Motion, forces and energy

P1.6.1 Energy

Energy stores

Energy can be stored in different ways

- Kinetic energy – energy of a moving object e.g. a rolling ball
- Gravitational potential energy - energy due to object's height above the ground e.g. a book on a shelf
- Chemical energy - energy stored in chemical bonds e.g. food, fuels, batteries
- Elastic energy - energy stored when objects are stretched or compressed e.g. stretched spring, stretched rubber band
- Nuclear energy - energy stored in the nucleus of atoms e.g. in uranium or the sun
- Heat (thermal) energy - energy due to temperature of an object e.g. hot water, heated metal.

Energy Transfer

Energy can move from one store to another – this is energy transfer. Examples include:

- By forces (e.g. work) – when a force moves an object e.g. lifting a box transfers energy to gravitational potential energy.
- By electrical currents (electrical work) – energy transferred by moving charges e.g. a fan uses electrical energy to move the blades (kinetic energy).
- By heating – energy transferred due to temperature difference e.g. heating water on an electric or gas hob increases its thermal (heat) energy.
- By waves – energy transferred by sound, light, or other waves e.g. a guitar string vibrates, creating sound waves that travel through the air to your ears, or sunlight transfers thermal energy from the Sun to the Earth, warming it.

Conservation of Energy

- Energy cannot be created or destroyed – it can only change from one store to another. Total energy before an event = Total energy after.
- Example: A falling ball:
  At the top: gravitational potential energy. While falling: some gravitational energy converted to kinetic energy. Just before hitting the ground: mostly kinetic energy. Hits the ground: heat and sound energy and elastic energy (if the ball deforms).
- Flow diagrams can show energy transfers in simple events, e.g. Chemical energy in food → Kinetic energy in muscles → Thermal energy released as heat

Kinetic Energy

- The energy of a moving object.
- Equation: $E_k = \frac{1}{2}mv^2$ where E_k = kinetic energy (J), m = mass (kg) and v = speed (m/s)
  e.g. A 2 kg ball moving at 3 m/s:
  $E_k = ½ \times 2 \times 3^2 = 9$ J

Gravitational Potential Energy

- Energy stored due to height raised above the ground.
- Equation: $\Delta E_p = mg\Delta h$ where ΔE_p = change in gravitational potential energy (J), m = mass (kg) and g = gravitational field strength (9.8 N/kg)
  e.g. lifting a 5 kg box by 2 m.
  $\Delta E_p = 5 \times 9.8 \times 2 = 98$ J

P1.6.2 Work

What is Work?

- In physics, work is done when a force is used to move an object in the same direction as the force. Work is a way of transferring energy.
- E.g. If you lift a box, you transfer energy from your muscles to the box (giving it gravitational potential energy).
- If no movement happens, no work is done (even if you push really hard!).

Work and Energy Transfer

- Mechanical work (force × distance) = energy transferred to or from an object.
- Electrical work (like in circuits) = energy transferred when charges move.

The Equation for Work $W = F \times d = \Delta E$

- $W = F \times d$ where W = work done (in joules, J), F = force (in newtons, N) and d = distance moved in the direction of the force (in metres, m).
- This is the same as saying: $W = \Delta E$ (Work done equals the change in energy).
- 1 joule = work done when 1 newton moves an object 1 metre.

  E.g. Lifting a book: Force = weight of book (say 10 N). Distance lifted = 2 m. $W = F \times d$ Work done = 10 × 2= 20 J. Energy transferred = 20 J (stored as gravitational potential energy). E.g. Pushing a trolley: Force = 50 N. Distance = 5 m. Work done = 50 × 5 = 250 J. Energy transferred = 250 J (to kinetic energy + overcoming friction).