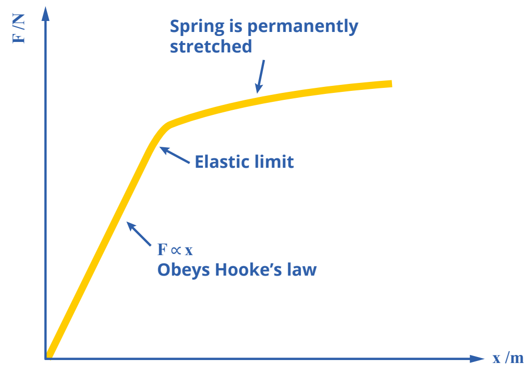
GCE Physics Unit 1.5 Solids under stress

Hooke's law:

Hooke's law states that the tension in a spring or wire is proportional to its extension from its natural length, provided the extension is not too great.



The relationship $F = kx$ can be used to calculate the extension up to the elastic limit. k is the spring constant and represents the stiffness of the spring.

For a wire with cross sectional area A, original length l and under tension F, you can determine **the stress, strain and Young modulus** using these equations. This information will allow you to compare the stiffness of different materials.

Strain is the extension per unit length due to applied stress.

$$\varepsilon = \frac{\Delta l}{l}$$

Stress is the tension per unit cross sectional area.

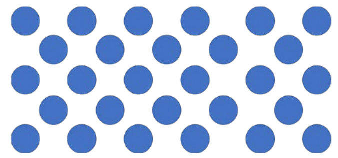
$$\sigma = \frac{F}{A}$$

Young modulus is the ratio of stress to strain for a material in the Hooke's law region.

$$E = \frac{\sigma}{\varepsilon}$$

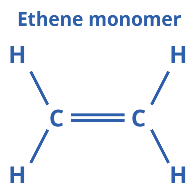
Classes of solid material:

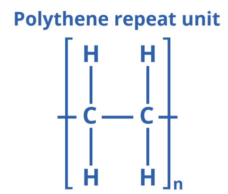
Crystalline materials are solids with long-range order; the particles are arranged in a lattice.



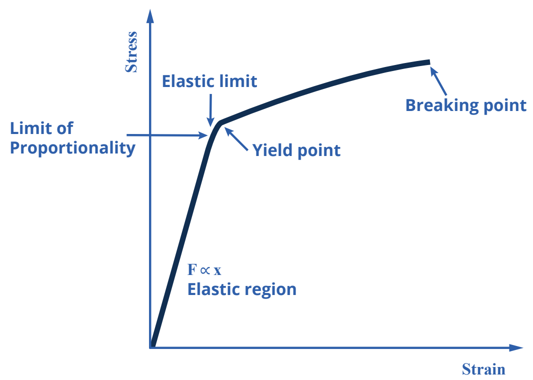
Amorphous materials e.g. glass and ceramics, have no long-range order.

Polymeric materials e.g. polythene and rubber, have very long molecules consisting of a large number of repeated monomers making one polymer.





F-x graphs for a metal (Stress-strain relationship):



In metals it is important to understand **edge dislocations** and **ductile fractures**. Edge dislocations are where there is an extra plane in the crystals, plastic deformation occurs when the **dislocations move** due to the large stress. Ductile fractures **(necking)** is where the number of edge dislocations increases and causes the elongation of the metal which increases the stress at the neck (smaller A).

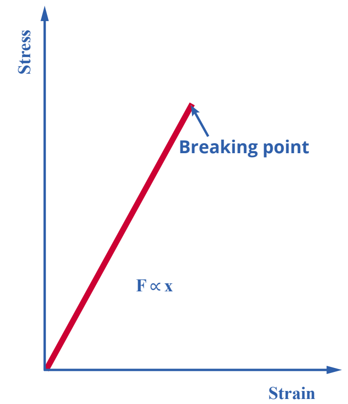
Remember from Unit 1.4, **the energy stored in a spring is equal to the area under the F-x graph**.

$$W = \frac{1}{2}Fx = \frac{1}{2}kx^2$$

The same is true for the work done in stretching a material.

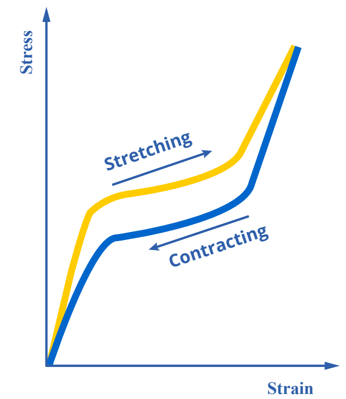
F-x graphs for brittle materials:

Brittle materials obey Hooke's law, although they do not stretch very much. These materials tend to fracture at a lower stress than expected, due to a process known as **brittle fracture**. This occurs when cracks in the surface of the materials magnify the stress at that point and cause the material to break. To avoid this, materials like concrete and pre-stressed glass are **always under compression** to stop cracks opening.



F-x graphs for rubber:

Most important to note from this graph is that the stretching and contracting curves are different. This is **elastic hysteresis**. As the area under the curve = the work done, **more work is done when stretching than when contracting**. This means the extra energy used to stretch is transferred to vibrational energy in the rubber molecules.



F = force in N | W = work done in J | σ = stress in Pa (N m^{-2}) | ε = strain | E = Youngs modulus in Pa (N m^{-2})

k = spring constant in N m^{-1} | x = extension in m | A = area in m^2 | l = length in m