

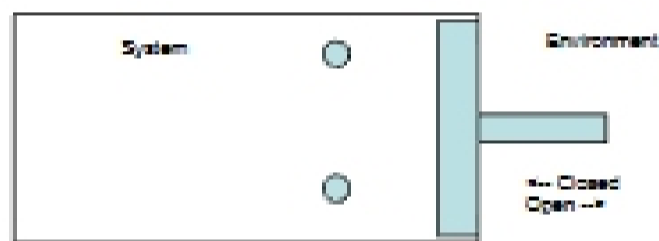
Review from Ch. 1

- Thermodynamic quantities
- Composition
- Pressure
- Density
- Temperature
- Kinetic Theory of Gases

Curry and Webster, pp. 1-17
Feynman, Book I, ch. 39

Thermodynamic Quantities

- Classical vs. Statistical thermodynamics
- Open/closed systems
- Equation of state $f(P,V,T)=0$
- Extensive/intensive properties
- Thermal, engine, heat/work cycles



Intensive quantities: P, T, v, n
Extensive quantities: V, N

Concentration: $n=N/V$
Volume: $v=V/N$

Composition

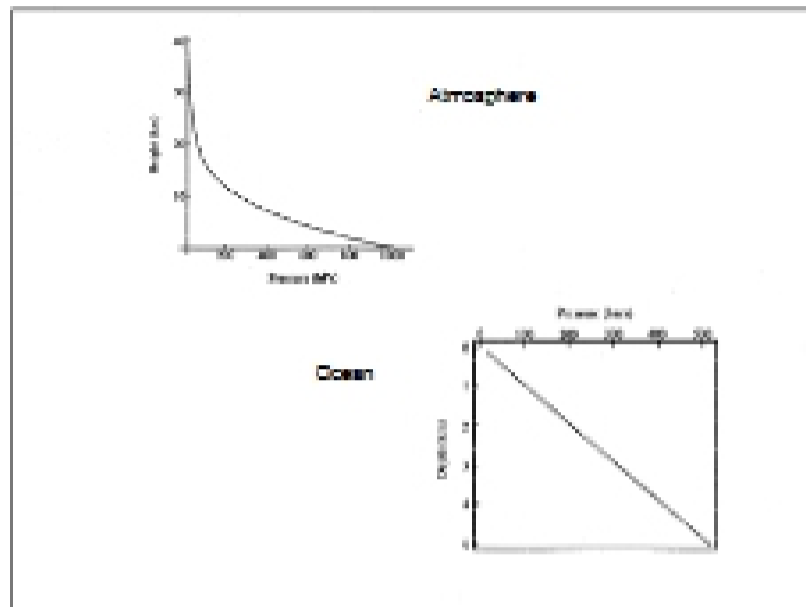
- Structure
 - Comparison to other planets
- N_2, O_2, Ar, CO_2, H_2O : 110 km constitute 99%
- Water, hydrometeors, aerosol

Table 1.1 Main gaseous constituents of air, relative to the percent composition of dry air.

Constituent	Formula	Molecular weight	% by volume	% by mass
Nitrogen	N_2	28.018	78.08	75.51
Oxygen	O_2	31.999	20.95	23.14
Argon	Ar	39.948	0.93	1.28
Carbon dioxide	CO_2	44.010	0.03	0.05
Water vapor	H_2O	18.016	0-4	

Pressure

- Force per unit area
- $1 \text{ bar} = 10^5 \text{ Pa}$; $1 \text{ mb} = 1 \text{ hPa}$; $1 \text{ atm} = 1.013 \text{ bar}$
- Atmosphere vs. Ocean

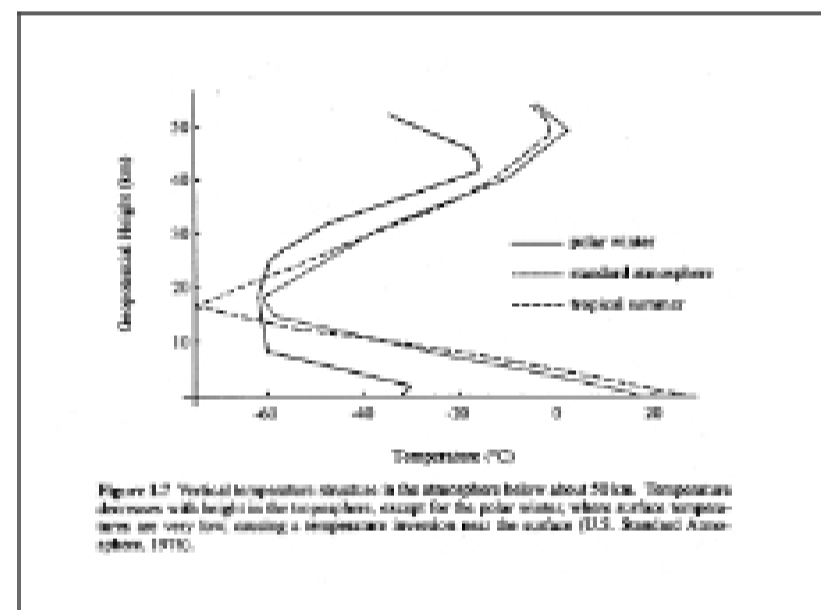


Density

- Specific volume: $v=V/m$
- Density: $\rho=m/V$
 - 1.29 kg/m³
- Mean free path
 - frequency of intermolecular collisions

Temperature

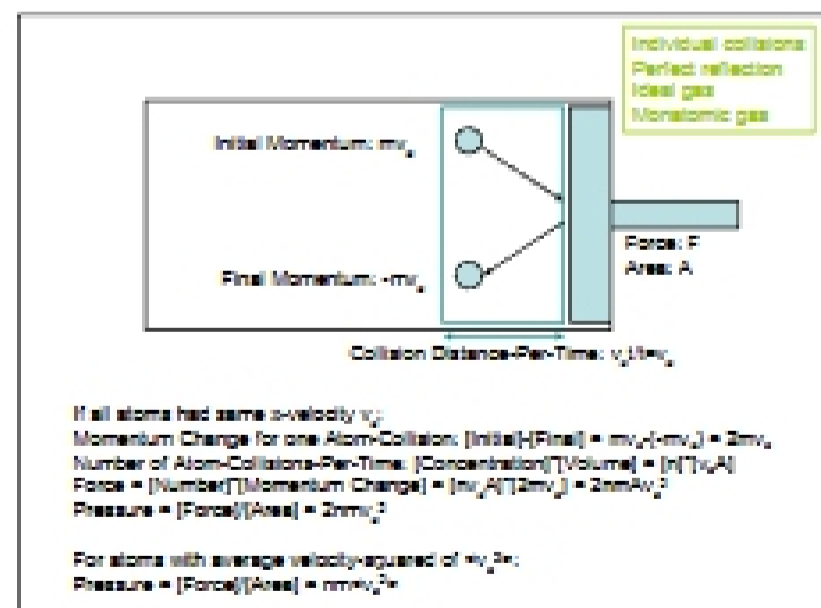
- "Zeroeth" Law of Thermodynamics
 - Equilibrium of two bodies with third
 - Allows universal temperature scale
- Temperature scale
 - Two fixed points: Kelvin, Celsius
 - Thermometer
- Lapse Rate $\Gamma = -\delta T/\delta z$
 - Change in temperature with altitude
 - Typically $\Gamma=6.5$ K/km
- Temperature Inversion $\Gamma < 0$
 - Boundary layer "cap"
 - Tropopause between troposphere and stratosphere

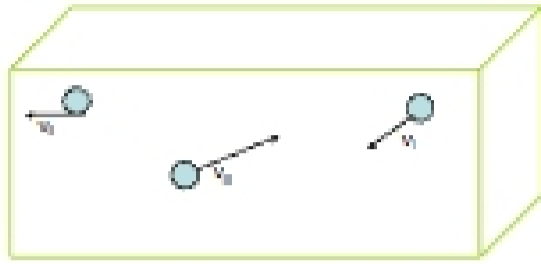


Kinetic Theory of Gases

- Pressure of a gas
- Kinetic energy
- Internal energy
- Temperature of a gas
- Pressure-volume-temperature relationship

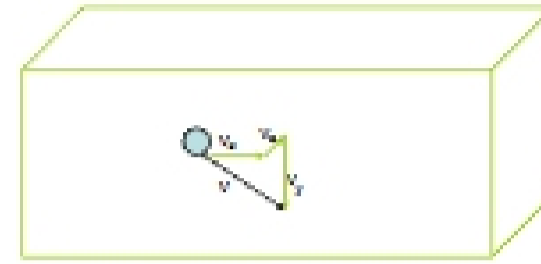
- The "fine print"



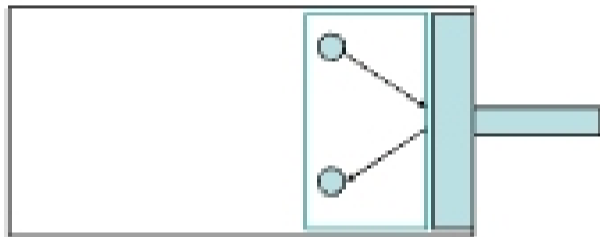


Population-averaged Velocity: $\frac{m_1\mathbf{v}_1 + m_2\mathbf{v}_2 + m_3\mathbf{v}_3 + \dots + m_N\mathbf{v}_N}{N}$
 Scalar multipliers: $\frac{m_1v_1^2 + m_2v_2^2 + m_3v_3^2 + \dots + m_Nv_N^2}{2N}$

How many will hit "right" wall? $n/2$



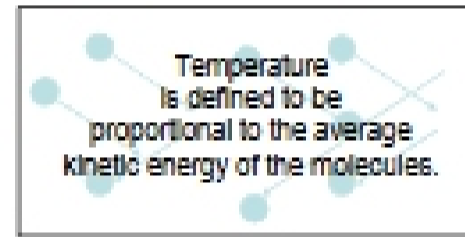
3D velocity: $\mathbf{v} = v_x\mathbf{e}_x + v_y\mathbf{e}_y + v_z\mathbf{e}_z$
 Random motion (no preferred direction): $\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle$
 $\langle v_x^2 \rangle = \langle v^2 \rangle / 3$



$P = \frac{F}{A}$
 $= \frac{(2/3)nm\langle v^2 \rangle}{A}$
 $= \frac{2}{3}n\langle mv^2 \rangle$
 $= \frac{2}{3}n(\text{kinetic energy of molecule})$

$PV = \frac{2}{3}nN\langle mv^2 \rangle$
 $= \frac{2}{3}U$
 $= \frac{2}{3}E_k$

Concentration: $n = N/V$
 Total "internal" energy: U
 Kinetic energy of gas



$PV = \frac{2}{3}E_k$
 $E_k = \frac{3}{2}PV$

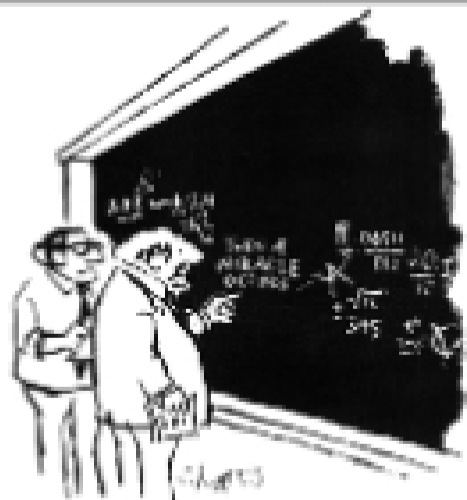
Define $T = 1/(k_B)$
 For scale choose $T = (2/3Nk_B)E_k$
 $E_k = \frac{3}{2}Nk_B T$

Then $PV = Nk_B T = nRT$

Kinetic energy of gas
 E_k is independent of gas
 \rightarrow so scale can be universal

Mean $k_B = E_k/N = (3/2)k_B T$
 $k_B = 1.38 \times 10^{-23} \text{ J/K}$

$R = N_A k_B = 8.314 \text{ J/mole}^\circ\text{C}$



"I think you should be more explicit here in step two."

Lecture Ch. 2a

- Energy and its properties
 - State functions or exact differentials
 - Internal energy vs. enthalpy
- First law of thermodynamics
- Heat/work cycles
 - Energy vs. heat/work?
 - Adiabatic processes
 - Reversible "P-V" work
- Homework problem Ch. 2, Prob. 2

Curry and Webster, Ch. 2 pp. 35-47
 Van Ness, Ch. 2