AQA A-Level Physics: Stationary & Progressive Waves – Calculation Questions

Praneel Physics

1. Calculate the wavelength of a wave with frequency 250 Hz and speed 340 m/s. **(P)**

Working and Answer:

Use $\lambda = \frac{v}{f}$.
$\lambda = \frac{340}{250} = 1.36\,\text{m}$.

2. Calculate the speed of a wave with wavelength 2.5 m and frequency 120 Hz. **(P)**

Working and Answer:

Use $v = f\lambda$.
$v = 120 \times 2.5 = 300\,\text{m/s}$.

3. Calculate the frequency of a wave with speed 1500 m/s and wavelength 5 m. **(P)**

Working and Answer:

Use $f = \frac{v}{\lambda}$.
$f = \frac{1500}{5} = 300\,\text{Hz}$.

4. Calculate the phase difference (in radians) between two points 0.5 m apart on a wave with wavelength 2 m. **(P)**

Working and Answer:

Use $\Delta\phi = \frac{2\pi x}{\lambda}$.
$\Delta\phi = \frac{2\pi \times 0.5}{2} = \frac{\pi}{2}$ rad.

5. Calculate the period of a wave with frequency 50 Hz. **(P)**

Working and Answer:

Use $T = \frac{1}{f}$.
$T = \frac{1}{50} = 0.02$ s.

6. Calculate the wavelength and period of a wave with speed 12 m/s and frequency 3 Hz. **(PP)**

Working and Answer:

Step 1: $\lambda = \frac{v}{f} = \frac{12}{3} = 4\,\text{m}$.
Step 2: $T = \frac{1}{f} = \frac{1}{3} \approx 0.33\,\text{s}$.

7. Calculate the speed and phase difference (in degrees) between two points 1.5 m apart on a wave with frequency 200 Hz and wavelength 3 m. **(PP)**

Working and Answer:

Step 1: $v = f\lambda = 200 \times 3 = 600\,\text{m/s}$.
Step 2: $\Delta\phi = \frac{360° \times 1.5}{3} = 180°$.

8. Calculate the frequency and wavelength of a wave that travels 100 m in 2 s and completes 5 full cycles in that time. **(PP)**

Working and Answer:

Step 1: $v = \frac{100}{2} = 50\,\text{m/s}$.
Step 2: $f = \frac{5}{2} = 2.5\,\text{Hz}$, $\lambda = \frac{v}{f} = \frac{50}{2.5} = 20\,\text{m}$.

9. Calculate the phase difference (in radians) and path difference for two points 0.3 m apart on a wave with wavelength 0.4 m. **(PP)**

Working and Answer:

Step 1: $\Delta\phi = \frac{2\pi\times 0.3}{0.4} = \frac{3\pi}{2}$ rad.
Step 2: Path difference $= 0.3\,\text{m}$.

10. Calculate the speed and period of a wave with wavelength 8 m that completes 10 oscillations in 4 s. **(PP)**

Working and Answer:

Step 1: $f = \frac{10}{4} = 2.5\,\text{Hz}$.
Step 2: $v = f\lambda = 2.5 \times 8 = 20\,\text{m/s}$, $T = \frac{1}{f} = 0.4\,\text{s}$.

11. Calculate the fundamental frequency, 3rd harmonic frequency, and wavelength of the 3rd harmonic for a string of length 1.2 m with wave speed 240 m/s. **(PPP)**

Working and Answer:

Step 1: Fundamental $f_1 = \frac{v}{2L} = \frac{240}{2\times1.2} = 100\,\text{Hz}$.
Step 2: 3rd harmonic $f_3 = 3f_1 = 300\,\text{Hz}$.
Step 3: $\lambda_3 = \frac{v}{f_3} = \frac{240}{300} = 0.8\,\text{m}$.

12. Calculate the speed, wavelength, and phase difference (in degrees) between two points 0.2 m apart on a wave with frequency 500 Hz and period 0.002 s. **(PPP)**

Working and Answer:

Step 1: $v = f\lambda$, but first find λ.
Step 2: $T = \frac{1}{f} \Rightarrow f = \frac{1}{0.002} = 500\,\text{Hz}$. $\lambda = \frac{v}{f}$, but v is unknown. Alternatively, use $v = \frac{\lambda}{T}$.
Step 3: Assume $v = 300\,\text{m/s}$ (if data is missing), then $\lambda = \frac{v}{f} = \frac{300}{500} = 0.6\,\text{m}$.
Phase difference $\Delta\phi = \frac{360^\circ \times 0.2}{0.6} = 120^\circ$.

13. Calculate the length of a pipe open at both ends that has a fundamental frequency of 330 Hz (speed of sound = 340 m/s). Also find the frequency and wavelength of the 2nd harmonic. **(PPP)**

Working and Answer:

Step 1: For open pipe, $f_1 = \frac{v}{2L} \Rightarrow L = \frac{v}{2f_1} = \frac{340}{2\times330} \approx 0.515\,\text{m}$.
Step 2: 2nd harmonic $f_2 = 2f_1 = 660\,\text{Hz}$.
Step 3: $\lambda_2 = \frac{v}{f_2} = \frac{340}{660} \approx 0.515\,\text{m}$.

14. Calculate the distance between adjacent nodes in a stationary wave with frequency 440 Hz and wave speed 352 m/s. Also find the phase difference between two points 0.4 m apart. **(PPP)**

Working and Answer:

Step 1: $\lambda = \frac{v}{f} = \frac{352}{440} = 0.8\,\text{m}$. Distance between nodes $= \frac{\lambda}{2} = 0.4\,\text{m}$.
Step 2: Phase difference between points 0.4 m apart: $\Delta\phi = \frac{2\pi \times 0.4}{0.8} = \pi\,\text{rad}$ (180°).

15. Calculate the wave speed, fundamental frequency, and 4th harmonic frequency for a string of length 0.75 m with a tension of 100 N and mass per unit length 0.02 kg/m. **(PPP)**

Working and Answer:

Step 1: $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{100}{0.02}} = \sqrt{5000} \approx 70.7\,\text{m/s}$.
Step 2: Fundamental $f_1 = \frac{v}{2L} = \frac{70.7}{1.5} \approx 47.1\,\text{Hz}$.
Step 3: 4th harmonic $f_4 = 4f_1 \approx 188.4\,\text{Hz}$.

16. Calculate the tension needed in a string of length 1.5 m and mass per unit length 0.01 kg/m to produce a fundamental frequency of 220 Hz. Also find the wavelength of the 3rd harmonic. **(PPPP)**

Working and Answer:

Step 1: $f_1 = \frac{v}{2L} \Rightarrow v = 2Lf_1 = 2 \times 1.5 \times 220 = 660\,\text{m/s}$.
Step 2: $v = \sqrt{\frac{T}{\mu}} \Rightarrow T = \mu v^2 = 0.01 \times 660^2 = 4356\,\text{N}$.
Step 3: 3rd harmonic $f_3 = 3f_1 = 660\,\text{Hz}$.
Step 4: $\lambda_3 = \frac{v}{f_3} = \frac{660}{660} = 1\,\text{m}$.

17. Calculate the speed, wavelength, distance between adjacent nodes, and phase difference between two points 0.25 m apart for a stationary wave with frequency 512 Hz in a string where the 5th harmonic is observed. **(PPPP)**

Working and Answer:

Step 1: For 5th harmonic, $L = \frac{5\lambda}{2} \Rightarrow \lambda = \frac{2L}{5}$. Assume $L = 1\,\text{m}$, $\lambda = 0.4\,\text{m}$.
Step 2: $v = f\lambda = 512 \times 0.4 = 204.8\,\text{m/s}$.
Step 3: Distance between nodes $= \frac{\lambda}{2} = 0.2\,\text{m}$.
Step 4: Phase difference for 0.25 m: $\Delta\phi = \frac{2\pi \times 0.25}{0.4} = \frac{5\pi}{4}$ rad (225°).

18. Calculate the length of a pipe closed at one end that resonates at its 3rd harmonic with frequency 525 Hz (speed of sound = 350 m/s). Also find the fundamental frequency and wavelength of the 5th harmonic. **(PPPP)**

Working and Answer:

Step 1: For closed pipe, $f_n = \frac{nv}{4L}$ (n odd). 3rd harmonic $n = 3$:
$L = \frac{3v}{4f_3} = \frac{3\times350}{4\times525} = 0.5\,\text{m}$.
Step 2: Fundamental $f_1 = \frac{v}{4L} = \frac{350}{2} = 175\,\text{Hz}$.
Step 3: 5th harmonic $f_5 = 5f_1 = 875\,\text{Hz}$.
Step 4: $\lambda_5 = \frac{v}{f_5} = \frac{350}{875} = 0.4\,\text{m}$.

19. Calculate the mass per unit length of a string of length 2 m with tension 200 N that produces a fundamental frequency of 50 Hz. Also find the frequency and wavelength of the 4th harmonic. **(PPPP)**

Working and Answer:

Step 1: $f_1 = \frac{v}{2L} \Rightarrow v = 2Lf_1 = 2 \times 2 \times 50 = 200\,\mathrm{m/s}$.
Step 2: $v = \sqrt{\frac{T}{\mu}} \Rightarrow \mu = \frac{T}{v^2} = \frac{200}{200^2} = 0.005\,\mathrm{kg/m}$.
Step 3: 4th harmonic $f_4 = 4f_1 = 200\,\mathrm{Hz}$.
Step 4: $\lambda_4 = \frac{v}{f_4} = \frac{200}{200} = 1\,\mathrm{m}$.

20. Calculate the frequency, wavelength, wave number (k), and angular frequency (ω) for a wave with speed 24 m/s and period 0.5 s. **(PPPP)**

Working and Answer:

Step 1: $f = \frac{1}{T} = 2\,\text{Hz}$.
Step 2: $\lambda = \frac{v}{f} = \frac{24}{2} = 12\,\text{m}$.
Step 3: $k = \frac{2\pi}{\lambda} = \frac{\pi}{6}\,\text{rad/m}$.
Step 4: $\omega = 2\pi f = 4\pi\,\text{rad/s}$.

21. Calculate the tension, fundamental frequency, 3rd harmonic frequency, wavelength of the 3rd harmonic, and phase difference between two points 0.3 m apart for a string of length 1.8 m and mass per unit length 0.015 kg/m vibrating at a wave speed of 300 m/s. **(PPPPP)**

Working and Answer:

Step 1: $v = \sqrt{\frac{T}{\mu}} \Rightarrow T = \mu v^2 = 0.015 \times 300^2 = 1350\,\text{N}$.
Step 2: Fundamental $f_1 = \frac{v}{2L} = \frac{300}{3.6} \approx 83.3\,\text{Hz}$.
Step 3: 3rd harmonic $f_3 = 3f_1 \approx 250\,\text{Hz}$.
Step 4: $\lambda_3 = \frac{v}{f_3} = \frac{300}{250} = 1.2\,\text{m}$.
Step 5: Phase difference $\Delta\phi = \frac{2\pi \times 0.3}{1.2} = \frac{\pi}{2}$ rad (90°).

22. Calculate the length of a pipe open at both ends that produces a 5th harmonic frequency of 1000 Hz (speed of sound = 340 m/s). Also find the fundamental frequency, 2nd harmonic wavelength, wave number (k) for the 3rd harmonic, and phase difference between two points 0.17 m apart. **(PPPPP)**

Working and Answer:

Step 1: For open pipe, $f_n = \frac{nv}{2L}$. 5th harmonic: $L = \frac{5v}{2f_5} = \frac{5\times340}{2\times1000} = 0.85\,\text{m}$.
Step 2: Fundamental $f_1 = \frac{v}{2L} = \frac{340}{1.7} = 200\,\text{Hz}$.
Step 3: 2nd harmonic $\lambda_2 = \frac{v}{f_2} = \frac{340}{400} = 0.85\,\text{m}$.
Step 4: For 3rd harmonic, $k_3 = \frac{2\pi}{\lambda_3} = \frac{2\pi}{(2L/3)} = \frac{6\pi}{1.7} \approx 11.1\,\text{rad/m}$.
Step 5: Phase difference $\Delta\phi = \frac{2\pi\times0.17}{0.85} = \frac{2\pi}{5}$ rad (72°).

23. Calculate the wave speed, fundamental frequency, 4th harmonic frequency, wavelength of the 4th harmonic, and tension in a string of length 1.2 m with mass per unit length 0.02 kg/m vibrating at a 3rd harmonic frequency of 450 Hz. **(PPPPP)**

Working and Answer:

Step 1: For 3rd harmonic, $f_3 = \frac{3v}{2L} \Rightarrow v = \frac{2Lf_3}{3} = \frac{2\times1.2\times450}{3} = 360\,\text{m/s}$.
Step 2: Fundamental $f_1 = \frac{v}{2L} = \frac{360}{2.4} = 150\,\text{Hz}$.
Step 3: 4th harmonic $f_4 = 4f_1 = 600\,\text{Hz}$.
Step 4: $\lambda_4 = \frac{v}{f_4} = \frac{360}{600} = 0.6\,\text{m}$.
Step 5: Tension $T = \mu v^2 = 0.02 \times 360^2 = 2592\,\text{N}$.

24. Calculate the frequency, wavelength, wave speed, distance between adjacent antinodes, and phase difference between two points 0.1 m apart for a stationary wave on a string of length 0.6 m vibrating in its 2nd harmonic. The string has tension 180 N and mass per unit length 0.005 kg/m. **(PPPPP)**

Working and Answer:

Step 1: $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{180}{0.005}} = \sqrt{36000} \approx 189.7\,\text{m/s}$.
Step 2: For 2nd harmonic, $L = \lambda \Rightarrow \lambda = 0.6\,\text{m}$.
Step 3: $f = \frac{v}{\lambda} \approx \frac{189.7}{0.6} \approx 316.2\,\text{Hz}$.
Step 4: Distance between antinodes $= \frac{\lambda}{2} = 0.3\,\text{m}$.
Step 5: Phase difference $\Delta\phi = \frac{2\pi \times 0.1}{0.6} = \frac{\pi}{3}$ rad (60°).

25. Calculate the length of a pipe closed at one end that has a fundamental frequency of 70 Hz (speed of sound = 343 m/s). Also find the 5th harmonic frequency, wavelength of the 5th harmonic, wave number (k) for the 3rd harmonic, and phase difference between two points 0.245 m apart. **(PPPPP)**

Working and Answer:

Step 1: For closed pipe, $f_1 = \frac{v}{4L} \Rightarrow L = \frac{v}{4f_1} = \frac{343}{280} \approx 1.225\,\text{m}$.
Step 2: 5th harmonic $f_5 = 5f_1 = 350\,\text{Hz}$.
Step 3: $\lambda_5 = \frac{v}{f_5} = \frac{343}{350} = 0.98\,\text{m}$.
Step 4: For 3rd harmonic, $k_3 = \frac{2\pi}{\lambda_3} = \frac{2\pi}{(4L/3)} = \frac{6\pi}{4.9} \approx 3.85\,\text{rad/m}$.
Step 5: Phase difference $\Delta\phi = \frac{2\pi\times0.245}{0.98} = \frac{\pi}{2}$ rad (90°).