Young Modulus

A Level
Practical Notes

Theory: The Young (or Young's) modulus is a measure of a material's stiffness. It quantifies the relationship between the tensile stress and strain up to the elastic limit.

The following equations apply:

$$E = \frac{\sigma}{\varepsilon} \qquad \sigma = \frac{F}{A} \qquad \varepsilon = \frac{e}{L} \qquad E = \frac{FL}{eA}$$

Where:

E is the Young modulus

σ is the tensile stress

ε is the tensile strain

e / ΔL / Δx is the change in length

F is the force

A is the area

L / x is the original length

Note that if the diameter of a wire is measured then the area is equal to:

$$A = \frac{\pi d^2}{4}$$

A high Young modulus indicates that a material is rigid and does not deform easily under stress, while a low Young modulus suggests that the material is more flexible.

Typical values are about 110 GPa for copper and 200 GPa for steel.

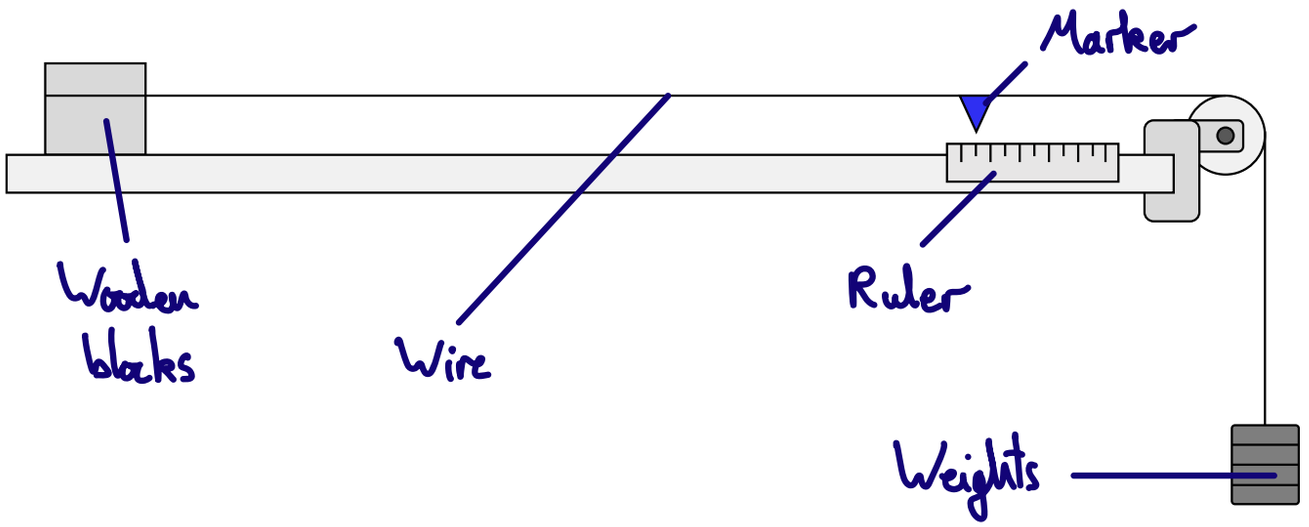
Risks and Hazards

Eye injuries: If the wire snaps, the end could quickly flick into your eye. Ensure eye protection is worn throughout.

Falling masses: If the wire snaps, the masses will fall to the floor. Cushion this area and watch where your feet are placed.

Method 1. Horizontal Wire

The extension of a wire can be measured as it is loaded with weights. A typical approach is shown below:



A piece of wire can be securely clamped between two pieces of wood. The initial length should be as long as possible, so the extension is large enough to measure. As additional masses are added to the mass hanger, the extension can be measured with a small piece of tape attached to the wire.

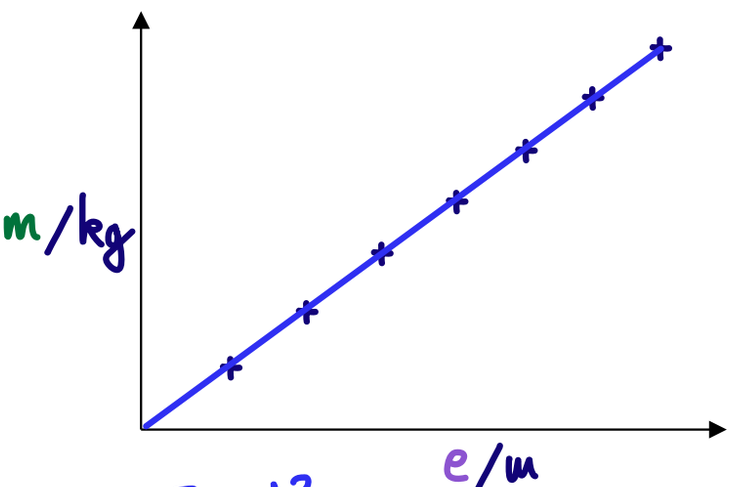
The diameter of the wire should be measured in at least three places to ensure it is circular in cross-section.

$$E = \frac{FL}{eA} \qquad F = W = mg \qquad A = \frac{\pi d^2}{4}$$

$$m = \frac{E e \pi d^2}{4gL}$$

$$m = \frac{E\pi d^2}{4gL} e$$

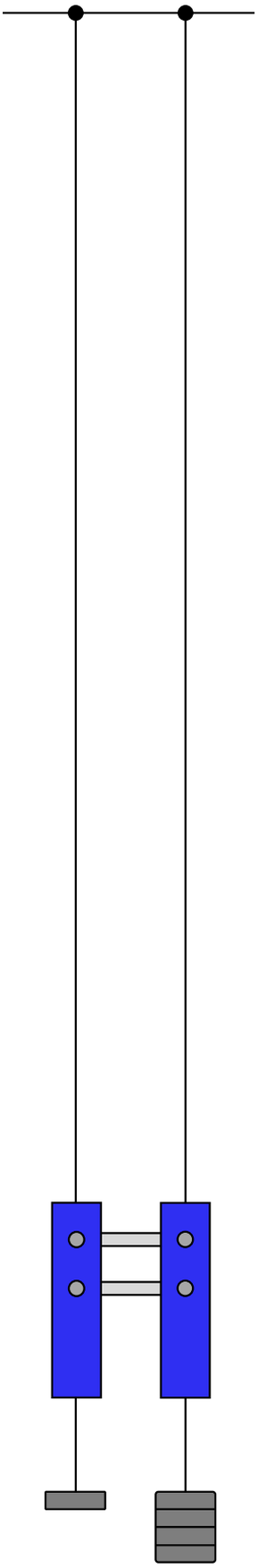
$$y = mx + c$$



$$\text{gradient} = \frac{E\pi d^2}{4gL}$$

$$E = \text{gradient} \times \frac{4gL}{\pi d^2}$$

Method 2. Vertical Wire (Searle's Apparatus)



Some schools have access to this apparatus that can be used to measure the extension of a vertical wire.

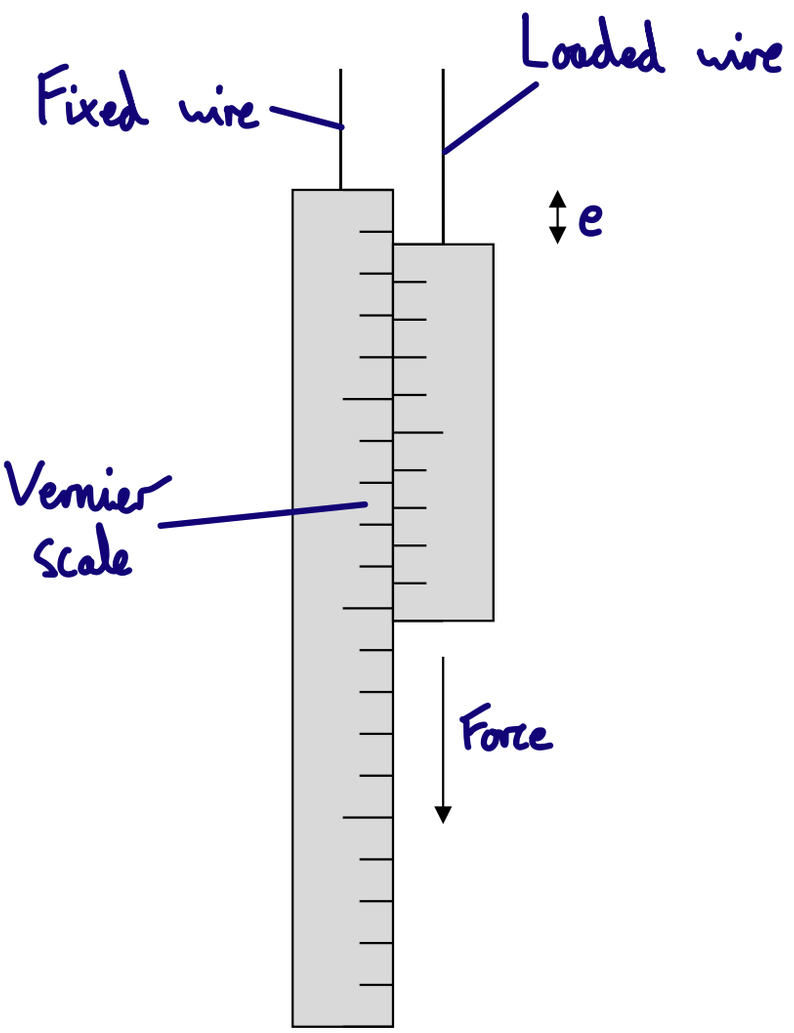
Two parallel wires are hung from a secure point on the ceiling. As one wire is loaded, it will extend relative to the other.

An advantage of this specialist equipment is that small extensions can be measured, so materials with a high Young modulus can be tested.

A typical piece of equipment may use a vernier scale, this minimises the absolute uncertainty in the measurement of extension.

Alternatively, a screw gauge is adjusted to level a small spirit level, measuring the small extension of the wire in the process.

Data is taken for extension and applied force, then processed in the same way as for **Method 1** to determine a value for the Young modulus.



Teacher and Technician Notes

- This experiment builds on the standard practical for Hooke's law, where the extension for a spring is measured as a force is applied. That measures the properties for a particular size and shape of an object, whereas this practical, by measuring stress and strain, investigates the bulk properties of the material the wire is made from.
- The energy stored in a wire under tension can be large. If the wire breaks, which is quite likely with copper, the ends can flick around incredibly fast and scratch the front of an unprotected eye. This means safety glasses are essential.
- A key discussion point for students, linked to minimising uncertainties in the data, is the best way to record the small extension of the material being tested. A marker on the wire next to a ruler is a good starting point, but it may be possible to increase the extension with a much longer starting length of wire or fashion your own vernier scale attached to the wire.
- If the extension of a metal wire is too small with the equipment you have, an alternative method is to use nylon fishing line. This is cheap, comes in many widths and the experimental setup is identical to the horizontal arrangement for a metal wire.

Suitable Equipment

36 SWG Copper Wire

Item Code: EWR070120

This standard copper wire has many uses in the physics lab. 36 SWG is thin enough to provide a good extension without breaking.

Youngs Modulus of Wire Apparatus

Item Code: VTN12302230

Two types of kit are available. One uses a linear vernier scale, the other uses a micrometer screw and a spirit level to measure small extensions.

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