

## Work, energy and power

**Energy:** the capacity to do work

**Power:** the rate of doing work / the rate of energy transfer

In the case that the direction of the force is in line with the direction of displacement, i.e.  $\cos \theta = 1$ ,  $W = F \cdot s$  (J)

$$W = F \cdot s \cos \theta$$

$$W = F \cdot s$$

**Work done / energy transfer:**

$$P = \frac{\Delta W}{\Delta t}$$

$$P = F \cdot v$$

**Rate of energy transfer:**

**Efficiency:**

$$\text{efficiency ratio} = \frac{\text{useful output power}}{\text{input power}}$$

$$\text{efficiency percentage} = \frac{\text{useful output power}}{\text{input power}} \times 100\%$$

## Conservation of energy

**Principle of conservation of energy:**

For an isolated system, energy is conserved. Energy cannot be created or destroyed, only transferred into different forms.

Examples of different forms of energy:

- heat
- sound
- kinetic
- gravitational

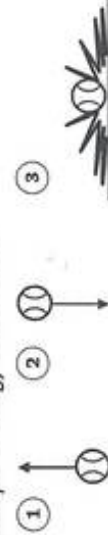
**Kinetic energy:**

$$E_k = \frac{1}{2}mv^2$$

**Potential energy:**

$$E_p = mgh$$

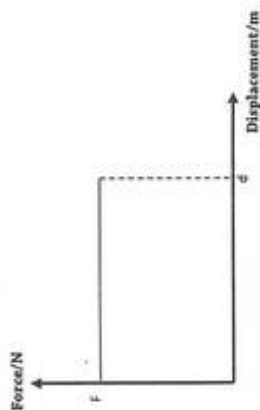
**Example of energy conservation:**



1. As a ball is thrown upwards, the kinetic energy given to it by the throw is converted into potential energy and the ball slows down. All of the kinetic energy has been converted to potential energy at the highest point the ball reaches.
2. As the ball falls, potential energy is converted back into kinetic energy and the ball accelerates back towards the ground.
3. When the kinetic energy of the ball hits the ground its kinetic energy is transferred to the ground and converted to heat and sound.

## Force-displacement graph

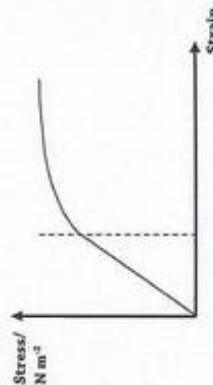
A force-displacement graph indicates the force  $F$  required to move an object by a displacement  $s$ .



Area under  $F-s$  graph =  $F \times s$   
Area under  $F-s$  graph = Work done

## Young modulus

$$\text{Young modulus} = \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{FL}{A\Delta L}$$



The Young modulus can be determined from the gradient of a stress-strain graph by comparing the equation for Young modulus ( $E$ ):

$$\sigma = E \epsilon$$

(Tensile stress = Young modulus  $\times$  tensile strain)

and the equation for the straight line up until the graph begins to curve:

$$y = mx + c$$

## Bulk properties of materials

**Density:**

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

**Hooke's law:**

$$F = k\Delta L$$

**Elastic energy:**

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

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

$k$  = spring constant or stiffness



Area under force-extension graph =  $\frac{1}{2}F\Delta L$   
Area under force-extension graph = elastic energy stored in material

**Plastic deformation:**

A process that changes the shape of an object, which remains even when the compressive or tensile force is removed.

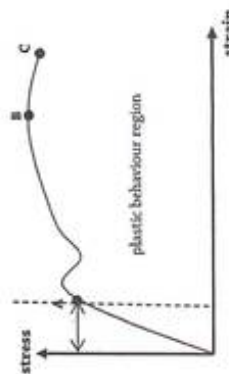
Plastic behaviour can be identified on a force-extension graph as the non-linear region.

**Brittle behaviour:**

An attribute of a material that does not show plastic deformation and has little change when under stress. A brittle material does not absorb much energy before breaking.

**Ductile material**

- A: the limit of proportionality
- B: ultimate tensile stress
- C: breaking point



By hanging masses from a wire we can vary the force applied on the wire and measure the change in length. The cross-sectional area of the wire can be found using a micrometer, so we can plot stress against strain. The Young's modulus of the material can be found from the gradient of the straight section of the stress-strain graph.