

Stationary waves on a string • Required Practical 1

35–40 minutes independent practice + 15–20 minutes review | 36 marks

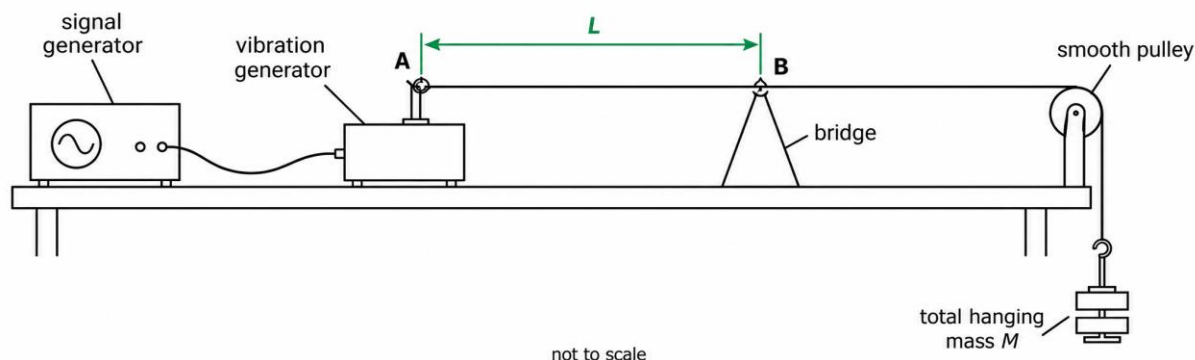
AQA AS Physics 7407 • First-year A Level 7408

Specification points covered

AQA AS 7407 / first-year A Level 7408: 3.3.1.3 — stationary waves, nodes, antinodes, harmonics; first-harmonic frequency and Required Practical 1: effects of length, tension and mass per unit length. Supporting content: 3.3.1.1 — $v = f\lambda$, wavelength and phase; 3.1.2 — absolute and percentage uncertainties and combining uncertainties.

A resonance tester for instrument cords

A sensor manufacturer is developing a resonance tester for tension in lightweight instrument cords. The team first validates its method on a bench rig, then checks whether a replacement cord can meet a frequency target without exceeding the tester's tension limit.



Use $g = 9.80 \text{ m s}^{-2}$ and $T = Mg$; M includes the hanger and all added masses. For the first harmonic, $f_1 = (1/(2L))\sqrt{(T/\mu)}$, where μ is mass per unit length. Assume uniform cords, negligible bridge/pulley friction and a stationary hanging mass. With small drive amplitude, A and B are approximate nodes. Diagrams are not to scale.

1. Prepare the resonance tester [2 marks]

Measure the vibrating length L from attachment A to bridge B, not along the whole cord.

(a) Calculate μ in kg m^{-1} for an unstretched uniform cord sample of length 4.00 m and mass 3.20 g. [1 mark]

(b) The total hanging mass is 0.200 kg. Calculate the tension T in the cord. [1 mark]

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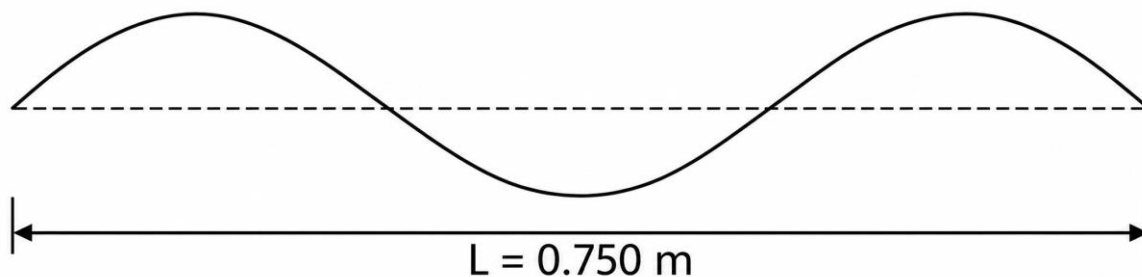
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2. Identify a resonance [8 marks]

With $L = 0.750 \text{ m}$, the driver is set to 99.0 Hz . The snapshot shows the third harmonic at an instant of maximum displacement. Use the measured drive frequency in calculations.

(a) On the diagram, label every node N and every antinode A. [2 marks]



snapshot at maximum displacement — not to scale

(b) Determine the wavelength of each travelling wave that forms this pattern, then calculate the wave speed. [2 marks]

(c) State the phase relationship between two particles within the same loop. Then state the phase difference between particles at the centres of adjacent loops. [2 marks]

(d) Explain how a wave from the driver and a reflected wave form this stationary-wave pattern. [2 marks]



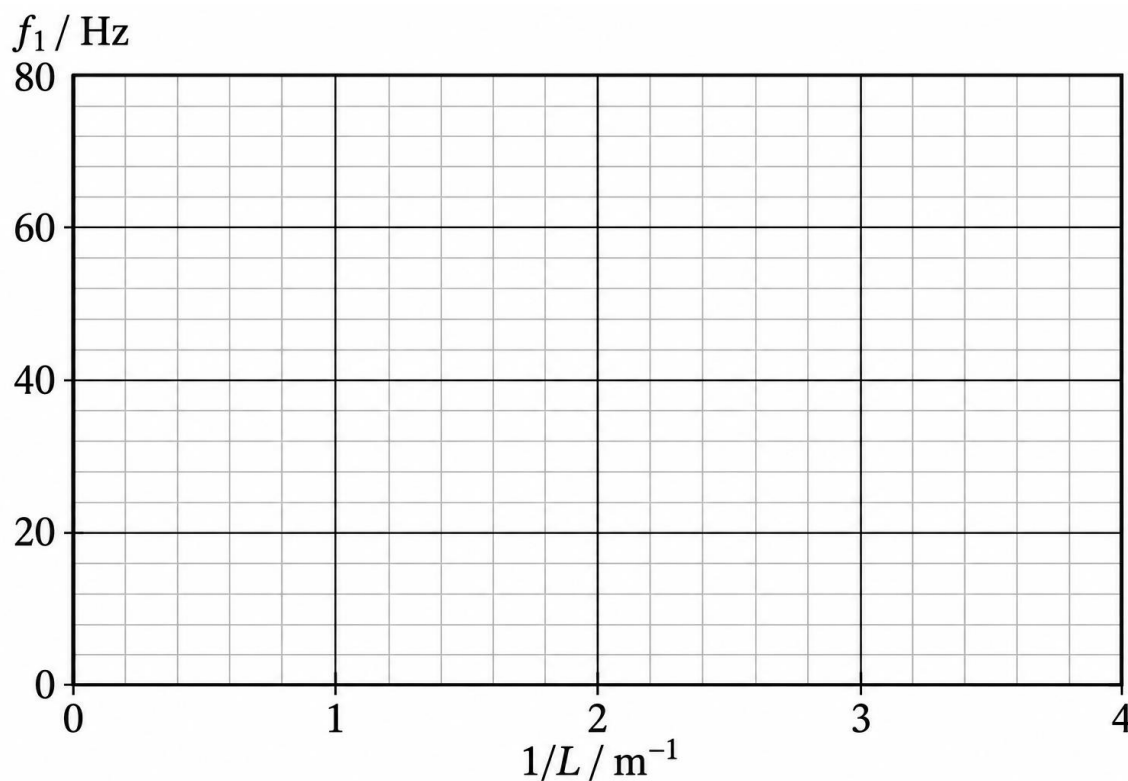
3. Use a length investigation [7 marks]

Using the same cord and total hanging mass, the team changes L and retunes the driver each time to give one loop: the first harmonic. The table contains rounded measurements.

Vibrating length L / m	Frequency f_1 / Hz	$1/L$ / m^{-1}
0.320	77.2	3.13
0.400	61.8	2.50
0.500	49.4	2.00
0.625	39.6	
0.800	30.9	
1.000	24.7	1.00

(a) Complete the two missing values of $1/L$ in the table. [1 mark]

(b) Plot all six values of f_1 against $1/L$ on the grid. Draw a single straight line of best fit; do not join successive points. [3 marks]



Question 3 continued

(c) Use a large triangle on your best-fit line to determine the gradient. Show the values you use and give the unit. [2 marks]

(d) Use the first-harmonic relationship to obtain the wave speed from your gradient. [1 mark]

4. Approve a cord for the tester [6 marks]

Use $v = 49.4 \text{ m s}^{-1}$ and $T = 1.96 \text{ N}$ in part (a), even if your graph result differs. For parts (b) and (c), use the weighed μ values stated, not your answer to (a).

(a) The model gives $v = \sqrt{T/\mu}$. Infer μ from the graph result and compare it with the weighed value $8.00 \times 10^{-4} \text{ kg m}^{-1}$. [2 marks]

(b) For the original cord, $\mu = 8.00 \times 10^{-4} \text{ kg m}^{-1}$. Calculate the tension needed for first-harmonic frequency 66.0 Hz when $L = 0.750 \text{ m}$. [2 marks]

(c) A replacement cord has $\mu = 1.80 \times 10^{-3} \text{ kg m}^{-1}$. It must resonate at a first-harmonic frequency of 33.0 Hz with $L = 0.750 \text{ m}$. The tester's maximum permitted tension is 4.00 N. Decide, with a calculation, whether this cord meets that requirement. [2 marks]

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5. Plan the complete Required Practical 1 [6 marks]

Parts (a)–(c) scaffold a six-mark-style practical method. Write enough detail for another team to investigate all three variables with this rig. Use first-harmonic resonances throughout.

(a) Describe how to investigate the effect of vibrating length L on frequency, including how L is measured, how a resonance is identified and what is kept constant. [2 marks]

(b) Describe how to investigate the effect of tension. Identify the quantity changed, the quantities kept constant and a suitable graph to test the expected relationship. [2 marks]

(c) Describe how to determine μ for different cords and investigate its effect on frequency. Include how you would improve confidence in the frequency readings. [2 marks]



6. Evaluate the calibration [7 marks]

The tester will infer cord properties from measured frequency and length. The team checks its uncertainty budget and a software mass entry.

(a) The endpoint readings are $x_A = (0.125 \pm 0.001)$ m and $x_B = (0.875 \pm 0.001)$ m. Calculate L , its absolute uncertainty and its percentage uncertainty using a worst-case approach. [2 marks]

(b) For $f_1 = (1/(2L))\sqrt{T/\mu}$, the percentage uncertainties in T and μ are 2.0% and 3.0%. Use your length uncertainty from (a) to calculate the worst-case percentage uncertainty in the predicted first-harmonic frequency. [2 marks]

(c) The software calculates $\mu = T/(2Lf_1)^2$. A technician enters only 150 g of added masses and omits the 50 g hanger. L and f_1 are measured correctly. Calculate the percentage error in the inferred μ and state whether repeating the readings removes this error. [2 marks]

(d) Suggest one specific precaution against injury from falling masses that still allows the cord to have the intended tension during a reading. [1 mark]

