GCE Physics Unit 3.4 Thermal Physics

Internal energy:

The internal energy, U, is the sum of the kinetic and potential energies of the molecules of a system.

For a monatomic gas, there is no potential energy, so the internal energy is equal to the total translational kinetic energy of the gas (see unit 3.3).

$$U = \frac{3}{2}nRT = \frac{3}{2}NkT$$

where n is the number of moles of the gas and N is the total number of molecules of gas.

Absolute zero:

Absolute zero is the temperature where the internal energy of a system **is at a minimum**.

For a gas, this is the temperature at which $pV = 0$. Therefore, it has minimum kinetic energy (and internal energy).

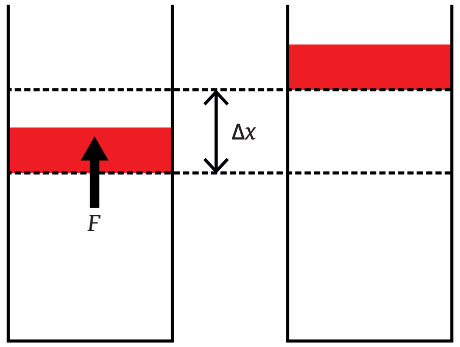
Heat flow:

Heat energy is always transferred from a region of **higher temperature to lower temperature**. It is unreasonable to describe the heat as being in a system as heat will always **enter or leave a system through its boundary or wall** depending on whether the temperature on the other side of the boundary is higher or lower.

If the temperature is the same on both sides of the boundary it is said to be in **thermal equilibrium** and there is no heat flow between them.

Work:

Energy can also be transferred by doing work on a system. Work therefore can also be described as a flow of energy into or out of a system, work being done on the system or work being done by the system.



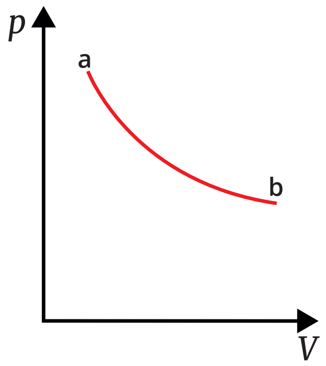
A change in this system causes a force, F, on the piston, causing it to move a distance Δx.

As work = $F\Delta x$, and $F\Delta x$ is equivalent to $p\Delta V$. This can be written as:

Work = $p\Delta V$

where p is the constant pressure in the system and ΔV is the change in volume of the gas.

This can be used to calculate the work done by the system if ΔV is positive and the work done on the system if ΔV is negative.



Even in a system where p is not constant the work can be calculated using a p-V graph. If the p and V in a system changed from a to b according to this curve then the work done can be calculated using this equation:

Work = **area under a p-V curve**

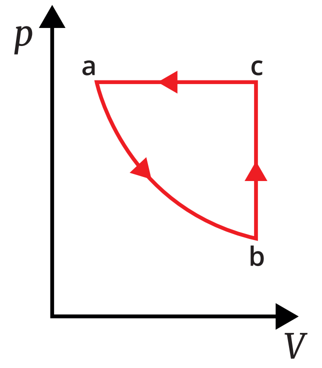
If the p and V changed from b to a, the value of the work would be equal, but negative.

First law of thermodynamics:

The **first law of thermodynamics** states that the increase, ΔU, in internal energy of a system is $\Delta U = Q - W$ in which Q is the heat entering the system and W is the work done by the system.

$$\Delta U = Q - W$$

Note that all these values can be positive or negative. If Q is negative, heat is leaving the system and if W is negative then work is being done by the system.



From **a to b** represents **isothermal** (slow) expansion of a gas where work is done by the system as $\Delta U=0$, Q = W.

From **b to c** represents a change in pressure at constant V, no work is being done.

From **c to a** represents a change in volume at constant pressure, where work is done on the system.

As the work done is the area under the curve, the overall **work done is the area inside the loop** abc.

Solids and liquids:

In solids and liquids, there is very little change in volume so the **work is negligible**. This means the heat flow into the system is equal to the change in internal energy.

$$\Delta U = Q$$

The change in temperature due to the heat flow can be calculated using this equation:

$$Q = mc\Delta\theta$$

where c, specific heat capacity, is the heat required, per kilogram, per degree Celsius or kelvin, to raise the temperature of a substance.

U = internal energy in J
T = temperature in K
R = Molar gas constant
p = pressure in Pa
Q = heat energy
m = mass in kg
n = number of moles of gas
N = number of gas molecules
k = Boltzmann constant
ΔV = change in volume in m^3
c = specific heat capacity in J kg^{-1} K^{-1}
W = work in J
$\Delta\theta$ = change in temperature in K