Warming up to looking at “Energy inwards”!

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Let us get to Work with Ideal Gas!

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

- $PV = N_{Ava} * K_{Boltzmann\ constant} * T = R_{gas\ constant} * T$

- $\frac{mv^2}{2} = 3 * \left(\frac{K_B * T}{2}\right)$!!!-Equipartition theorem-3 DOF

- v=Average velocity of an ideal gas atom; It is NOT C.O.M velocity!

- What has been accomplished: Meaning of measured macroscopic TD T in terms of microscopic mechanical variable v

Energy of a "continuum" in classical mechanics

- Continuum: "a continuous sequence in which adjacent segments are not perceptibly different from each other…"
- We are not resolving material segments into atoms/electrons…
- Energy due to the motion of the Center Of Mass: Kinetic energy
- Energy due to position of the C.O.M in a force-field: Potential Energy
- From mechanics to thermodynamics…?
- Is the "energy content" of Bumbrah's ball at 150 km/h same when he is bowling in Australian winter and Kanpur summer?
- Is the "energy content" of Cu metal block elevated to 1000 m different when it is at 50°C and 500 °C?
- In addition to K. E & P.E, how does T affect the energy content?

Work-Energy theorem of classical mechanics

- The net work done on a particle equals the change in the particle's kinetic energy: $W_{net} = K_B - K_A$
- $dW_{net} = \overrightarrow{F}.\overrightarrow{dr}$
- $\overrightarrow{F} = \frac{\overrightarrow{dv}}{dt}$
- How do we extend work-energy theorem to thermodynamics?

Joule's Experiments (1843 to 1848)

- https://demonstrations.wolfram.com/JoulesExperiment/

- What happens to the work done on the system contained within a adiabatically walled container whose C.O.M Kinetic & Potential Energy does not change?

- Temperature increased!

- By equipartition theorem, temperature is correlated to average velocity of atoms of the liquid in the adiabatically walled contained

- Note: Not C.O.M velocity; Atomic velocities are random and are correlated to temperature

Microscopic DOF provides additional ways of storing energy

- Beyond C.O.M "directional positional change" (potential E) & "directional motion" (kinetic E), there is "internal energy" due to "random" motion atoms

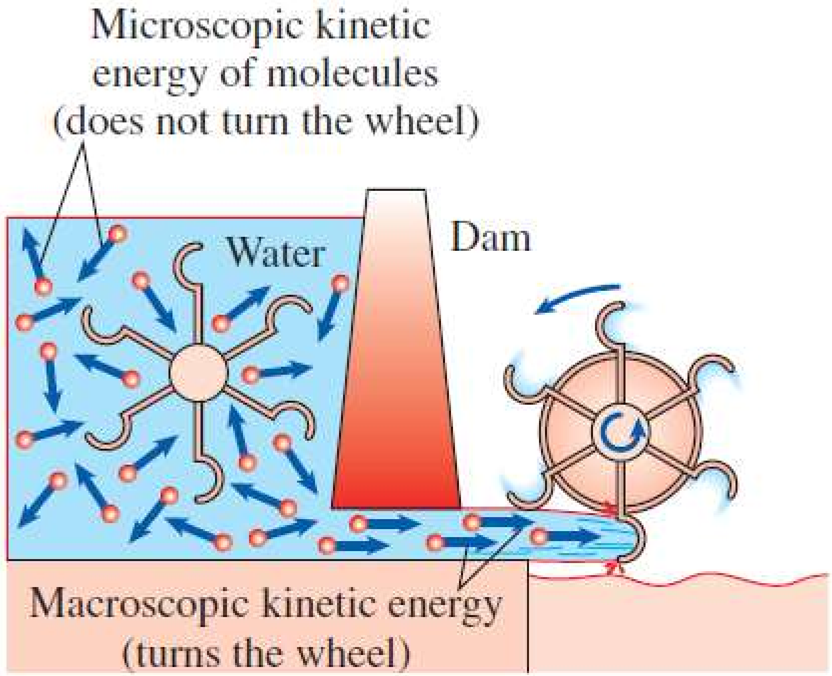
- In Joule's experiment, the work done on the system within the adiabatically walled container increased the capacity of the system to store heat, with the increase corresponding to an increase in temperature

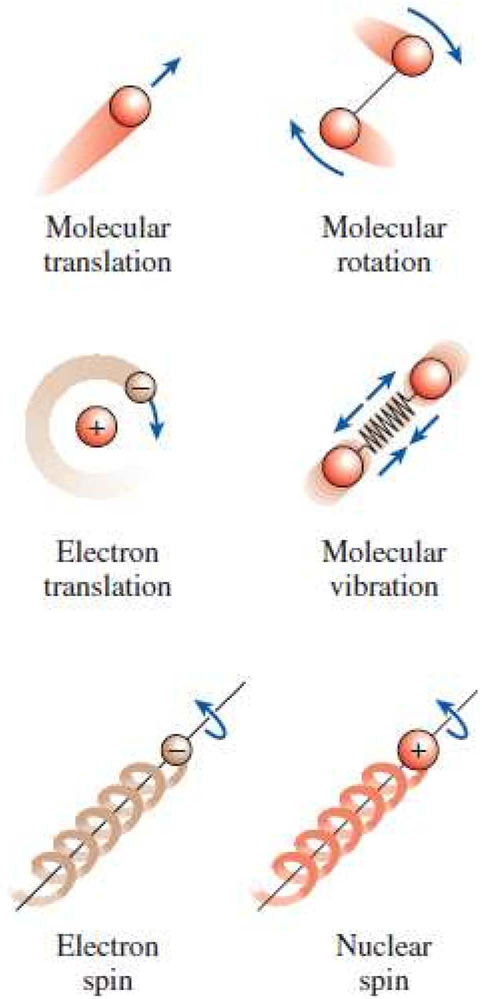
- Joule also found that similar amount of other forms of work (like electrical) also gave raise to similar increase in temperature

- All work can be converted to heat resulting in increase of temperature!

Relevant microscopic DOF depends on T

- Excitable DOF
- Typically, engineering systems are "cold" in terms of electronic and nuclear DOF





Figs: Cengel & Boles

Multi Scale Nature of Energy

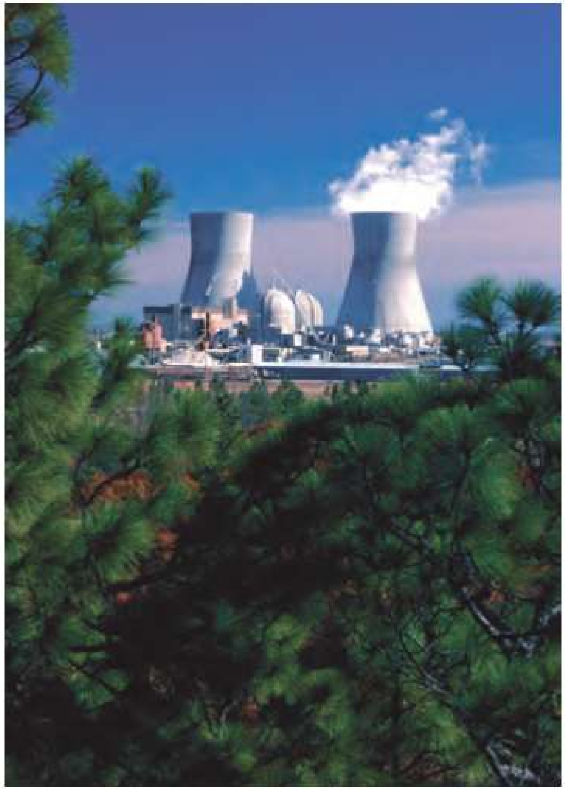


FIGURE 2–3
At least six different forms of energy are encountered in bringing power from a nuclear plant to your home: nuclear, thermal, mechanical, kinetic, magnetic, and electrical.

Fig: Cengel & Boles

Advertising First Law of Thermodynamics: Extending Work-Energy beyond mechanics

$$\Delta U = Change\ in\ Internal\ Energy\ U = "Heat\ \&\ work\ exchange" = "q - W"$$