Stress and Strain

To know what stress is, be able to explain it, calculate it and state its units
To know what strain is, be able to explain it, calculate it and state its units
To be able to calculate the elastic strain energy per unit volume

Deforming Solids

Forces can be used to change the speed, direction and shape of an object. This section of Physics looks at using forces to change of shape of a solid object, either temporarily or permanently.

If a pair of forces are used to *squash* a material we say that they are *compressive* forces.
If a pair of forces is used to *stretch* a material we say that they are *tensile* forces.

Tensile Stress, σ

Tensile stress is defined as the force applied per unit cross-sectional area (which is the same as pressure). This is represented by the equations:

$$stress = \frac{F}{A} \qquad \boxed{\sigma = \frac{F}{A}}$$

The largest tensile stress that can be applied to a material before it breaks is called the ultimate tensile stress (UTS). Nylon has an UTS of 85 MPa whilst Stainless steel has a value of 600 MPa and Kevlar a massive 3100 MPa

Stress is measured in Newtons per metre squared, N/m^2 or N m^{-2}

Stress can also be measured in Pascals, Pa

A tensile stress will cause a tensile strain. *Stress causes Strain*

Tensile Strain, ε

Tensile strain is a measure of how the extension of a material compares to the original, unstretched length. This is represented by the equations:

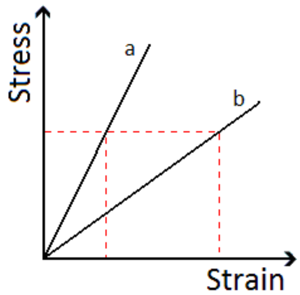
$$strain = \frac{e}{l} \qquad \boxed{\varepsilon = \frac{e}{l}}$$

Steel wire will undergo a strain of 0.01 before it breaks. This means it will stretch by 1% of its original length then break. Spider silk has a breaking strain of between 0.15 and 0.30, stretching by 30% before breaking

Strain has no units, it is a ratio of two lengths

Stress-Strain Graphs

A stress-strain graph is very useful for comparing different materials.
Here we can see how the strain of two materials, **a** and **b**, changes when a stress is applied.
If we look at the dotted lines we can see that the same amount of stress causes a bigger strain in **b** than in **a**. This means that **b** will increase in length more than **a** (compared to their original lengths).



Elastic Strain Energy

We can build on the idea of energy stored from the previous lesson now that we know what stress and strain are. We can work out the amount of elastic strain energy that is stored *per unit volume* of the material.

It is given by the equation: $\boxed{E = \tfrac{1}{2} stress \times strain}$

There are two routes we can take to arrive at this result:

Equations

If we start with the equation for the total energy stored in the material: $E = \tfrac{1}{2} Fe$

The volume of the material is given by: $V = Al$

Now divide the total energy stored by the volume: $E = \dfrac{\tfrac{1}{2} Fe}{Al}$ which can be written as: $E = \tfrac{1}{2} \dfrac{F}{A} \dfrac{e}{l}$

If we compare the equation to the equations we know for stress and strain we see that: $E = \tfrac{1}{2} stress \times strain$

Graphs

The area under a stress-strain graph gives us the elastic strain energy per unit volume (m^3). The area is given by:

$A = \frac{1}{2} base \times height$ → $A = \frac{1}{2} strain \times stress$ or $A = \frac{1}{2} stress \times strain$ → $E = \frac{1}{2} stress \times strain$