Today

I. Days that we'll be taking a break: no class Wed Nov 25th, or Fri Nov 27th.
II. Upcoming exam, a week from this Friday, Nov 6th.
III. Last Time
IV. Temperature continued
V. Ideal Gas Law
VI. Work done by expanding gas
VII. Internal Energy

I. Yanpei Deng this week due to exam (will help in the lab. She's available M from 7-8pm in Brody lab).

This week: Antu Antu will be providing homework support. Hours are: Tu 8-9pm, Th 8-9pm.

II. Temperature:

- heating causes expansion, "thermal expansion"
- Temperature as a measure of <u>average</u> (random) kinetic energy.
- Absolute zero: all molecular motion ceases (classical) roughly at $-273°\text{C}$: $\#\text{K} = \#°C + 273$.

Kinetic Theory showed us that:

Collisions with walls <u>cause</u> the pressure, we found

$$PV = \frac{1}{3}Nm\overline{v^2} = \frac{2}{3}N\overline{K.E.}.$$

III. (4) <u>Boltzmann's constant</u>

Boltzmann turned the observation that temperature = average kinetic energy into an equation:

$$\overline{K.E.} = \frac{3}{2}kT,$$

Here k is Boltzmann's constant $1.38 \times 10^{-23}\,\text{J/K}$.

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IV. Ideal Gas Law

(1) Combine $\overline{K.E.} = \frac{3}{2}kT$ with kinetic theory, then:

$$PV = NkT. \quad \text{(Ideal gas law; or equation of state)}$$

(2) "Standard" # of molecules: called Avogadro's #

$N_A = 6.02 \times 10^{23}$,

$$1 \text{ mole} = N_A \text{ molecules.}$$

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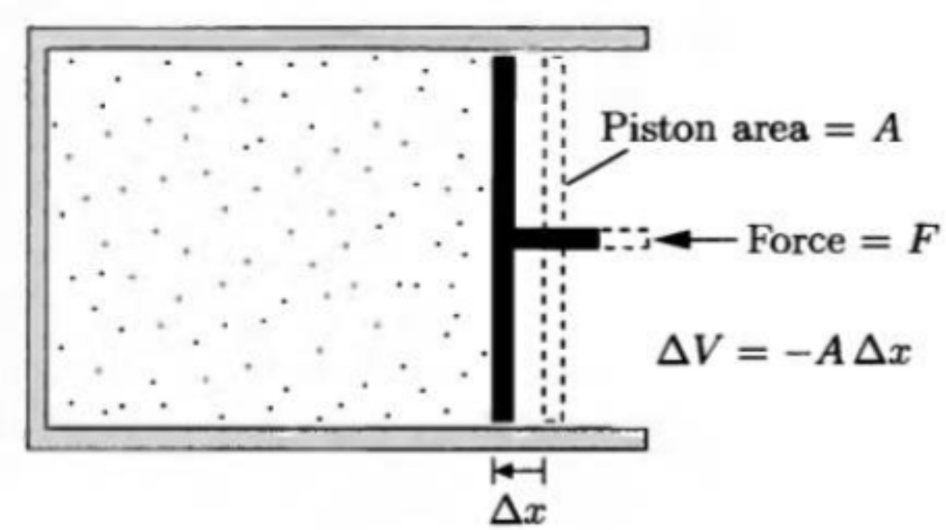
Then,

$$PV = n(N_A k)T = nRT,$$

Where R is the ideal gas constant and has the value

$$R = 6.02 \times 10^{23}(1.38 \times 10^{-23}) = 8.31 \text{ J/K}.$$

V. Work How much work is done on the gas by this force?



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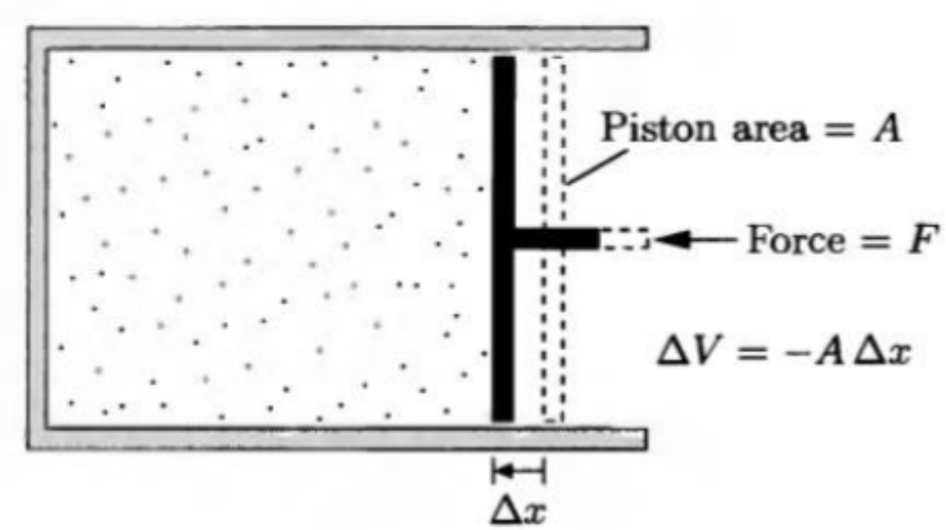
How general is this result? Well, it's correct whenever the pressure is well defined. This requires that we do the process slowly so that the system can equilibrate to a good pressure at each step. We call these processes "quasi-static". What is the work for a quasi-static process? We can get it by integrating:

$$W = -\int_{V_i}^{V_f} P(V)dV.$$

<u>Ex. 1</u>: Compression of an ideal gas at const. pressure (isobaric)

$$W = -P\int dV = -P(V_f - V_i),$$

which is indeed a positive work *on the gas*.



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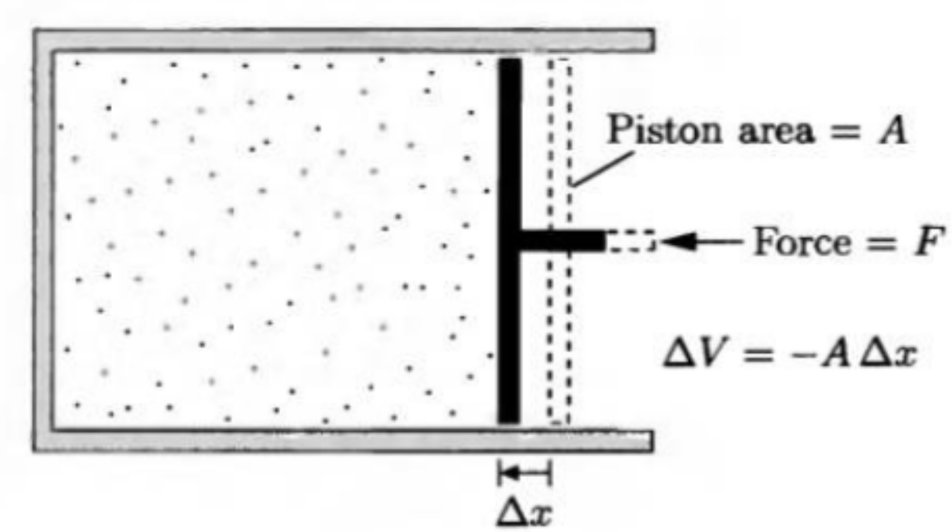
Ex. 2: Ideal gas compressed at constant temperature. We can use the ideal gas law to find $P(V)$,

$$P = \frac{NkT}{V},$$



Then

$$W = -\int_{V_i}^{V_f} P(V)dV = -NkT\int_{V_i}^{V_f} \frac{1}{V}dV$$

$$= -NkT[\ln(V_f) - \ln(V_i)] = -NkT\ln\left(\frac{V_f}{V_i}\right)$$

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Notice that this expression means that we can interpret work graphically: the work is negative the area under the curve on a *PV* diagram.