16 Thermodynamics

An understanding of energy from Cambridge IGCSE/O Level Physics or equivalent is assumed.

16.1 Internal energy

Candidates should be able to:	
1	understand that internal energy is determined by the state of the system and that it can be expressed as the sum of a random distribution of kinetic and potential energies associated with the molecules of a system
2	relate a rise in temperature of an object to an increase in its internal energy

- The internal energy of a substance (U) is defined as **the sum of the random distribution of kinetic and potential energies within a system of molecules.**
- The internal energy of an object is intrinsically related to its temperature.
- For e.g., when gas is heated up in a container, the gas molecules begin to move faster increasing its KE.
- For solid objects, when you heat them up, the molecules begin to vibrate faster.
- Both solid and liquid objects molecules are bound by intermolecular forces.
- However, ideal gas molecules are assumed to have **no intermolecular forces**.
- This implies that for an ideal gas the internal energy consists of only KE and no potential energy.
- Thus, the change in internal energy for an ideal gas can be rewritten as

$$\Delta U = \frac{3}{2}k\Delta T$$

We can therefore say that the change in internal energy is directly proportional to the change in temperature

$$\Delta U \propto \Delta T$$

16.2 The first law of thermodynamics

Candidates should be able to:	
1	recall and use $W = p\Delta V$ for the work done when the volume of a gas changes at constant pressure and understand the difference between the work done by the gas and the work done on the gas
2	recall and use the first law of thermodynamics $\Delta U = q + W$ expressed in terms of the increase in internal energy, the heating of the system (energy transferred to the system by heating) and the work done on the system

- For a gas in a cylinder enclosed by a moveable piston, the gas does work by exerting a pressure on the piston and pushing the piston outwards.

- Since the piston moves outwards the volume of gas changes at **constant external pressure (p)**.
- Therefore, the gas **does work on the piston.**
- Thus, we can say that word done when a volume of gas changes at constant external pressure is

$$W = p\Delta V$$

- When gas **expands** (V increases), word is done **by** the gas.
- When gas **compressed** (V decreases), work is done **on** the gas.
- The first law of thermodynamics is based on the principle of conservation of energy
- When energy is put into a gas by heating it or doing work on it, its internal energy must increase:
- The increase in internal energy = Energy supplied by heating + Work done on the system
- The first law of thermodynamics is therefore defined as:

$$\Delta U = q + W$$

Where q is the energy (heat) supplied to the system by heating and W is the work done on the system

- A **positive** value $+\Delta U$ means that
  -The internal energy (U) increases
  -Heat (q) is added to the system or
  -Work (W) is done on the system
- A negative value $-\Delta U$ implies that
  -The internal energy (U) decreases
  -Heat (q) is taken away from the system or
  -Work (W) is done by the system
- Therefore, when gas expands and work is done by the gas, work done is negative (-W)
- When gas is compressed, work is done on the gas (+W)