Let us get to Work with Ideal Gas!

Raj Pala,
rpala@iitk.ac.in
Department of Chemical Engineering,
Associate faculty of the Materials Science Programme,
Indian Institute of Technology, Kanpur.

All work & No heat!

- Mechanical quantities vs. thermodynamical quantities
- ESO-TD: Extend notions of work, work-energy theorem, conservation and conversion of energy as seen in simple mechanical systems to thermodynamical systems
- First step…

What does $1.03 * 10^4 kg$ *acted by Earth's gravitational field of* $9.80\ \frac{m}{s^2}$ *over a square meter mean?*

- Atmospheric pressure
- 1.013*$\mathbf{10^4}\ \frac{N}{m^2}$=760 mm Hg

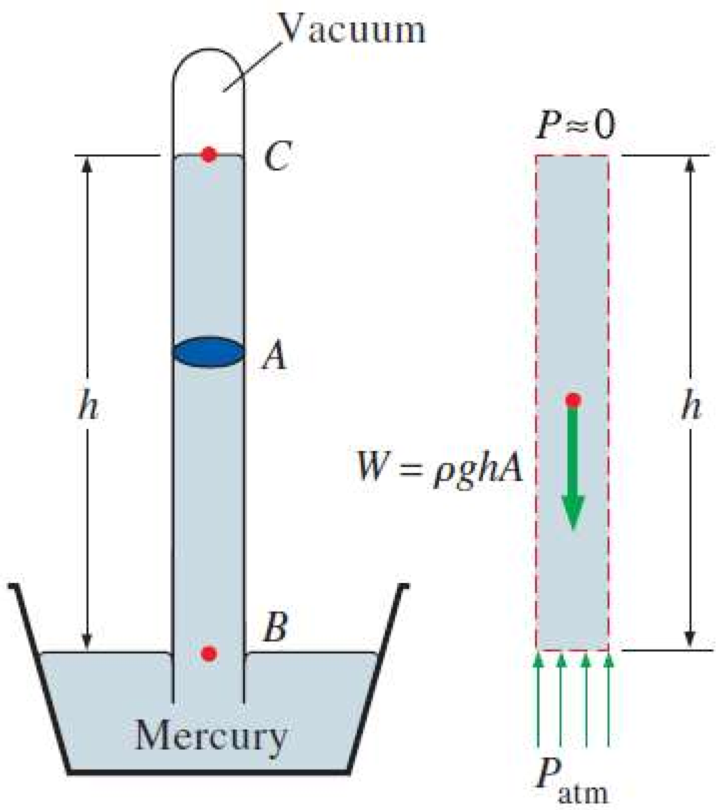

Fig: Cengel & Boles, TD

Resistance Movement: A Toy Model

- Closed chamber (L*L*L) with piston containing N_{Ava} ideal gas atoms
- Ideal gas atomic energy=Only Kinetic Energy
- Pressure exerted by gas on the piston=$P_{external}$; No acceleration
- $\text{Work}=F_{external} * (\Delta x) = \frac{F_{resisting}}{\boldsymbol{A}} * \boldsymbol{A} * (\Delta x) = P_{external} * (\Delta V)$
- $F_{external}$= *"Average steady"* force on the wall=$F_{gas\text{-}N_A\ atoms}$
- $F_{gas\text{-}1atom}$= *"Stochastic"* force due to single atom collision
- $F_{gas\text{-}1atom}$=(momentum change per collision) * $\left(\frac{\textit{Collisions}}{\textit{Second}}\right)$
- $F_{gas\text{-}1\ atom} = \left(2 * \boldsymbol{m} * \boldsymbol{velocity}_{\boldsymbol{ideal\ gas\ atom}}\right) * \frac{\boldsymbol{velocity}_{\boldsymbol{ideal\ gas\ atom}}}{2\boldsymbol{L}_{\boldsymbol{Chamber}}}$
- $F_{gas\text{-}N\ atoms}$ (*"Average steady"*)= $F_{gas\text{-}1\ atom} * \frac{\boldsymbol{N}_{\boldsymbol{A}}}{\boldsymbol{3}}$
- $P_{external} = \frac{F_{external}}{\boldsymbol{L}^2} = \frac{F_{gas-N_A\ atoms}}{\boldsymbol{L}^2} = \frac{\boldsymbol{N}_{\boldsymbol{A}}\boldsymbol{m}\boldsymbol{v}^2}{\boldsymbol{3}\boldsymbol{L}^3}$

P from "first principles" & empirical connection to T

- Charles' Law: $PV = N_{Ava} * K_{Boltzmann\ constant} * T = R_{gas\ constant} * T$

- $P_{external} * V = \frac{F_{external}}{L^2} * L^3 = \frac{N_A m v^2}{3L^3} * L^3 = \frac{N_A m v^2}{3} = N_A * K_B * T$

- $\frac{mv^2}{2} = \frac{3K_B * T}{2}$!!!

- What has been accomplished: Meaning of measured macroscopic TD variables P & T in terms of "derived" microscopic mechanical variables

- What is the second step: Warming up to looking at "energy inwards"