LAST CLASS:

change in energy

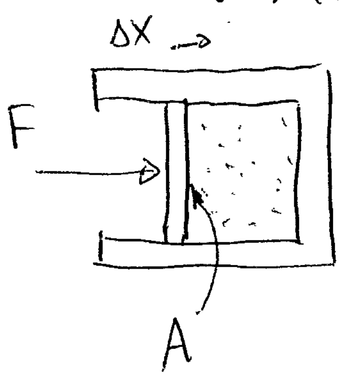
$$\boxed{\Delta E = Q + W}$$

$\Delta E = n C_v \Delta T$

C_v depends on material.

add or remove heat. (fire, ice, etc.)

Work done on gas.



$W = F \Delta x$

$= PA \Delta x$

$= -P \Delta V$

this is the volume of gas. as $\Delta x \uparrow$ $\Delta V \downarrow$.

valid when P constant, or when ΔV is "tiny". (otherwise, need to integrate).

WHAT IS C_V? (How is energy stored?)

$$\boxed{T = \frac{2}{3k_B}\epsilon_{avg}}$$

← average translational kinetic energy per molecule. This is temperature.

- translational 3 dofs
- rotational 2 (3 really but one doesn't count)
- vibrational 2 (1 KE, 1 PE)

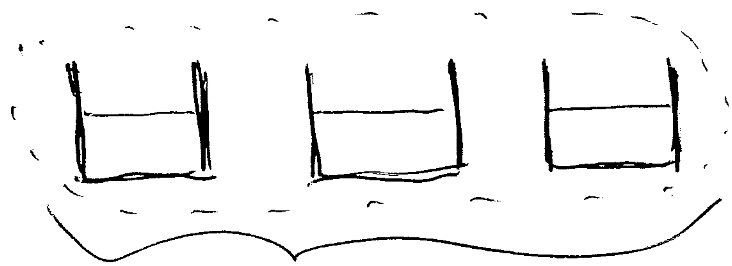
$$E_{total} = \underbrace{3\left(\tfrac{1}{2}nRT\right)}_{\text{translational (temperature)}} + \text{rot} + \text{vib}$$

Equipartition theorem: All degrees of freedom get the same energy.

Because ϵ_{avg} has 3 dofs, a unit of energy a dof gets is $\frac{1}{2}nRT$.
$\left(\frac{1}{2}Nk_BT\right)$

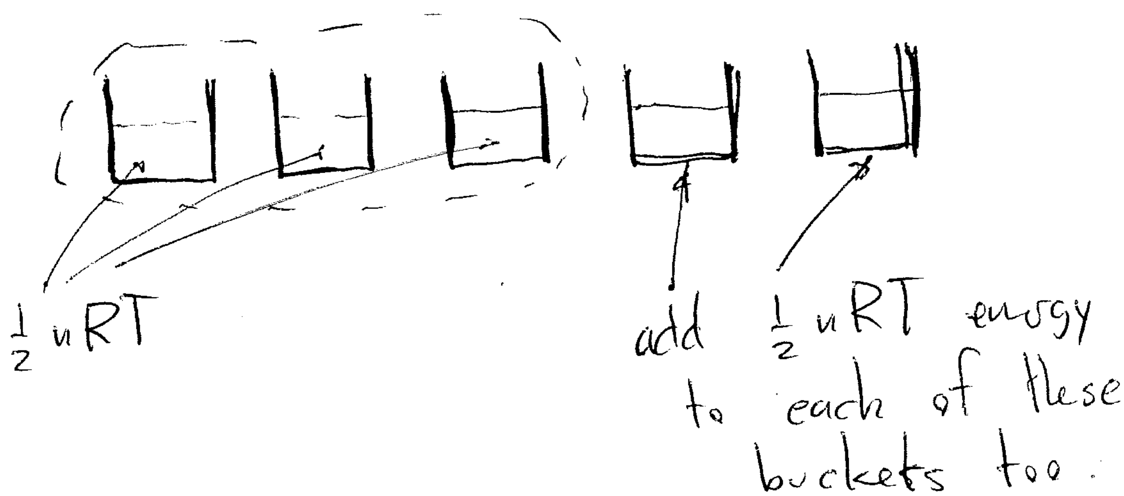
Monatomic gas:

translational KE.
all energy contributes to temp.



$$E = \frac{3}{2} nRT \Rightarrow C_v = \frac{3}{2} R$$

Diatomic gas:



$$E = \frac{5}{2} nRT \leftarrow C_v = \frac{5}{2} R$$

You have to add more energy to fill the translational energy buckets to the same level as the monatomic.

BASIC PROCESSES:

$$PV = nRT$$

Simplest processes hold one variable constant.

① Const V: isochoric

$$\Delta E = Q + W$$

← volume doesn't change so $W = -PdV = 0$

$$\Rightarrow Q = \Delta E = n C_V \Delta T$$

↑ heat flow goes directly into temp change. origin of the V subscript.

② Constant P:

$$\Delta E = Q + W$$

($\Delta E = nC_v\Delta T$)

$$W = -P\Delta V$$
$$= -nR\Delta T$$ (ideal gas law)

$$\Rightarrow Q = nC_v\Delta T + nR\Delta T$$
$$= n\underbrace{(C_v + R)}_{C_p}\Delta T$$
$$= nC_p\Delta T$$

← relates how heat changes temp at const P.

where $C_p = C_v + R$

③ Constant T: isothermal.

$$\Delta E = nC_v\Delta T = 0$$

$$\Rightarrow Q = -W$$

← The change in heat is related to the work done on the system.

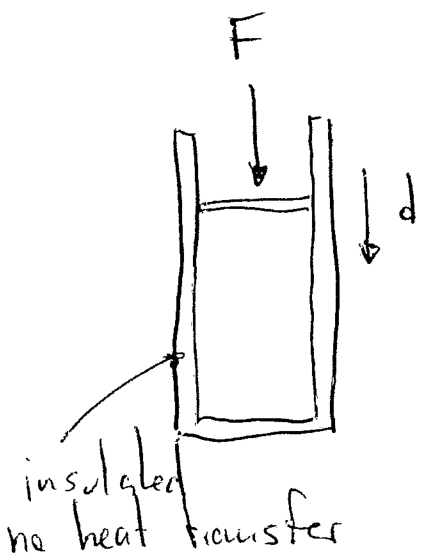
remember $W_{gas} = -W$

④ What about $Q = 0$? Adiabatic.
Valid for well insulated or fast processes.

$$\Delta E = \cancel{Q}^{0} + W$$

$$W = n C_v \Delta T = Fd$$

↑ work on system changes temperature.



$$n C_v \Delta T = Fd$$

$$\Delta T = \frac{Fd}{n C_v}$$

$$n = \frac{P_1 V_1}{R T_1} = \frac{P_1 A h_1}{R T_1}$$

$$\text{So } \Delta T = T_1 \frac{Fd}{PAh\left(\frac{C_v}{R}\right)}$$

if $F = 500\,N$, $d = 14\,cm$, $P = 100\,kPa$

$A = 0.25\,cm^2$, $\frac{C_v}{R} = \frac{3}{2}$, $T = 300\,K$

$h = 15\,cm$