11 Materials

11.1 Density

The density of a substance is defined as mass per unit volume.

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

for a certain amount of substance of mass m and volume V.

$$[\rho] = \text{kgm}^{-3}$$

Density Measurements

- A **regular solid**
  1. **Measure its mass** using a top pan balance.
  2. **Measure its dimensions** using vernier calipers.
  3. **Calculate its volume** using the appropriate equation.
  4. **Calculate its density** from mass/volume.
- A **liquid**
  1. **Measure the mass** of an empty measuring cylinder.
  2. **Pour some liquid** into the cylinder and **measure the volume** of the liquid.
  3. **Measure the mass** of the cylinder and liquid.
  4. **Calculate the mass** of the liquid.
  5. **Calculate the density** from mass/volume.
- An **irregular solid**
  1. **Measure the mass** of the object.
  2. **Immerse the object** in liquid in a measuring cylinder.
  3. **Observe the increase** of liquid level, this is the volume of the object.
  4. **Calculate the density** from mass/volume.

11.2 Springs

A **stretched spring** exerts a pull on the object holding each end of the spring, this full is referred to as the **tension** of the spring.

- The tension in the spring is equal and opposite to the force needed to stretch the spring.

Hook's law states that the force needed to stretch a spring is directly proportional to the extension of the spring from its natural length.

$$F = k\Delta L$$

where k is the **string constant** and ΔL the extension from its natural length L.

- $[k] = \mathrm{Nm}^{-1}$, the greater the value of k, the stiffer the spring is.
- The graph of F against ΔL is a straight line of gradient k through the origin.

If a spring is stretched beyond its **elastic limit**, it will not regain its initial length when the force applied to it is removed.

Springs in Parallel

If weight is supported by two springs P and Q in parallel, where the extension ΔL of each spring is the same.

- $F_P = k_P \Delta L$
- $F_Q = k_Q \Delta L$

Since the weight is supported by both springs.

$$W = F_P + F_Q = k_P \Delta L + k_Q \Delta L = k \Delta L$$

giving **effective spring constant** $k = k_P + k_Q$

Springs in Series

If a weight is supported by two springs joined end-on in series with each other, the tension in each spring is the same and equal to W.

- $\Delta L_P = \dfrac{W}{k_P}$
- $\Delta L_Q = \dfrac{W}{k_Q}$

Therefore total extension

$$\Delta L = \Delta L_P + \Delta L_Q = \frac{W}{k_P} + \frac{W}{k_Q} = \frac{W}{k}$$

giving **effective spring constant**

$$\frac{1}{k} = \frac{1}{k_P} + \frac{1}{k_Q}$$

Elastic Potential Energy

Elastic potential energy is the energy stored in a stretched spring.

- If a spring is released, the elastic energy stored in it is **transferred into kinetic energy** of the spring.

The **work done** to stretch a spring by extension ΔL from its unstretched length is $\frac{1}{2} F \Delta L$. Giving

$$E_P = \frac{1}{2} F \Delta L = \frac{1}{2} k \Delta L^2$$