which gives ≈ 331 m s^{-1}. (1)

12. **(i)** When two or more waves overlap, the resultant displacement at any point is the **algebraic sum** of the displacements due to the individual waves; each wave moves as if the others were absent. (1) **(2)**
(ii) $y = (+3) + (-2) =$ **+1 cm** (1 cm above the mean position). (1)

SECTION C

13. **(i)** $\mu = m/L = 2.5/20 =$ **0.125 kg m^{-1}**. (1) **(3)**
(ii) $v = \sqrt{(T/\mu)} = \sqrt{(200/0.125)} = \sqrt{1600} =$ **40 m s^{-1}**. (1)
(iii) $t = L/v = 20/40 =$ **0.5 s**. (1)

14. **(i)** Closed pipe: $\nu_1 = v/4L = 340/(4 \times 0.5) =$ **170 Hz**. (1) **(3)**
(ii) Only odd harmonics occur: $3\nu_1 =$ **510 Hz** and $5\nu_1 =$ **850 Hz**. (1)
(iii) 340 Hz $= 2\nu_1$ is an even multiple, which a closed pipe cannot support: **no resonance**. (1)

OR

(i) Open pipe: $\nu_1 = v/2L = 340/(2 \times 0.5) =$ **340 Hz**. (1)
(ii) All harmonics occur: $2\nu_1 =$ **680 Hz** and $3\nu_1 =$ **1020 Hz**. (1)
(iii) 680 Hz $= 2\nu_1$ is the second harmonic: **resonance occurs**. (1)

15. **(i)** $|\nu_B - 440| = 4$, so $\nu_B =$ **436 Hz or 444 Hz**. (1) **(3)**
(ii) Increasing the tension increases the frequency of B. The beat frequency rose (4 → 6), so the gap to A widened: B was already higher than A. Original $\nu_B =$ **444 Hz**. (1)
(iii) New frequency = 440 + 6 = **446 Hz**. (1)

SECTION D

16. **(a)** Amplitude $a =$ **0.02 m**. (1) **(5)**
(b) $k = 2\pi$ m^{-1}, so $\lambda = 2\pi/k =$ **1 m**. (1)
(c) $\omega = 100\pi$ rad s^{-1}, so $\nu = \omega/2\pi =$ **50 Hz**. (1)
(d) $v = \omega/k = 100\pi/2\pi =$ **50 m s^{-1}** ($= \nu\lambda$). (1)
(e) $y = 0.02 \sin(2\pi \times 0.25) = 0.02 \sin(\pi/2) =$ **0.02 m**. (1)

OR

(a) $y = 2a \sin kx \cos \omega t$, so $2a = 0.01$ and each travelling wave has amplitude $a =$ **0.005 m**. (1)
(b) $k = 2\pi$, so $\lambda =$ **1 m**. (1)
(c) Nodes: $\sin 2\pi x = 0 \rightarrow x = n\lambda/2 = n/2$: ***x* = 0, 0.5, 1.0, 1.5 m**. (1)
(d) Consecutive antinodes are $\lambda/2$ apart = **0.5 m**. (1)
(e) $v = \omega/k = 100\pi/2\pi =$ **50 m s^{-1}**. (1)

17. **(a)** $v = \sqrt{(T/\mu)} = \sqrt{(90/0.1)} = \sqrt{900} = \mathbf{30\ m\ s^{-1}}$. (1) **(5)**

(b) Fundamental: $L = \lambda/2 \rightarrow \lambda = 2L = \mathbf{1.2\ m}$. (1)

(c) $\nu_1 = v/\lambda = 30/1.2 = \mathbf{25\ Hz}$. (1)

(d) $\nu_4 = 4\nu_1 = \mathbf{100\ Hz}$. (1)

(e) $v \propto \sqrt{T}$: with $4T$ the speed doubles to 60 m s^{-1}, so $\nu_1 = 60/1.2 = \mathbf{50\ Hz}$. (1)

OR

(a) **Beats** (waxing and waning of the amplitude/intensity). (1)

(b) $\nu_{beat} = 11 - 9 = \mathbf{2\ Hz}$. (1)

(c) Number of beats = $2 \times 3 = \mathbf{6}$. (1)

(d) Resultant frequency = $(11 + 9)/2 = \mathbf{10\ Hz}$. (1)

(e) Maximum amplitude = $1 + 1 = \mathbf{2\ units}$ (peaks of the envelope in the figure). (1)

— END OF SOLUTIONS —