## Exemplar Solutions for Class 11 Physics Chapter 14 – Waves

### Very Short Answer Questions

**18.** A sonometer wire is vibrating in resonance with a tuning fork. Keeping the tension applied same, the length of the wire is doubled. Under what conditions would the tuning fork still be in resonance with the wire?

**Answer:** The frequency of a sonometer wire is given by: $f = (n/2L)\sqrt{(T/\mu)}$

When length is doubled ($L \to 2L$), for the same tension and linear mass density: $f_2 = (n/4L)\sqrt{(T/\mu)} = f_1/2$

For resonance to continue with the same tuning fork, the wire must vibrate in the second harmonic ($n = 2$) instead of the fundamental ($n = 1$).

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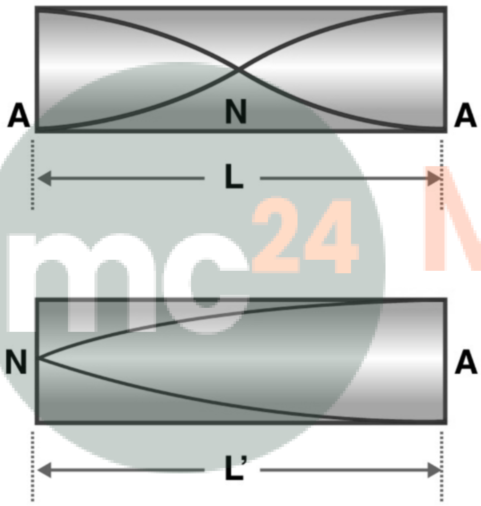
**19.** An organ pipe of length L open at both ends is found to vibrate in its first harmonic when sounded with a tuning fork of 480 Hz. What should be the length of a pipe closed at one end, so that it also vibrates in its first harmonic with the same tuning fork?

**Answer:**






For open pipe: $L = \lambda/2$ For closed pipe: $L' = \lambda/4$

Since both pipes use the same tuning fork (same frequency and wavelength): $\lambda = 2L$ (from open pipe condition)

For closed pipe: $L' = \lambda/4 = 2L/4 = L/2$

The length of the closed pipe should be half the length of the open pipe.

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**20.** A tuning fork A, marked 512 Hz, produces 5 beats per second when sounded with another unmarked tuning fork B. If B is loaded with wax the number of beats is again 5 per second. What is the frequency of the tuning fork B when not loaded?

**Answer:** Initially: $|f_B - 512| = 5$ So $f_B = 517$ Hz or $f_B = 507$ Hz

When loaded with wax, frequency decreases. If $f_B$ was initially 507 Hz, loading would make it even lower, changing the beat frequency. Since beats remain 5 per second, the initial frequency must have been 517 Hz.

When loaded: $f_B' = 517 - x$, and $|f_B' - 512| = 5$ This gives $f_B' = 507$ Hz, confirming $f_B = 517$ Hz initially.

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**21.** The displacement of an elastic wave is given by the function $y = 3 \sin \omega t + 4 \cos \omega t$ where y is in cm and t is in second. Calculate the resultant amplitude.

**Answer:** Converting to standard form $y = A \sin(\omega t + \phi)$:

Let $3 = A \cos \phi$ and $4 = A \sin \phi$

$A^2 = 3^2 + 4^2 = 9 + 16 = 25$ Therefore, $A = 5$ cm

The resultant amplitude is 5 cm.

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**22.** A sitar wire is replaced by another wire of same length and material but of three times the radius. If the tension in the wire remains the same, by what factor will the frequency change?

**Answer:** Frequency of a stretched wire: $f = (n/2L)\sqrt{(T/\mu)}$

Linear mass density $\mu = \rho A = \rho \pi r^2$

For the new wire: $r_2 = 3r_1$ $\mu_2 = \rho\pi(3r_1)^2 = 9\rho\pi r_1^2 = 9\mu_1$

$f_2/f_1 = \sqrt{(\mu_1/\mu_2)} = \sqrt{(\mu_1/9\mu_1)} = 1/3$

The frequency reduces to 1/3 of its original value.

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**23.** At what temperature will the speed of sound in air be 3 times its value at 0°C?

**Answer:** Speed of sound: $v = \sqrt{(\gamma RT/M)} \propto \sqrt{T}$

$v_T/v_0 = \sqrt{(T/T_0)} = \sqrt{(T/273)}$

Given: $v_T = 3v_0$ $3 = \sqrt{(T/273)}$ $9 = T/273$ $T = 9 \times 273 = 2457$ K = 2184°C

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**24.** When two waves of almost equal frequencies $n_1$ and $n_2$ reach at a point simultaneously, what is the time interval between successive maxima?

**Answer:** Beat frequency = $|n_2 - n_1|$ Time interval between successive maxima = 1/(beat frequency) = $1/|n_2 - n_1|$ seconds

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## Short Answer Questions

**25.** A steel wire has a length of 12 m and a mass of 2.10 kg. What will be the speed of a transverse wave on this wire when a tension of $2.06 \times 10^4$ N is applied?

**Answer:** Given:

- Length, L = 12 m
- Mass, M = 2.10 kg
- Tension, T = $2.06 \times 10^4$ N

Linear mass density: $\mu = M/L = 2.10/12 = 0.175$ kg/m

Speed of transverse wave: $v = \sqrt{(T/\mu)} = \sqrt{(2.06 \times 10^4/0.175)} = \sqrt{(117{,}714)} \approx 343$ m/s

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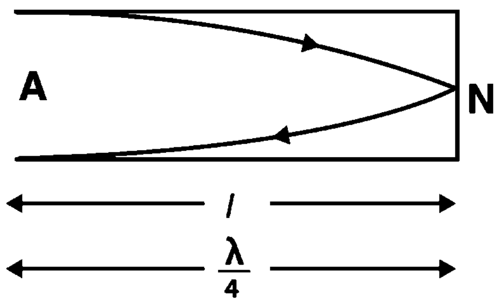
**26.** A pipe of 20 cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a source of 1237.5 Hz?

**Answer:** Given:




- Length, L = 20 cm = 0.2 m
- Frequency, f = 1237.5 Hz
- Speed of sound in air, v ≈ 330 m/s

For closed pipe, fundamental frequency: $f_1 = v/4L = 330/(4 \times 0.2) = 412.5$ Hz

Harmonic number: $n = f/f_1 = 1237.5/412.5 = 3$

The third harmonic is excited.

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**27.** A train standing at the outer signal of a railway station blows a whistle of frequency 400 Hz in still air. The train begins to move with a speed of 10 m/s towards the platform. What is the frequency of the sound for an observer standing on the platform?

**Answer:** Doppler effect formula when source moves towards stationary observer: $f' = f(v/(v - v_s))$

Given:

- Original frequency, f = 400 Hz
- Source speed, $v_s$ = 10 m/s
- Sound speed, v = 330 m/s

$f' = 400 \times (330/(330 - 10)) = 400 \times (330/320) = 412.5$ Hz

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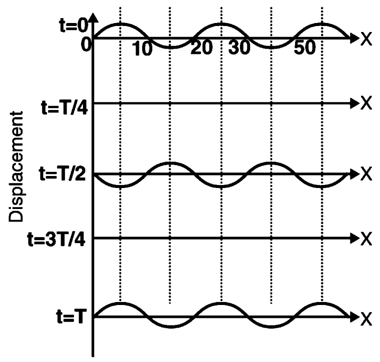
**28.** The wave pattern on a stretched string is shown in the figure. Interpret what kind of wave this is and find its wavelength.



**Answer:** The figure shows a stationary wave pattern with nodes and antinodes clearly visible.
From the pattern, the distance between consecutive nodes = $\lambda/2$ = 10 cm Therefore, wavelength $\lambda$ = 20 cm
This is a stationary wave formed by the superposition of two identical waves traveling in opposite directions.

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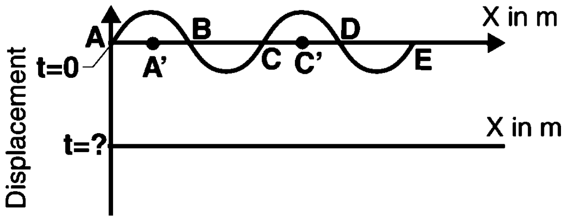
**29.** The pattern of standing waves formed on a stretched string at two instants of time are shown in the figure. The velocity of two waves superimposing to form stationary waves is 360 m/s and their frequencies are 256 Hz.




a) Calculate the time at which the second curve is plotted
b) Mark nodes and antinodes on the curve
c) Calculate the distance between A' and C'
**Answer:** Given: v = 360 m/s, f = 256 Hz
a) The second curve shows particles at mean position, which occurs at t = T/4 after maximum displacement. $T = 1/f = 1/256$ s $t = T/4 = 1/(4 \times 256) = 9.8 \times 10^{-4}$ s
b) Nodes: A, B, C, D, E (points that never move) Antinodes: A', C' (points of maximum displacement)
c) Distance between A' and C' = $\lambda = v/f = 360/256 = 1.41$ m

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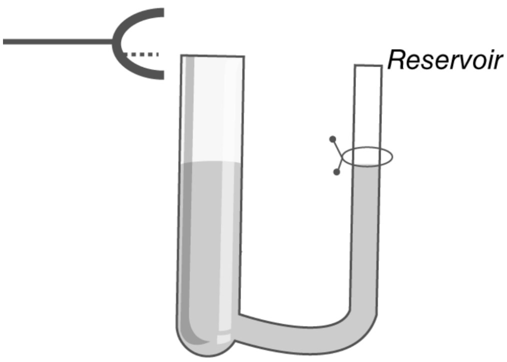
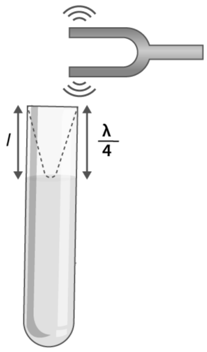
**30.** A tuning fork vibrating with a frequency of 512 Hz is kept close to the open end of a tube filled with water. The water level in the tube is gradually lowered. When the water level is 17 cm below the open end, maximum intensity of sound is heard. If the room temperature is 20°C, calculate: a) speed of sound in air at room temperature




b) speed of sound in air at 0°C

c) if the water in the tube is replaced with mercury, will there be any difference in your observations?

**Answer:** a) For first resonance in closed tube: $L = \lambda/4$ $\lambda = 4L = 4 \times 0.17 = 0.68$ m $v = f\lambda = 512 \times 0.68 = 348.16$ m/s




b) $v_0/v_{20} = \sqrt{(273/293)}$ $v_0 = 348.16 \times \sqrt{(273/293)} = 343$ m/s

c) No difference would be observed because the acoustic properties depend only on the air column, not on the liquid used to adjust the column length.

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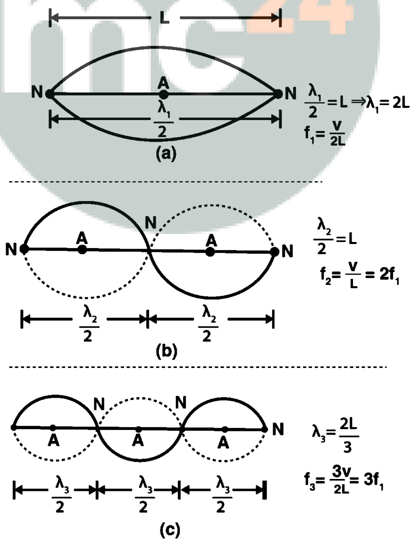
**31.** Show that when a string fixed at its two ends vibrates in 1 loop, 2 loops, 3 loops, and 4 loops, the frequencies are in the ratio 1:2:3:4.

**Answer:** For a string fixed at both ends, the frequency of the nth harmonic is: $f_n = (n/2L)\sqrt{(T/\mu)}$






For different modes:

- n = 1 (1 loop): $f_1 = (1/2L)\sqrt{(T/\mu)}$
- n = 2 (2 loops): $f_2 = (2/2L)\sqrt{(T/\mu)} = 2f_1$
- n = 3 (3 loops): $f_3 = (3/2L)\sqrt{(T/\mu)} = 3f_1$
- n = 4 (4 loops): $f_4 = (4/2L)\sqrt{(T/\mu)} = 4f_1$

Therefore: $f_1 : f_2 : f_3 : f_4 = 1 : 2 : 3 : 4$