Properties of matter

Matter is defined as anything, from the smallest objects as like atoms to bigger objects like galaxies, that occupies space and has got mass. Properties of matter describe how objects feel, look, behave etc. Examples of matter are

- Gasses
- Solids
- Liquids

Properties of Solids

There are two types of properties of solids one may look at i.e.

- Chemical properties - behaviour of a substance when it undergoes a chemical change or reaction.
- Mechanical properties - describe the behaviour of a material when it is exposed to external forces.

Mechanical properties are important when choosing which material to use for a particular purpose, e.g. building houses, manufacturing cars, or a toddler's toy. Some of the examples of the mechanical properties are

Strength- describes what forces it can stand before breaking
Toughness – indicates how much energy a material can absorb before breaking, for example how brittle it is.
Stiffness - describes a material's resistance to deformation (more flexible, less stiff)
Ductility - relates to how malleable a material is. (more malleable, easy to bend)
Stress and
Strain

Stress and strain

When a force is applied to an object, the object will always deform in some way, even when no change is apparent. In order to make comparisons of the effects of an external force on different materials we introduce the concepts of **stress** and **strain**.

Stress (σ) is the force per unit area applied to a material. If we consider an applied force F on a cross-sectional area A then mathematically the stress is given by,

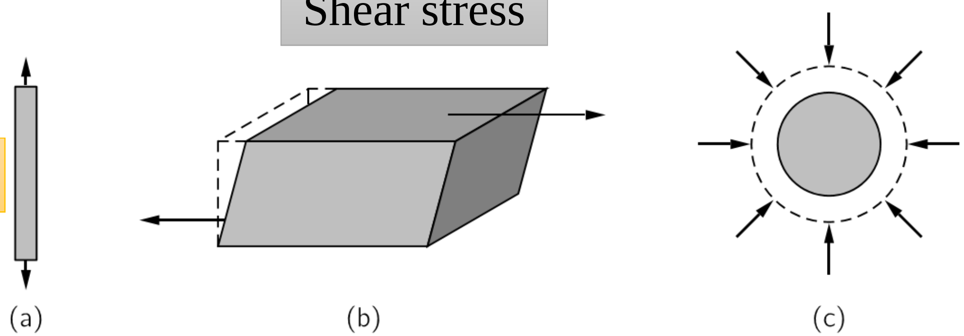
$$\sigma = \frac{F}{A}$$

The unit of stress is the Nm^{-2} or pascal (Pa).

The **strain** (ε) is define as a fractional deformation of the body. Informally, the strain is what result when an object is subject to the stress. There are different types of stress which result in different kinds of deformation or strain as shown below.

Shear stress

Longitudinal stress



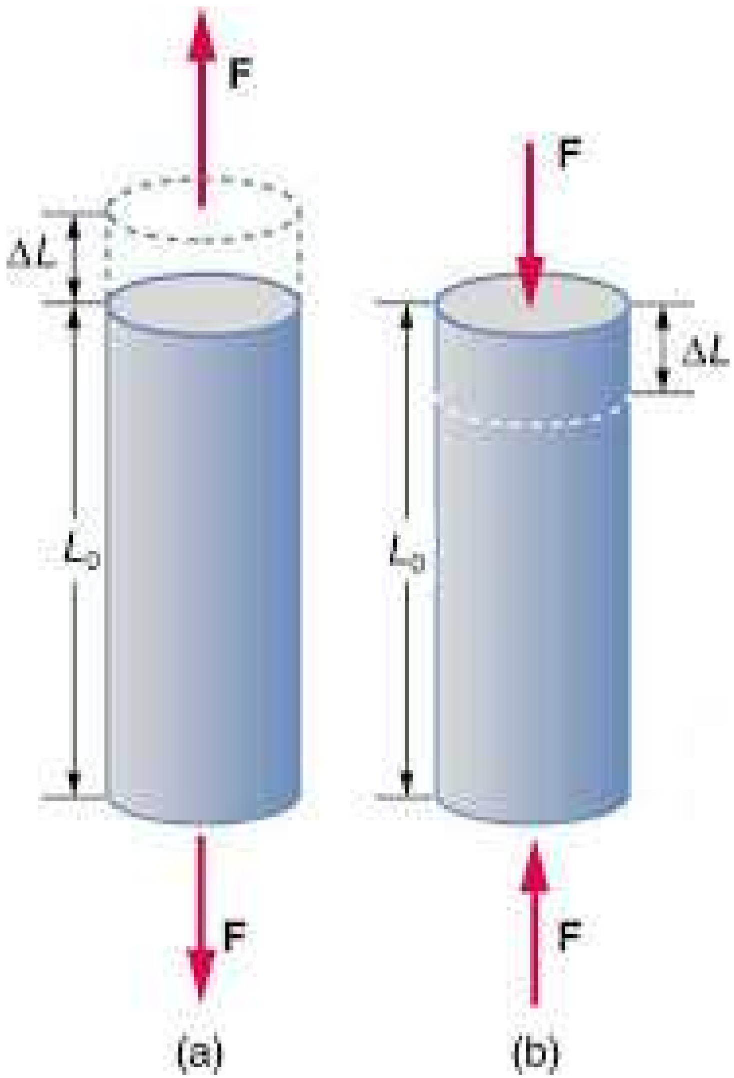
Bulk stress

Longitudinal stress

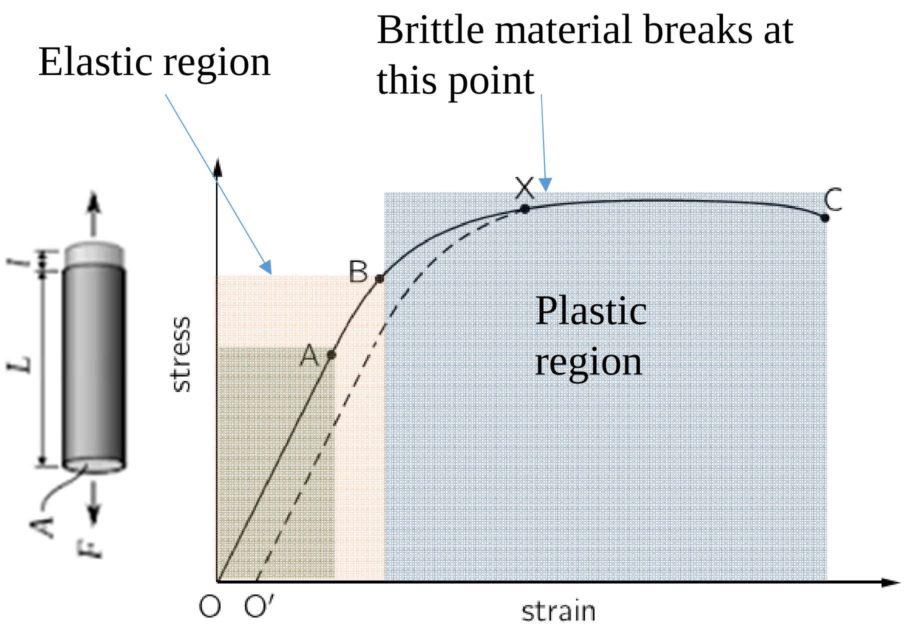
A longitudinal stress, which produces an **increase** in length of a sample is referred to as a **tensile** stress, while a stress that produces a **decrease** in length is referred to as a **compressive** stress. For a longitudinal tensile or compressive stress, the corresponding strain is defined as the change in length per unit length. If a stress produces a change of length $\Delta\ell$ in a sample material of original length ℓ, then

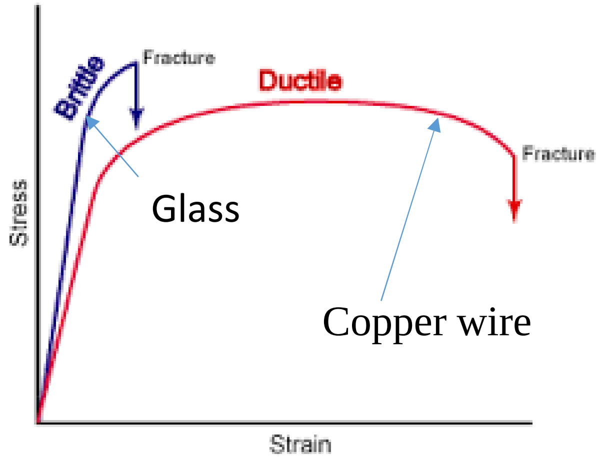
$$\varepsilon = \frac{\Delta\ell}{\ell} \qquad \varepsilon = \frac{\Delta L}{L_o}$$

ε has no units since it is a ratio



Longitudinal stress





Consider a material subjected to a **tensile stress**. The graph below shows an experimental results of the relationship between the **stress** and the resulting **strain**.

For elastic deformations in the linear region (the straight line OA in figure above), the constant of proportionality (the slope) is called the Young's modulus (Y) for a material and is defined by

$$Y = \frac{stress}{strain} = \frac{\sigma}{\varepsilon} = \frac{F/A}{\Delta\ell/\ell}$$

Y describes the **stiffness** of the material

	Young's modulus Y $\times 10^{10}$ (Pa)	Elastic limit $\times 10^{8}$ (Pa)
Aluminium	7	1.8
Copper	11	1.5
Steel	20	2.5
Cast iron	19	1.6
Concrete	2	
Bone	1.5	

Examples

Example 5.1: Mass suspended from a wire.

A mass of 10 kg is suspended from a wire of length 1.700 m and diameter 2.00 mm. This causes it to stretch by 5.00 mm. Calculate

(a) the stress in the wire,

(b) the strain in the wire, and

(c) Young's modulus for the wire material.

Example 5.2: Minimum diameter of a wire under stress.

A steel wire 2.00 metres long supports a load of 15 kg. Calculate the minimum diameter allowable if its extension under this load is not to exceed 3.0 mm. (Young's modulus for steel is 2.0×10^{11} Pa)