Day 6: **First Law of Thermodynamics**

If U is the total internal energy of all the molecules of a system (or thermal energy) and Q is the heat flowing into a system, then it is easy to see by the conservation of energy that

$$\Delta U = Q + W$$ law of cons. of E.

where W is the net work done ***on*** the system.

(Note that this represents a change from your textbook, which states ΔU = Q - W, but W is the work done ***by*** the system).

This is the first law of thermodynamics.

Simple Systems

An ***isothermal*** process – constant T. ($\Delta T =$ ☺)

$U = \frac{3}{2}NkT = \frac{3}{2}N\overline{KE}$

$\Delta U =$ ☺ $= Q + W$

$Q = -W$

$PV = NkT = \text{const}$

$P = \frac{\text{const}}{V}$

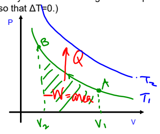
This system is in contact with a ***heat reservoir*** - a body so large that its temperature does not change significantly with heat exchange. The expansion and compression also take place slowly, so that ΔT=0.)

$P = [\frac{N}{m^2}]$

$V = [m^3]$

$PV = [J]$

Area = −W



$$W = -\int_{V_1}^{V_2} P\,dV$$
$$= -\int_{V_1}^{V_2} \frac{NkT}{V}\,dV$$
$$= -NkT \int_{V_1}^{V_2} \frac{dV}{V}$$
$$= -NkT \ln V \Big|_{V_1}^{V_2}$$
$$= -NkT(\ln V_2 - \ln V_1)$$
$$= -NkT \ln \frac{V_2}{V_1}$$
$$W = NkT \ln\left(\frac{V_1}{V_2}\right)$$

An ***adiabatic*** process $Q =$ ☺ No heat flow.

Happens so quickly that no heat transfers (ideal → t → ☺)

$\Delta U = \cancel{Q} + W$ (Q = ☺)

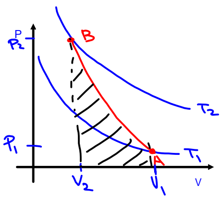
$\Delta U = W$

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

$\Delta U = \frac{3}{2}Nk\Delta T = W$

W = − Area

$= \frac{3}{2}Nk\Delta T$



— isotherm

— adiabat

An ***isobaric*** process – constant P

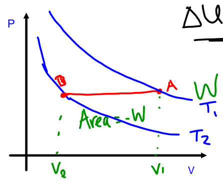
$PV = NkT$

$P\Delta V = Nk\Delta T$

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

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

$\Delta U = \frac{3}{2}P(V_2 - V_1)$



$W = -\int_{V_1}^{V_2} P\,dV = -P(V_2 - V_1)$

$W = P(V_1 - V_2)$

$\Delta U = Q + W$

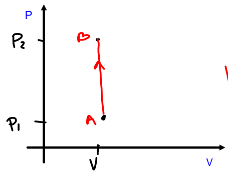
$\frac{3}{2}P(V_2 - V_1) = Q - P(V_2 - V_1)$

$Q = \frac{5}{2}P(V_2 - V_1)$

An ***isochoric*** process – Constant V

$PV = NkT$

$V\Delta P = Nk\Delta T$



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

$= \frac{3}{2}V\Delta P$

$= \frac{3}{2}V(P_2 - P_1)$

$W =$ ☺ $=$ Area

$\therefore \Delta U = Q$

$= \frac{3}{2}V(P_2 - P_1)$