Core practical 5: Determine the Young modulus of a material

Objective

- To take measurements of a long wire to determine the Young modulus for copper

Safety	Specification links
• The wire will be under tension so safety spectacles should be worn. • Although the masses used are not too heavy, you should still take care when adding and removing them.	• Practical techniques 1, 5 • CPAC 1a, 3b, 5b

Procedure	Notes on procedure
1. Fix the bench pulley at the end of the bench. Trap one end of the wire between the two wood blocks and secure these to the bench approximately 3 m from the pulley. Lay out the wire so that it passes over the pulley and attach the slotted mass hanger to the end. Measure the diameter *d* of the wire. 2. Lay the metre ruler under the wire near the pulley and attach the sticky label to act as a length marker. You judge the length by looking vertically down over the edge of the paper onto the scale of the metre ruler. The set square will help you to do this. 3. Measure the length of wire *L* from the wood blocks to the edge of the paper. 4. Add masses to the hanger and record the position of the marker against the metre ruler. Calculate the extension *x* for each mass added. 5. You might notice significant creep occurring at higher loads. This indicates the elastic limit has been exceeded.	• It is important that the length of the wire is long as the extension will only be small before creep sets in. • 0.5 N weights will allow more readings to be taken.

Answers to questions

1. A long wire makes the extension large enough to read. Since $x = \frac{FL}{AE}$, a large value for *L* and a small value for *A* make *x* sufficiently large to measure with a metre ruler.
2. Take pairs of readings at right angles to each other. This ensures the wire is circular. Repeat these readings down the length of the wire: five times should be sufficient. Calculate the mean of all 10 values.
3. The extension is very small and, using a metre ruler, we get only one significant figure. Plotting the mass added against extension for the gradient means that we might trust two significant figures although one significant figure is strictly correct.

Sample data

m/kg	*x*/mm
0.100	0
0.200	3
0.300	5
0.400	8
0.500	11
0.600	14

Using 36 swg, copper – diameter = 1.93×10^{-4} m and 3.100 m length
Gives $E = 3.7 \times 10^{10}$ Nm^{-2}

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All the maths you need

- $E = \frac{\sigma}{\varepsilon}$ where $\sigma = \frac{m\mathbf{g}}{A}$

  Remember to use the radius when calculating the cross-sectional area A of the wire.

  m is the mass added.
- $\varepsilon = \frac{x}{L}$
- Recognise and make use of appropriate units in calculations.
- Recognise and use expressions in decimal and standard form.
- Use an appropriate number of significant figures.
- Change the subject of an equation, including non-linear equations.
- 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

- 3.1 m length of 36 swg copper wire
- two wooden blocks and clamp to secure one end of the wire
- bench pulley
- slotted masses up to 600 g and hanger
- metre ruler
- micrometer screw gauge
- small piece of sticky label or similar to mark position on wire
- 90° set square

Procedure

1. Fix the bench pulley at the end of the bench. Trap one end of the wire between the two wood blocks and secure these to the bench approximately 3 m from the pulley. Lay out the wire so that it passes over the pulley and attach the slotted mass hanger to the end. Measure the diameter d of the wire.
2. Lay the metre ruler under the wire near the pulley and attach the sticky label to act as a length marker. You judge the length by looking vertically down over the edge of the paper onto the scale of the metre ruler. The set square will help you to do this.
3. Measure the length of wire L from the wood blocks to the edge of the paper.
4. Add masses to the hanger and record the position of the marker against the metre ruler. Calculate the extension x for each mass added.
5. You might notice significant creep occurring at higher loads. This indicates the elastic limit has been exceeded.

Analysis of results

1. Plot a graph of mass added against extension.
2. Measure the gradient of the straight portion of the graph and use this to calculate the Young modulus for the copper.
3. Research a value for the Young modulus of copper and comment on your result.

Questions

1. Explain why a long wire is most suitable for this experiment.
2. Describe a good technique for measuring the diameter.
3. Explain why a value with two significant figures is appropriate for the answer.

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• To take measurements of a long wire to determine the Young modulus for copper	• The wire will be under tension so safety spectacles should be worn. Some masses are suspended from the end.
Equipment per student/group	**Notes on equipment**
3.1 m length of 36 swg copper wire	
two wood blocks and G-clamp to secure one end of the wire	Any method of securing this end is suitable.
bench pulley	The wire is stretched horizontally and the wire passes over the pulley at the end of the bench. The masses hang below.
slotted masses up to 600 g and hanger	Include 1 × 50 g mass.
metre ruler	
micrometer screw gauge	
small piece of sticky label or similar to mark position on wire	
90° set square	
Notes	