ESO 201A: Thermodynamics

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Energy and Energy Transfer-part 1

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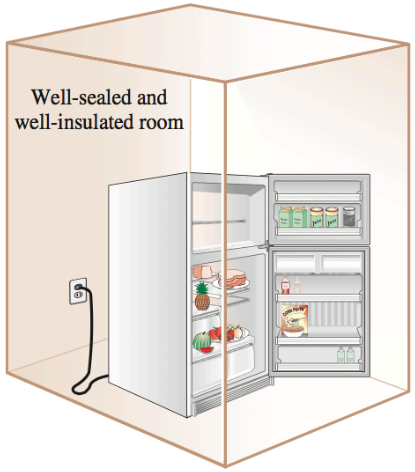
Learning objectives

- Introduce the concept of energy and define its various forms.
- Discuss the nature of internal energy.
- Define the concept of heat and the terminology associated with energy transfer by heat.
- Define the concept of work, including electrical work and several forms of mechanical work.
- Introduce the first law of thermodynamics, energy balances, and mechanisms of energy transfer to or from a system.
- Determine that a fluid flowing across a control surface of a control volume carries energy across the control surface in addition to any energy transfer across the control surface that may be in the form of heat and/or work.
- Define energy conversion efficiencies.

Energy conservation

- Temperature will rise
  - On the basis of conservation of energy
  - Electrical energy→ thermal energy stored in the room air



Forms of energy

- Thermal, Mechanical , Kinetics, Potential, Electrical, Magnetic, Chemical, Nuclear

Total energy **E** is sum of all forms of energy provided to the system.

- Macroscopic – Kinetic and Potential
- Microscopic – related to molecular structure- independent of outside reference
  - Sum of all microscopic forms of energy is called *Internal Energy, U*

Forms of energy

Macroscopic forms of energy

- Related to motion, influence of external field (gravity, magnetic field, electricity, surface tension)

Kinetic Energy

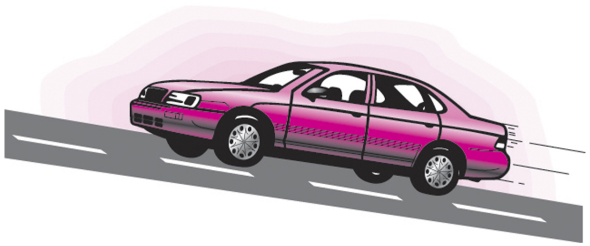
- The energy of the system associated with its relative motion with reference frame

$$\mathrm{KE} = m\frac{V^2}{2} \quad \text{(kJ)} \qquad \mathrm{ke} = \frac{V^2}{2} \quad \text{(kJ/kg)}$$

Potential Energy

- The energy of the system due to the elevation in a gravitational field

$$\mathrm{PE} = mgz \quad \text{(kJ)} \qquad \mathrm{pe} = gz \quad \text{(kJ/kg)}$$



The macroscopic energy of an object changes with velocity and elevation.

In the absence of *magnetic*, *electric*, and surface *tension* , total energy is given by

$$E = U + \mathrm{KE} + \mathrm{PE} = U + m\frac{V^2}{2} + mgz \quad \text{(kJ)}$$

Internal energy

Sensible energy

Portion of energy associated with KE of molecules

Latent energy

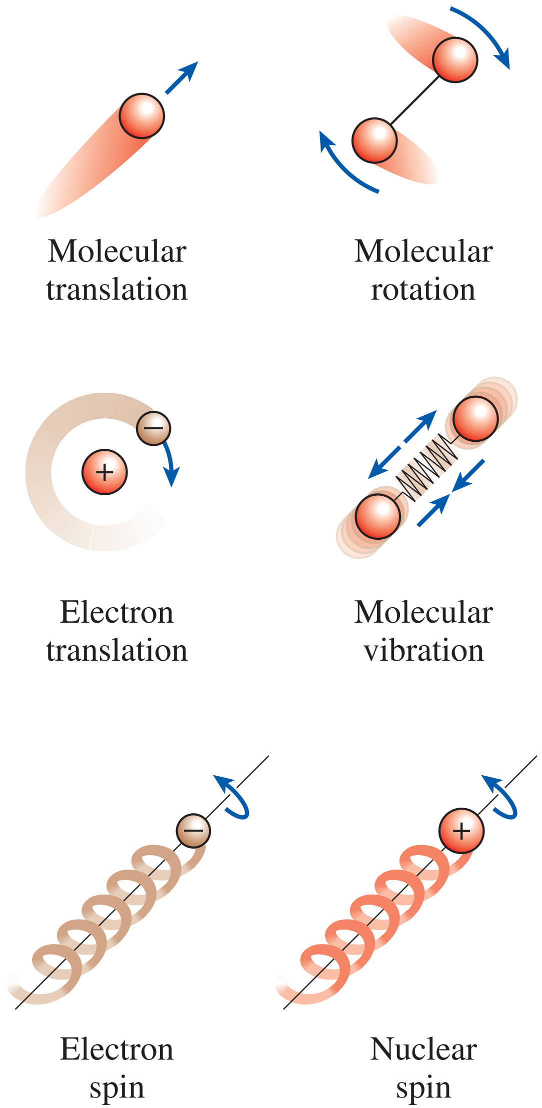
Energy required to change the phase of the system

Chemical Energy

Energy associated with chemical bonds in molecules

Nuclear Energy

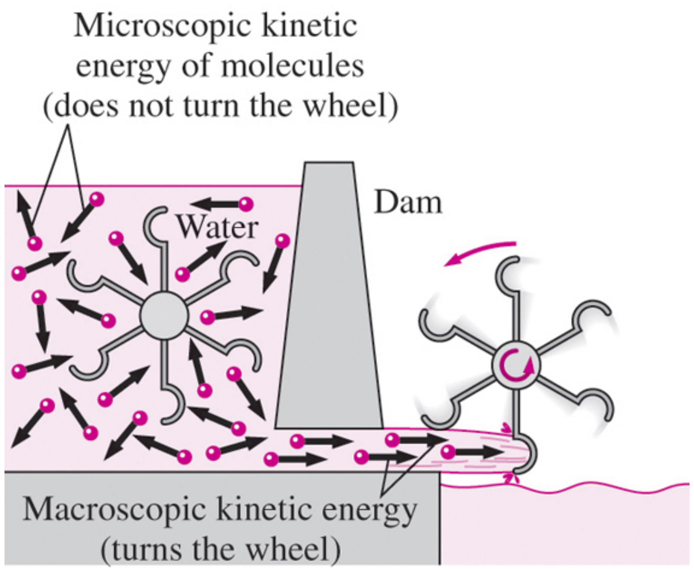
Energy associated with the strong bonds within the nucleus of the atom



Macroscopic vs. Microscopic Kinetic Energy

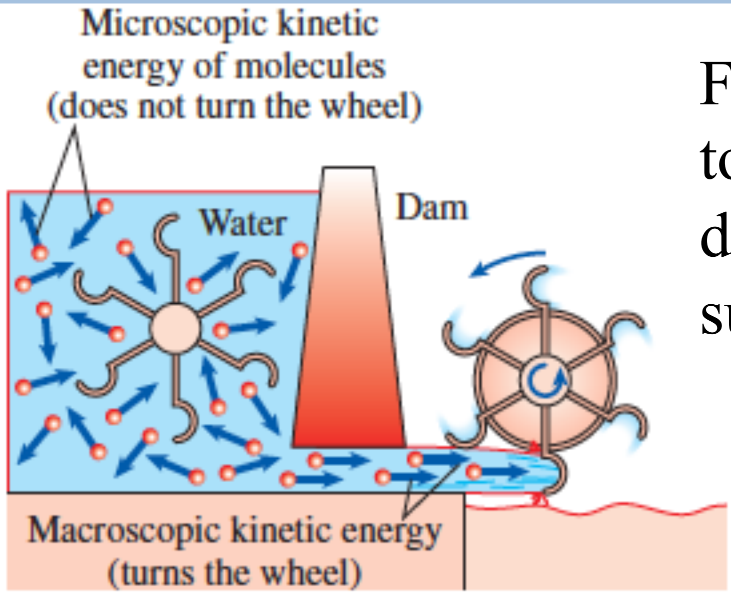
- The total energy of a system, can be *contained* or *stored* in a system, and thus can be viewed as the ***static* forms of energy**.
- The forms of energy not stored in a system can be viewed as the ***dynamic* forms of energy** or as ***energy interactions***.
- The dynamic forms of energy are recognized at the system boundary as they cross it, and they represent the energy gained or lost by a system during a process.
- The only two forms of energy interactions associated with a closed system are **heat transfer** and **work**.

The *macroscopic* kinetic energy is an organized form of energy and is much more useful than the disorganized *microscopic* kinetic energies of the molecules.



- **The difference between heat transfer and work:** An energy interaction is heat transfer if its driving force is a temperature difference. Otherwise it is work.

Mechanical energy



Form of energy that can be converted to mechanical work completely and directly by an ideal mechanical device such as an ideal turbine.

Examples: KE and PE

Mechanical energy per unit mass=flow energy+ KE + PE

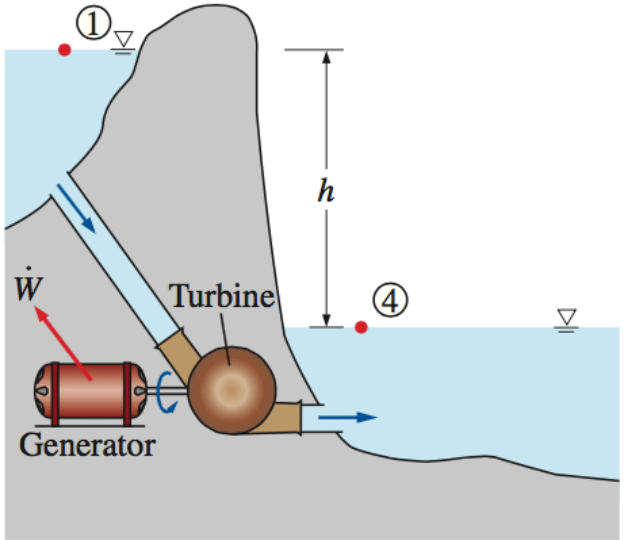
$$e_{\text{mech}} = \frac{P}{\rho} + \frac{V^2}{2} + gz$$

$$\dot{E}_{\text{mech}} = \dot{m}e_{\text{mech}} = \dot{m}\left(\frac{P}{\rho} + \frac{V^2}{2} + gz\right)$$

Mechanical energy change:

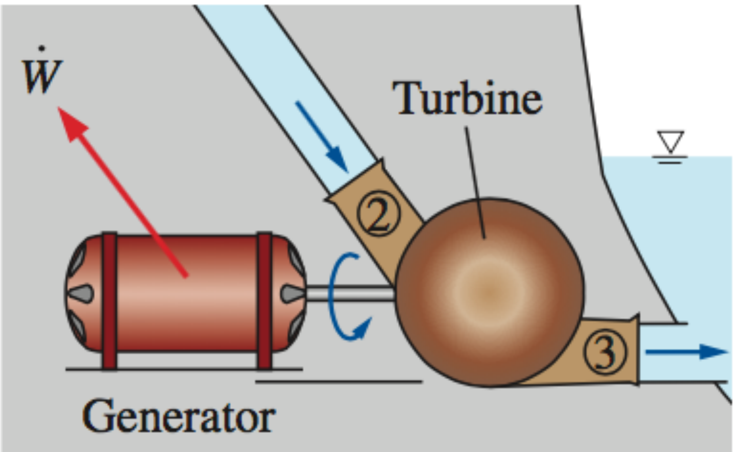
$$\Delta e_{\text{mech}} = \frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1) \qquad \text{(kJ/kg)}$$

Maximum (ideal) power



$$\dot{W}_{\max} = \dot{m}\Delta e_{\text{mech}} = \dot{m}g(z_1 - z_4) = \dot{m}gh$$

$$\text{since } P_1 \approx P_4 = P_{\text{atm}} \text{ and } V_1 = V_4 \approx 0$$



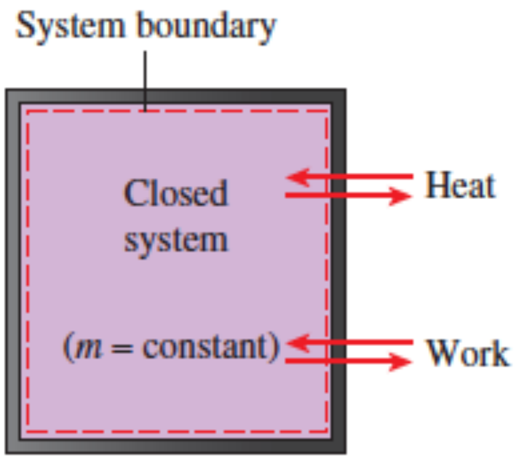
$$\dot{W}_{\max} = \dot{m}\Delta e_{\text{mech}} = \dot{m}\frac{P_2 - P_3}{\rho} = \dot{m}\frac{\Delta P}{\rho}$$

$$\text{since } V_2 \approx V_3 \text{ and } z_2 = z_3$$

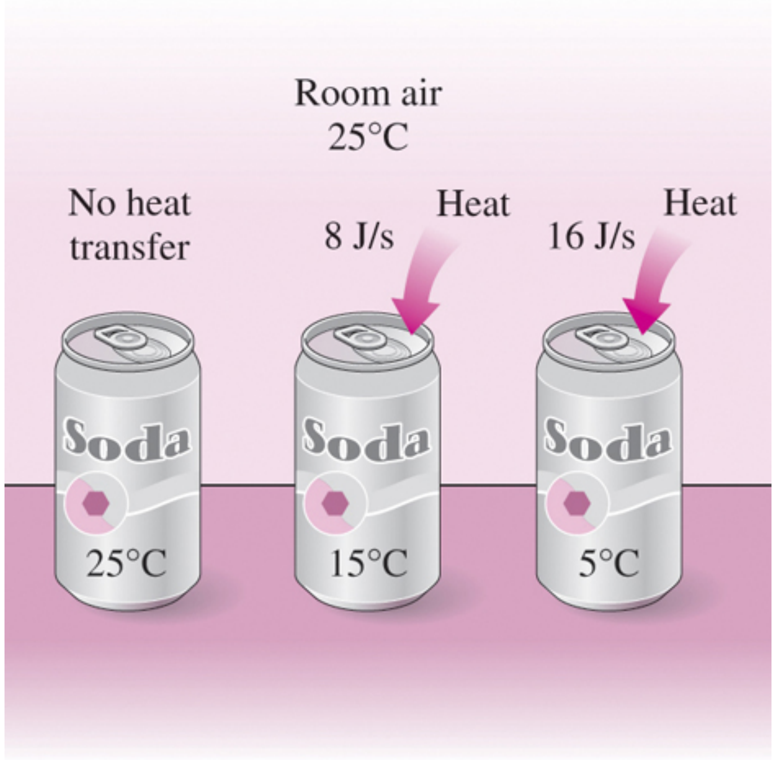
Energy transfer by heat

Heat- form of energy that is transferred, by virtue of temperature difference, between

- two systems
- a systems and its surrounding

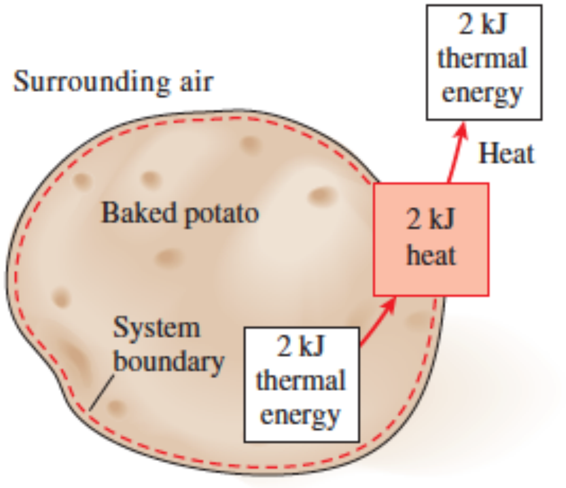


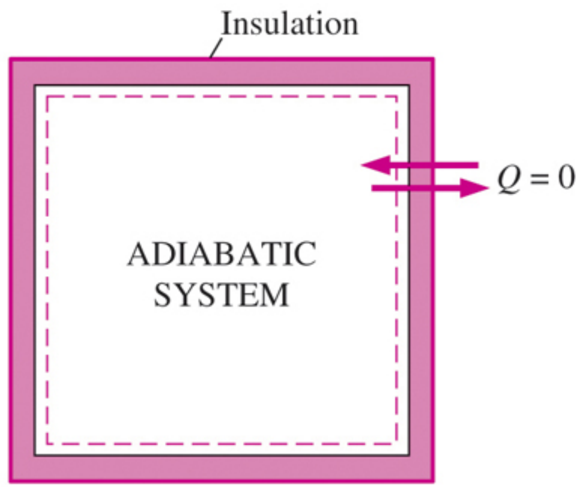
Energy can cross the boundaries of a closed system in the form of heat and work.



Temperature difference is the driving force for heat transfer. The larger the temperature difference, the higher is the rate of heat transfer.

Energy transfer by heat





Energy is recognized as heat transfer only as it crosses the system boundary.

During an adiabatic process, a system exchanges no heat with its surroundings.

Usually Q (kJ), or q (kJ/kg)

Many occasion, rate of heat transfer is needed, which is denoted by $\dot{Q}$:

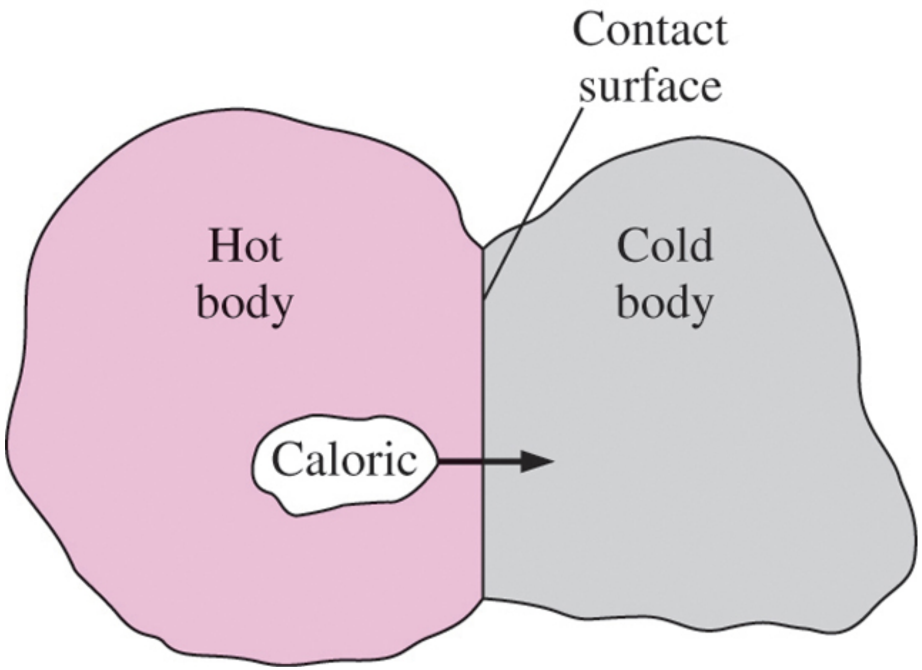
$$Q = \int_{t_1}^{t_2} \dot{Q}\, dt \qquad \text{(kJ)}$$

Historical Background of Heat

- **Kinetic theory**: Treats molecules as tiny balls that are in motion and thus possess kinetic energy.
- **Heat**: The energy associated with the random motion of atoms and molecules.

Heat transfer mechanisms:

- **Conduction:** The transfer of energy from the more energetic particles of a substance to the adjacent less energetic ones as a result of interaction between particles.
- **Convection:** The transfer of energy between a solid surface and the adjacent fluid that is in motion, and it involves the combined effects of conduction and fluid motion.
- **Radiation:** The transfer of energy due to the emission of electromagnetic waves (or photons).



In the early nineteenth century, heat was thought to be an invisible fluid called the ***caloric*** that flowed from warmer bodies to the cooler ones.

Next lecture

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