Density

24th March

Density is a measure of the compactness of a material.

It is defined as the mass per unit volume of a material.

$$\rho = \frac{m}{V}$$

ρ — in kilograms per cubic metre, kg m^{-3}

m — in kilograms, kg

V — in metres cubed, m^3

Note: if calculating a volume with values that are not in metres, it is a good idea to convert to metres before the volume calculation.

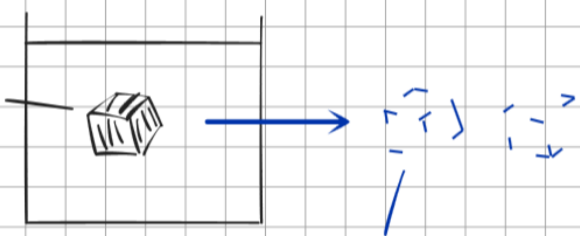
$1\ m^3 = 1{,}000{,}000\ cm^3$

For objects that are a mixture of materials of different densities:

total mass of object = sum of masses of each material it contains

total volume of object = sum of the volume of each material it contains

When an object is submerged in a fluid it will displace a volume of fluid equal to its own volume.

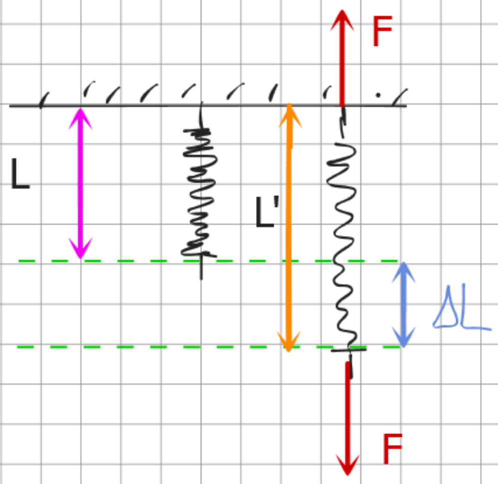


Any object in a fluid will experience a force of UPTHRUST.

This force will be equal in magnitude to the WEIGHT of the FLUID THAT WAS DISPLACED.

Elasticity

25th March



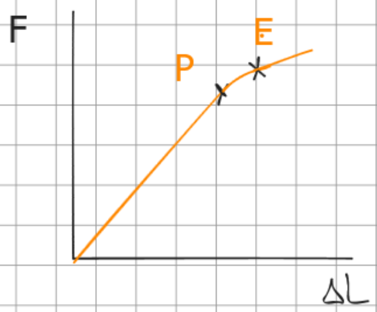
L is the natural length of the spring

L' is the stretched length

ΔL is the change in length of the spring

Note in this case ΔL is an extension, but it could also be a compression.

If an object obey's HOOKE'S LAW OF ELASTICITY then the change in length produced is DIRECTLY PROPORTIONAL to the FORCE APPLIED.



This object obey's Hooke's Law up to the point P, which is the LIMIT OF PROPORTIONALITY.

If the load is removed from this object before the point E (the ELASTIC LIMIT) then the object will return to its original length.

Adding a load that takes us beyond E will PERMANENTLY DEFORM the object (INELASTIC BEHAVIOUR).

From Hooke's Law:

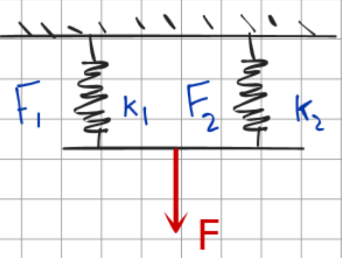
$$F \propto \Delta L$$

$$F = k\Delta L$$

k is the SPRING CONSTANT or 'stiffness' of the object

$$k = \frac{F}{\Delta L} \qquad \text{in N m}^{-1}$$

Combinations of Springs

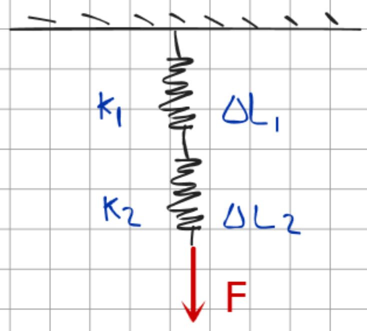


$$F = F_1 + F_2$$

$$k\cancel{\Delta L} = k_1\cancel{\Delta L} + k_2\cancel{\Delta L}$$

$$\boxed{k = k_1 + k_2}$$

Springs in parallel



$$\Delta L = \Delta L_1 + \Delta L_2$$

$$\frac{\cancel{F}}{k} = \frac{\cancel{F}}{k_1} + \frac{\cancel{F}}{k_2}$$

$$\boxed{\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2}}$$

Springs in series

Elastic (strain) Energy

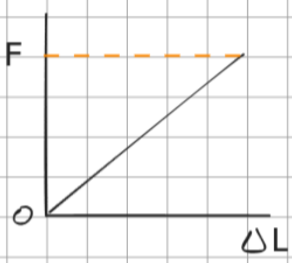
31st March

When we exert a FORCE on an object to change its length we are DOING WORK.

The work done in this case can separate the particles in the object slightly;

This energy is stored in the obect as ELASTIC STRAIN ENERGY (or elastic potential or just strain energy).

In some cases the work we do increases the THERMAL ENERGY stored in the object, and ends up dissipated to the surroundings.



Assuming no energy is dissipated:

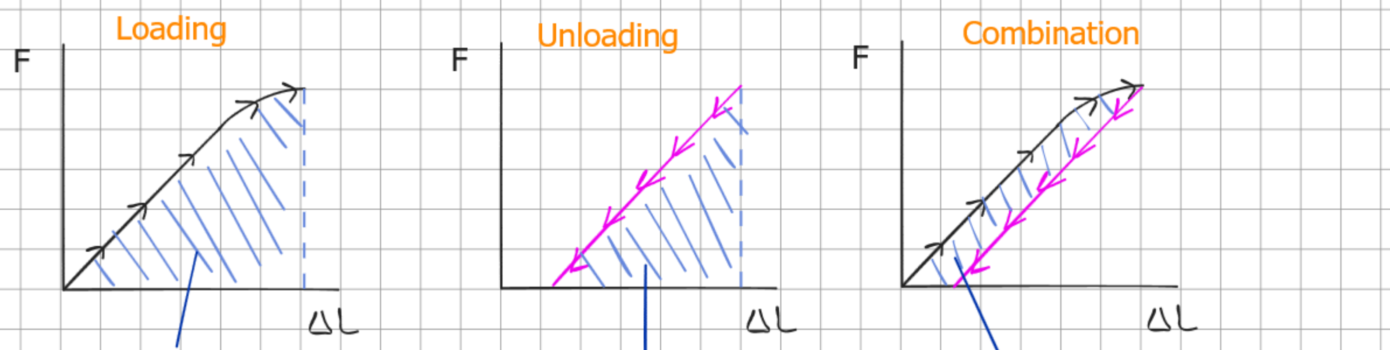
Work done = increase in strain energy

= average force applied x distance moved

$$\boxed{E = \frac{1}{2}F\Delta L}$$

We know, from Hooke's Law: $F = k\Delta L$

$$\boxed{E = \frac{1}{2}k\Delta L^2}$$



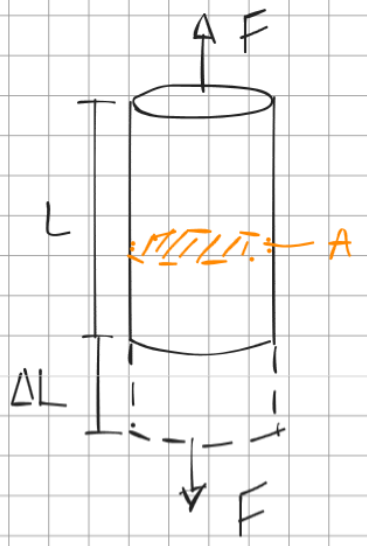
work done by the force stretching object

work done by the object exerting a force

the difference between the two tells us the energy dissipated or energy used to permanently change arrangement of particles

Stress and Strain

STRETCHING forces are TENSILE forces. SQUASHING forces are COMPRESSIVE forces.



The tensile STRESS on an object is the force applied per unit cross-sectional area:

$$\text{stress} = \sigma = \frac{F}{A}$$ in $N\,m^{-2}$ or Pa

A tensile stress always causes a STRAIN.

$$\text{strain} = \varepsilon = \frac{\Delta L}{L}$$ strain is dimensionless

The YOUNG'S MODULUS of a material is the ratio of stress to strain (or the stress per unit strain):

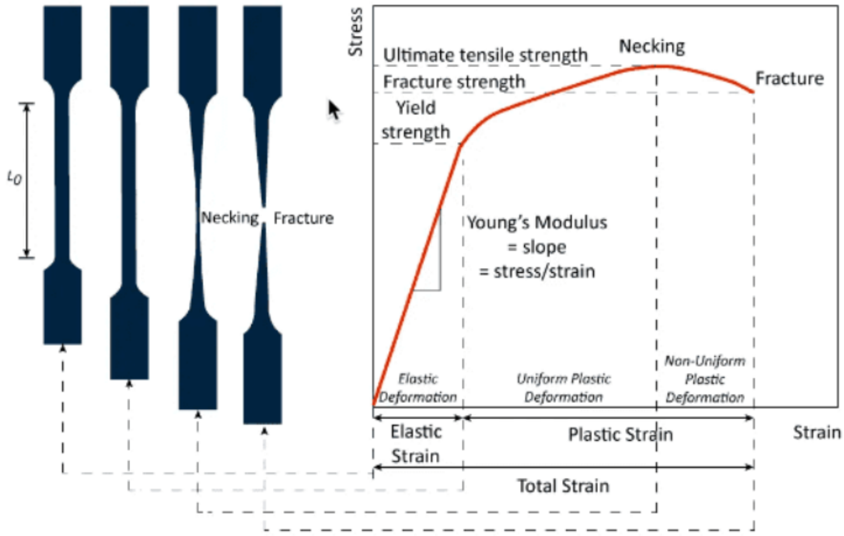
$$E = \frac{\text{stress}}{\text{strain}}$$ in $N\,m^{-2}$ or Pa

$$E = \frac{F/A}{\Delta L/L}$$

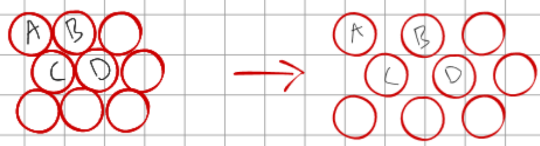
$$E = \frac{FL}{A\Delta L}$$ (dividing by a fraction is the same as multiplying by the reciprocal of the fraction)

Stress-Strain Graphs

28th April

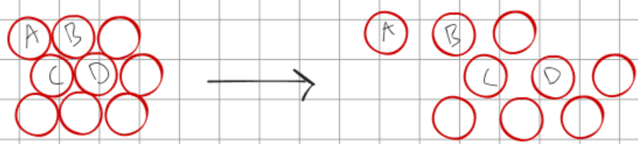


During elastic deformation:



Particles are pulled apart but keep their relative positions.

During plastic/inelastic deformation:



Particles are pulled apart and whole planes of atoms slide past each other.

This only tends to happen to any great extent in materials that are DUCTILE.

For a ductile material the ULTIMATE TENSILE STRESS tells us the maximum stress a material can withstand before breaking.

The YIELD POINT of a ductile material occurs just after the limit of proportionality. Past this point we see a large increase in strain, for small increase in stress.

A non-ductile material (BRITTLE) will fracture not long after the yield point.