Core practical 7: Investigate the effects of length, tension and mass per unit length on the frequency of a vibrating string or wire

Objectives

- To carry out an investigation into standing waves
- To develop the skills to carry out further investigations

Safety

- There are no hazards associated with this experiment if rubber is used as the medium. If using metal wire, safety spectacles should be worn.
- Follow the usual electrical precautions for mains apparatus including a visual inspection of the supply lead.

Specification links

- Practical techniques 1, 3, 8, 9
- CPAC 2a, 2b, 2c, 2d, 4a, 4b

Procedure

1. Attach one end of the ‘string’ to the vibration transducer. Pass the other end over the bench pulley and attach the mass hanger.
2. Add masses until the total mass is 100 g.
3. Turn on the signal generator to set the rubber oscillating. Vary the oscillating length by moving the vibration generator until resonance is observed.
4. In this investigation, you are observing standing waves. These can occur at a variety of resonant frequencies. You should investigate the effect of the factors affecting these frequencies.
5. You might use a cathode ray oscilloscope to determine the exact frequency of the vibration generator.
6. You should already have planned which variables you will test in this investigation and how you will carry it out. Your teacher will help you with any details.

Notes on procedure

- The emphasis here should be on the student making their own plan and carrying out their own investigation. They should have decided what to vary and what to measure even though they will not be able to find out the actual values until they are in front of the apparatus. The key instruction is step 3.

Answers to questions

1. This is likely to be the measurement of a resonant frequency unless the calibration of the signal generator is accurate. Measuring the wavelength is also uncertain as a thick blur is observed at the nodes.
2. The description should include mention of the control variables and some indication of the reason for the values and ranges selected.
3. It will probably be the sharpness of resonance that causes the biggest problem. Adjusting the frequency while looking closely at a node is a technique to gain the largest response. Looking at the amplitude is probably less helpful.
4. This answer can be as far reaching as desired. Research involving resonant cavities for lasers and radio frequency waves is easily accessible to students. Students might like to research the history of this measurement too.

Sample data

At a constant frequency of 56 Hz

T/N	*λ*/m
1.0	0.277
1.5	0.344
2.0	0.405
2.5	0.458
3.0	0.517
3.5	0.553

A graph of T against λ^2 gives a value for μ of 3.4 gm^{-1}.

At a constant T = 1.96 N

λ/m	*f*/Hz
1.250	19.2
0.975	24.1
0.785	30.3
0.650	36.6
0.557	42.3
0.493	48.8

A graph of λ against $\frac{1}{f}$ gives a value for μ of 3.4 gm^{-1}.

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All the maths you need

- $v = f\lambda$ and $v^2 = \frac{T}{\mu}$, so $f^2\lambda^2 = \frac{T}{\mu}$
- Use ratios, fractions and percentages.
- Use an appropriate number of significant figures.
- Find arithmetic means.
- Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined by addition, subtraction, multiplication, division and raising to powers.
- Substitute numerical values into algebraic equations using appropriate units for physical quantities.
- Translate information between graphical, numerical and algebraic forms.
- Plot two variables from experimental or other data.
- Understand that $y = mx + c$ represents a linear relationship.
- Determine the slope and intercept of a linear graph.

Equipment

- 2 m length of rubber 'string'
- vibration generator connected to a signal generator
- bench pulley
- slotted masses and hanger
- metre ruler

Procedure

1. Attach one end of the 'string' to the vibration transducer. Pass the other end over the bench pulley and attach the mass hanger.
2. Add masses until the total mass is 100 g.
3. Turn on the signal generator to set the rubber oscillating. Vary the oscillating length by moving the vibration generator until resonance is observed.
4. In this investigation, you are observing standing waves. These can occur at a variety of resonant frequencies. You should investigate the effect of the factors affecting these frequencies.
5. You might use a cathode ray oscilloscope to determine the exact frequency of the vibration generator.
6. You should already have planned which variables you will test in this investigation and how you will carry it out. Your teacher will help you with any details.

Analysis of results

1. You should graphically display your results to show the relationships between the variables you identified and measured.
2. You should assess the uncertainties in your measurements to determine whether these affect the reproducibility of your findings.

Learning tips

1. Your measurement has greater resolution if you measure as large a length as possible, or as many half-wavelengths as possible.

Questions

1. Identify the major sources of uncertainty in your work.
2. Explain why you chose the variables you did.
3. Describe what you found difficult to get right and how you did get it right.
4. Research how a standing wave can be set up and used to determine a value for the speed of electromagnetic radiation.

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Equipment per student/group	**Notes on equipment**
2 m length of rubber ‘string’	Elasticated cord, pulley cord from scientific suppliers and thin rubber tubing work well. It can also be done with ordinary string if necessary.
vibration generator connected to a signal generator	
bench pulley	To allow the masses to hang vertically
slotted masses and hanger	
metre ruler	
Notes	