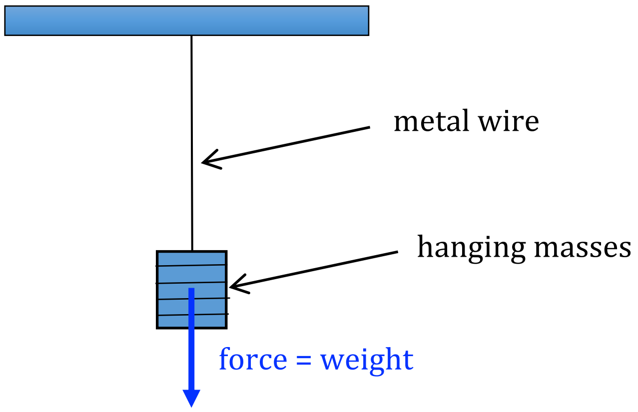
4.10.1 The Young Modulus

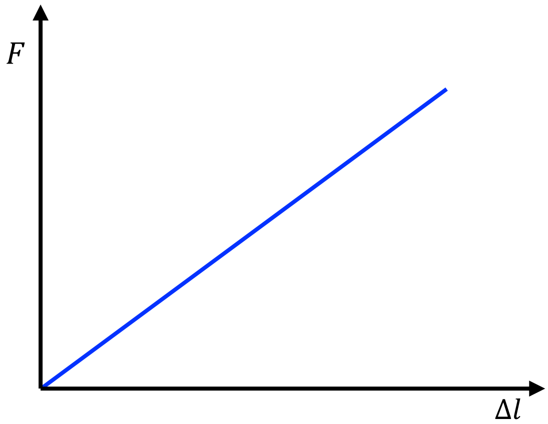
Stretching materials

Consider the following experiment:

videos



When a force (F) is applied to a metal wire it extends (Δl).

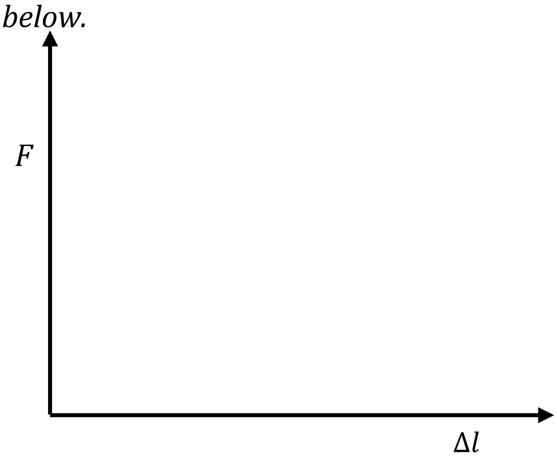


Just like the spring, we get a straight-line relationship (at least initially).

Δl is directly proportional to the applied force F.

(1)✎What would the graph look like if the wire were thicker? Sketch it on the graph below.

(2)✎What would the graph look like if the wire were longer? Sketch it on the graph below.

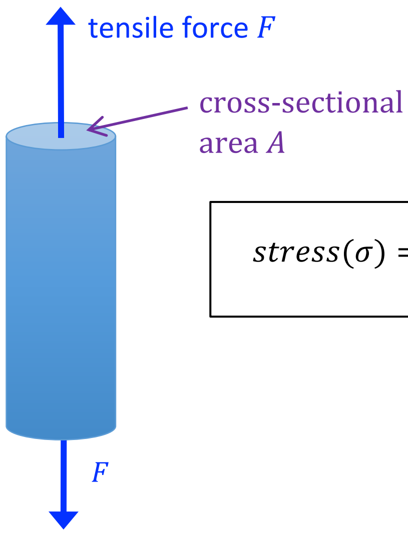


So, changing the thickness of the wire and the length of the wire affects the extension Δl.

However, the amount a material stretches should be a property of the material.

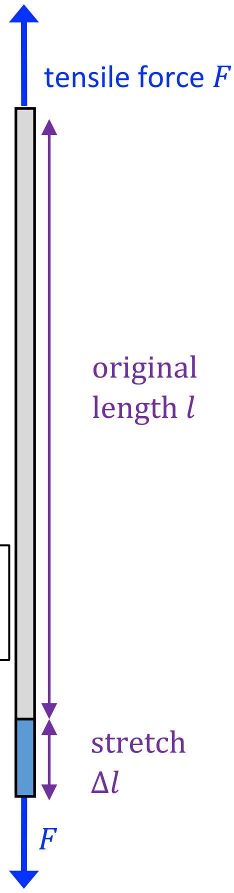
(3)✐What could we do to make a fair comparison between wires of different materials?

One way to compensate for the effect of length and cross-sectional area is to normalise. We can take the force per unit area (stress) and take the extension per unit length (strain).

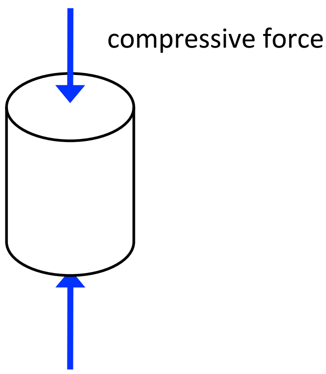


$$stress(\sigma) = \frac{F}{A}$$

$$strain(\varepsilon) = \frac{\Delta l}{l}$$



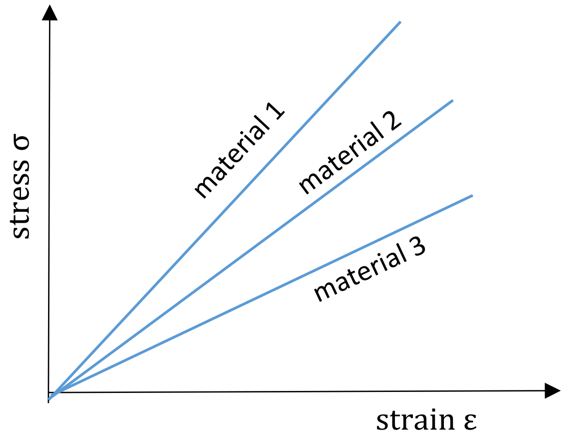
Note: The opposite of 'tensile' is 'compressive'.



Let us look at the units

tensile stress $\sigma = \frac{F}{A}$ like pressure in Nm^{-2} or pascals (Pa)

tensile strain $\varepsilon = \frac{\Delta l}{l}$ no units – just a ratio



Note: traditionally stress is plotted on the y-axis

The gradient of the stress-strain graph is a property of a material (e.g. copper will always show a characteristic gradient). The gradient (stress/strain) is called the Young modulus.

Young modulus $E = \frac{stress}{strain} = \frac{\sigma}{\varepsilon}$

(4)✎What are the units for the Young modulus?

(5)✎Find out the value of the Young modulus for steel, copper and glass.

(6)✎What do you notice about the magnitude of the Young modulus for these materials?