

Springs, wires and the stiffness of materials

Physics grades 11-12 (A Level · IB · Class 11-12) · Lab

Name: _____ Date: _____ Class: _____

How stiff is a steel wire? Hang increasing loads on a long thin wire, measure each tiny extension and use the gradient of a force-extension graph, together with the wire dimensions, to calculate the Young modulus.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** A Level 3.4.2

Aim

To determine the Young modulus of a metal wire from a graph of load against extension.

Equipment

- Long thin steel wire (about 2.5 m), strong clamp at the top
- Mass hanger and slotted masses, 0.50 kg each
- Fixed scale (a vernier or travelling microscope reading to 0.01 mm) and a small marker on the wire
- Micrometer screw gauge and metre rule

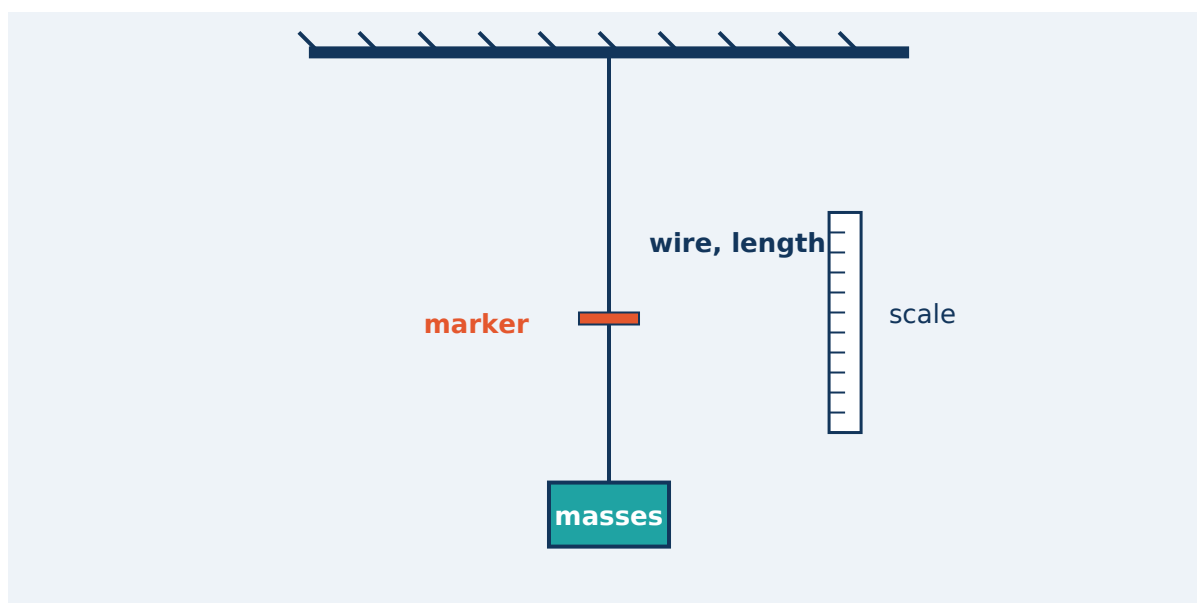
Safety

Safety

Wear eye protection because a wire under tension may snap. Place a thick pad or sand tray under the masses, keep your feet clear and do not exceed 3.0 kg.

Method

1. Measure the diameter of the wire in at least three places with the micrometer and find the mean.
2. Measure the length L from the clamp to the marker with the metre rule.
3. Hang the hanger and add a small preload to straighten the wire, then record the scale reading.
4. Add 0.50 kg and record the new scale reading; calculate the extension.
5. Continue up to 3.00 kg, then remove the masses in steps to check for a permanent extension.
6. Plot force (y) against extension (x) and find the gradient.



Set-up for measuring the extension of a long wire as the load increases.

Results

Wire length $L = 2.50$ m. Diameter readings: 0.50 mm, 0.51 mm, 0.49 mm (mean 0.50 mm).
Extension readings:

Mass / kg	Force F / N	Extension x / mm
0.50	4.91	0.31
1.00	9.81	0.63
1.50	14.71	0.93
2.00	19.62	1.26
2.50	24.53	1.55
3.00	29.43	1.88

Analysis questions

Question 1 Area of the wire

Calculate the mean diameter and the cross-sectional area.

Question 2 Forces

Check the force for 2.00 kg using $F = mg$ with $g = 9.81$ N/kg, and explain why we plot force rather than mass.

Question 3 Stress and strain at the largest load

Calculate the stress and strain at 3.00 kg.

Question 4 Gradient

Plot F against x and find the gradient using the first and last points.

Question 5 Young modulus

Use $E = \text{gradient} \times L \div A$ to find the Young modulus.

Question 6 Uncertainty

The diameter is uncertain by ± 0.01 mm. Calculate the percentage uncertainty in A and say what it does to E.

Question 7 Stored energy

Calculate the elastic energy stored in the wire at 3.00 kg.

Question 8 Improvements

Explain why a long, thin wire is used, and suggest one improvement.