Today

I. Days that we'll be taking a break: A week from this Friday, Oct 23rd there will be no class or homework meetings, Wed Nov 25th also no class, or Fri Nov 27th.

II. Last Time

III. Temperature

IV. Ideal Gas Law

V. Work done by expanding gas

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. Last time we discussed the notion of pressure:

$$P = \frac{F}{A}\ .$$

Talked about heat, which is energy that is being transferred between objects because they are at different temperatures.

We found how pressure increases with depth in a gravitational field, like that around the Earth:

$$P(z) = P(0) - \rho g z.$$

We made an implicit assumption in this derivation, namely that the fluid was incompressible. When you squeeze it, it doesn't get smaller, in other words, for an incompressible fluid (e.g. water), ρ is independent of P.

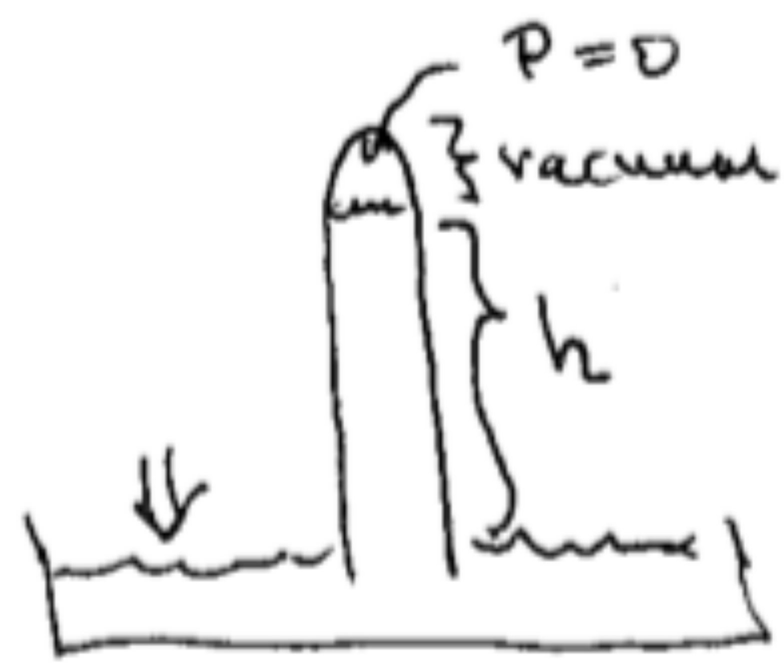
<u>Compressible:</u> Need to know how the density depends on pressure, the "equation of state".

II. Compressible: Need to know how the density depends on pressure, the "equation of state".

(3) <u>Atmospheric Pressure:</u> 1 Atmosphere = 1 atm

15 lbs/in^2 = 1.01×10^5 Pa.

Barometer—a tube sealed at one end, and open at the other. Fill the tube with water and tip it up vertically in a bowl:



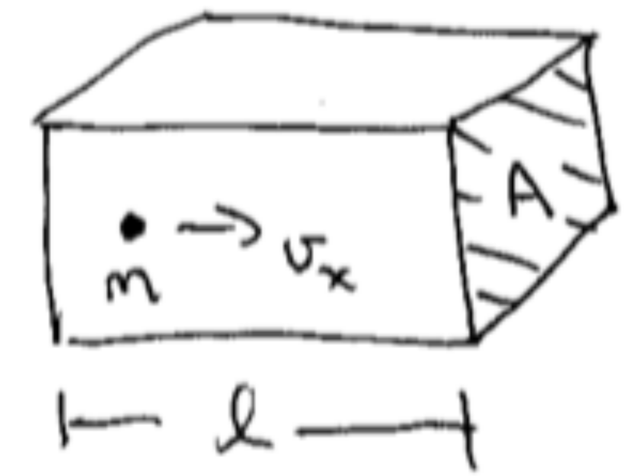
$\rho g h = 1$ atm and solving for h we have

$$h = \frac{1\text{atm}}{\rho g} = \frac{1.01 \times 10^5 \text{ Pa}}{10^3 \frac{\text{kg}}{m^3} \cdot 10 \frac{\text{m}}{\text{s}^2}} \approx 10 \text{ m.}$$

Or, use mercury: $h = 760$ mm.

xkcd: "What If?" Randall Munroe

III. (4) Kinetic Theory of Gases (or "What is pressure?")



In collision with the right wall, there is a momentum transfer, hence a force. The Momentum transfer is $\Delta p = 2mv_x$. The time between collisions with the right wall is

$$\Delta t = \frac{2\ell}{v_x}.$$

Then, the average force delivered to the wall is

$$F = \frac{\Delta p}{\Delta t} = \frac{2mv_x^2}{2\ell} = \frac{1}{\ell}mv_x^2.$$ For N molecules we have

$$P = \frac{F}{A} = \frac{N}{\ell \cdot A}m\overline{v_x^2} = \frac{N}{V}m\overline{v_x^2}.$$

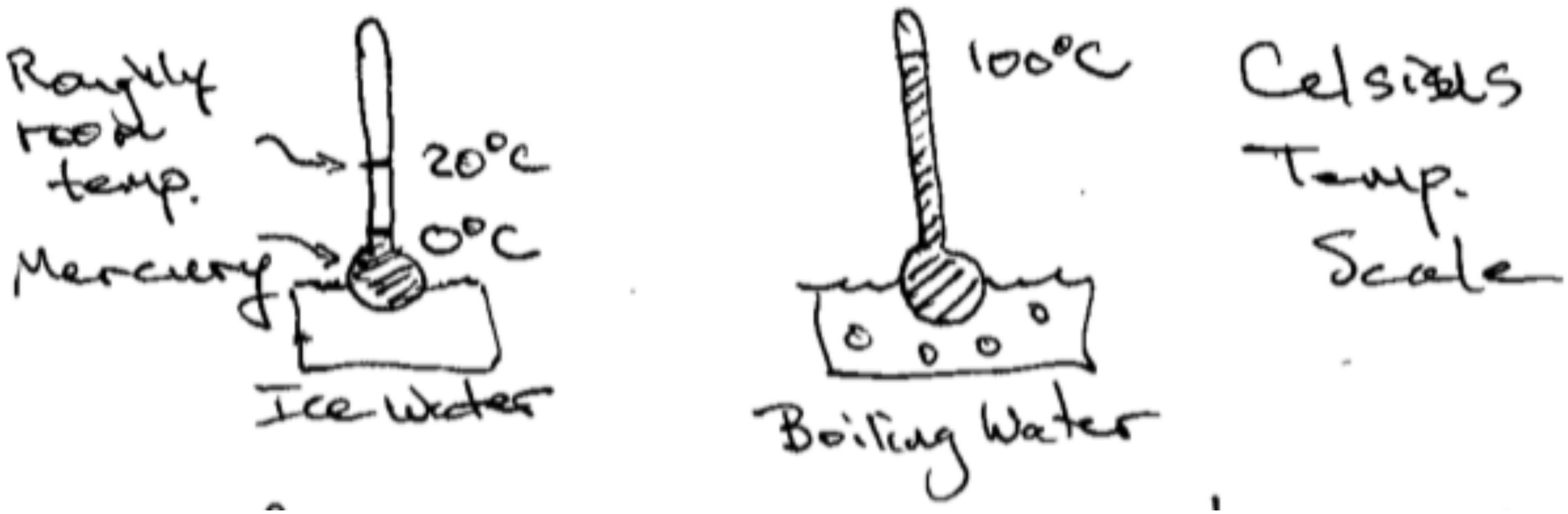
Because no direction is special we must have that $\overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2}$

$$\overline{v^2} = \overline{\vec{v}^2} = \overline{\vec{v} \cdot \vec{v}} = \overline{v_x^2 + v_y^2 + v_z^2} = \overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2} = 3\overline{v_x^2}.$$ Then,

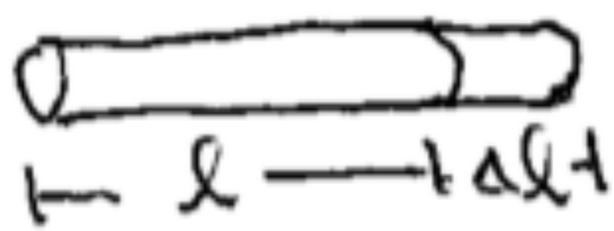
$$PV = N\frac{1}{3}m\overline{v^2} = \frac{2}{3}N\overline{K.E.}$$

IV. Temperature

(1) <u>Thermal Expansion:</u> Most substances expand as their temperature increases



Bar of iron: Initially at temperature T and heat it up by an amount ΔT, then



The fractional change in length is proportional to the change in temperature

$$\Delta \ell = \alpha \ell \Delta T,$$

here we call α the coeff. Of thermal expansion.

IV. Temperature

(2) Temperature of molecular (or atomic) energy

What is temperature? Temperature is a measure of the average (random) kinetic energy of the molecules or atoms in a substance. (This is inherently a statistical notion.) Also note, that it is only defined in thermal equilibrium, so one molecule going at 100 m/s is not temperature, but 100 going at 1 m/s is.

(3) Absolute zero: All molecular motion ceases (not actually possible, because of quantum mechanics): -273°C.

The Kelvin temperature scale is given by $K = {}^{\circ}C + 273$. Some examples: Freezing H_2O 273 K, Room temp.: 293 K, Boiling H_2O: 373 K.