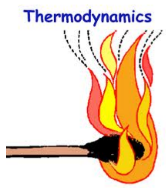
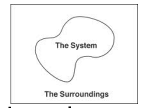
Chapter 15 - Thermodynamics

Why heat moves



Thermodymamics is only concerned with large scale observations

- Only "state" variables matter to describe the system (P, V, T)
- System is the gas
- Surroundings is everything else



Zeroth Law - Two systems in thermal equilibrium with a third are in equilibrium with each other

- Heat will flow between two systems at different temperatures until in equilibrium
- Heat always flows from HIGH T to LOW T

1st Law of Thermodynamics

What is the equation for internal energy?

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

How can you make the internal energy change? ΔT $+\Delta Q$ $+W$

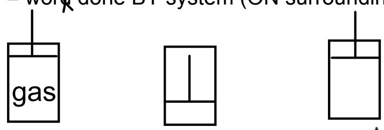
$\boxed{\Delta U = \Delta Q + W}$ Book: $\Delta U = \Delta Q - W$

+ΔQ = system GAINS heat (does NOT have to increase T)

-ΔQ = system LOSES heat (does NOT have to decrease T)

+ W = work done ON system (BY surroundings)

- W = wor~~d~~k done BY system (ON surroundings)



+W -ΔV

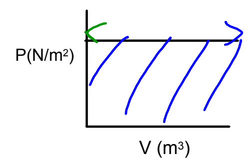
-W +ΔV

4 types of changes that can occur as gas moves from one state to another

1) Isobaric

NO CHANGE IN PRESSURE

changing volume



What does slope represent?

What does area represent?

$-P\Delta V = W$

$-P\Delta V = nR\Delta T = W$

PΔV = Nm = J = Work = area under P-V graph

But Work is opposite volume change so...

$\boxed{W = -P\Delta V}$

Note book uses OLD definition of work on SURROUNDINGS...this is work on SYSTEM

So for isobaric changes:

W = - PΔV

since PV = nRT

$\boxed{W = -nR\Delta T}$

***only if gas is at CONTANT PRESSURE

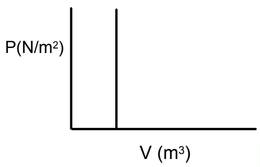
Also.... ΔU = W +ΔQ so ΔQ = ΔU - W

so...ΔQ = 3/2nRΔT - (-nRΔT)

$\boxed{\Delta Q = 5/2nR\Delta T}$ $= 5/2 Nk\Delta T$ $k = \frac{R}{N_A}$

2) Isochoric

= constant volume = NO WORK



W = 0....

since $\Delta U = W + \Delta Q$

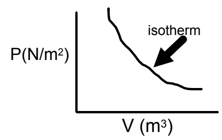
$\Delta U = \Delta Q$

$\boxed{\Delta Q = 3/2nR\Delta T}$

3) Isothermal

constant temperature

no change in INTERNAL ENERGY



Area under curve = integrate = $\boxed{W = -nRT(\ln(V_f/V_i))}$

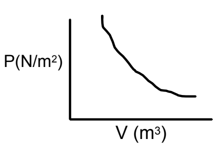
$\Delta U = 0 = W + \Delta Q$ ...so $\boxed{\Delta Q = -W}$

4) Adiabatic

constant heat

no change in HEAT

$\gamma = 5/3$ for ideal gas



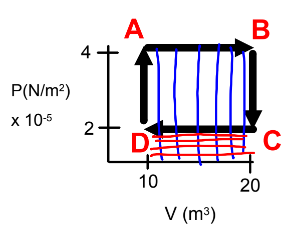
$\boxed{P_1V_1^{\gamma} = P_2V_2^{\gamma}}$

$\Delta Q = 0$

$\Delta U = \Delta Q + W$...so....$\Delta U = W$

and $\boxed{W = 3/2nR\Delta T}$

Check Question: What is the Work done on the SYSTEM that goes through the following four changes?



A→B = isobaric
$(4\times10^{-5})(10)$ = W = -4×10^{-4} Nm

B→C = isochoric
W = 0

C→D = isobaric
$(2\times10^{-5})(10)$ W = $+2\times10^{-4}$ Nm

D→A = isochoric
W = 0

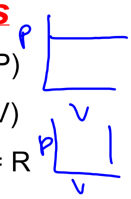
What is this the same as? Total Work = -2×10^{-4} Nm

Area of enclosed cycle = work done ON SYSTEM

Heat and ideal gases

$\boxed{\Delta Q = nC_p\Delta T}$ (gas at CONSTANT P)

$\boxed{\Delta Q = nC_v\Delta T}$ (gas at CONSTANT V)



$C_p = 5/2R \quad C_v = 3/2R \quad C_p - C_v = R$

$\gamma = \dfrac{C_p}{C_v} = \dfrac{5/2R}{3/2R} = \boxed{5/3 = \gamma}$

V γ

2nd Law of Thermodynamics

- Heat will only flow spontaneously from high temperature to low temperature
- Total entropy of the universe ALWAYS increases during heat exchange

This is why you cannot have a perpetual motion machine...some energy is always lost to non-useful energy = entropy*

Entropy = amount of disorder = S

According to 2nd Law

$\boxed{\Delta S = \Delta Q/T}$ (note T must be K!!!)

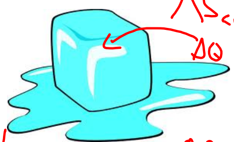
$\boxed{\text{units = J/K}}$

Check Question

Water freezes in your freezer causing a DECREASE in entropy. How does this not break the 2nd Law of Thermodynamics?

melting

$\Delta S_{ice} = \frac{\Delta Q}{T} = \frac{-mL_f}{273}$

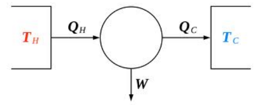


ΔQ

$\Delta S_{air} = \frac{+\Delta Q}{T} = \frac{+\Delta Q}{T}$

$\text{Spontaneous} = \Delta S_{ice} + \Delta S_{air} > 0$

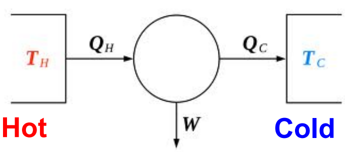
2nd Law and Heat Engines



*Uses the fact that heat flows from high to low temperature

*Creates work from heat the flows

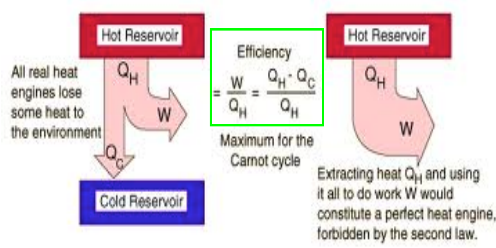
* Some heat lost to entropy (Qc)



Hot Reservoir

Cold Reservoir

efficiency = how well engine converts Q_H into W



Carnot Engine = maximum efficiency possible

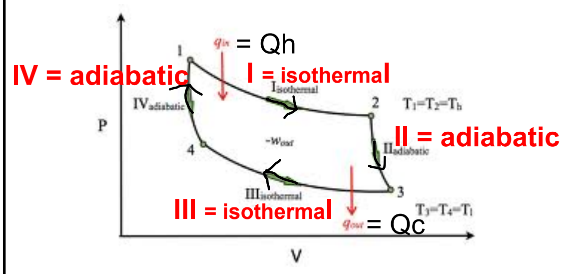
$$\frac{Q_c}{Q_h} = \frac{T_c}{T_h}$$

$$Q_h = Q_c + W$$

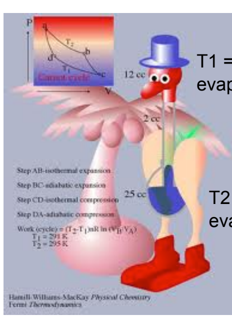
Since $e = \frac{Qh - Qc}{Qh} = 1 - Qc/Qh$

For Carnot $\boxed{e = 1 - Tc/Th}$ in K!!!

Carnot Cycle



Dippy Bird and the Carnot Cycle



T1 = Tc = cooler due to evaporation

T2 = Th = warmer (no evaporation)

How Dippy Really works:

1) System is at equilbrium (Th = Tc)

2) Evaporation caused vapor inside to condense (lose energy), reducing PV/RT (less gas inside = less n)

3) P at bottom is bigger so it increases pushing fluid up

4) Fluid causes change in CM above PP so bird dips

5) There is a tube at the bottom exposed to vapor so bubble rises rises when dips, causing fluid to move back down