ME265: Thermal Engineering & Heat Transfer

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1. Energy Scenario
2. Thermodynamics
3. Mechanical Devices & Systems
4. Heat Transfer

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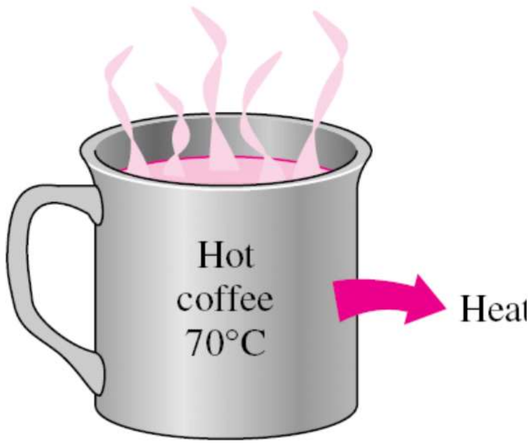
4.1 Introduction to Heat Transfer

4.1.1 Fundamentals

- People have always understood that something flows from hot objects to cold ones. They refer to that as heat transfer.
- Heat transfer (or heat) is the *energy in transit* due to a temperature difference.

- *Whenever* there exists a temperature difference in a medium or between media, heat transfer *must* occur.
- The higher the temperature, the higher the rate of temperature.



- Heat transfer need *not* always result due to a change in the temperature; e.g. during phase change……

4.1 Introduction to Heat Transfer

4.1.1 Fundamentals

- Heat transfer is *all-pervasive*. This scientific understanding came as early as 19th century!

Joseph Fourier (1768-1830) said---“Heat, like gravity, penetrates *every* substance of the universe; its rays occupy all parts of space.”

- Having studied “Thermodynamics”, why should we study Heat Transfer?

- What do we seek from a course on Heat Transfer?

4.1 Introduction to Heat Transfer

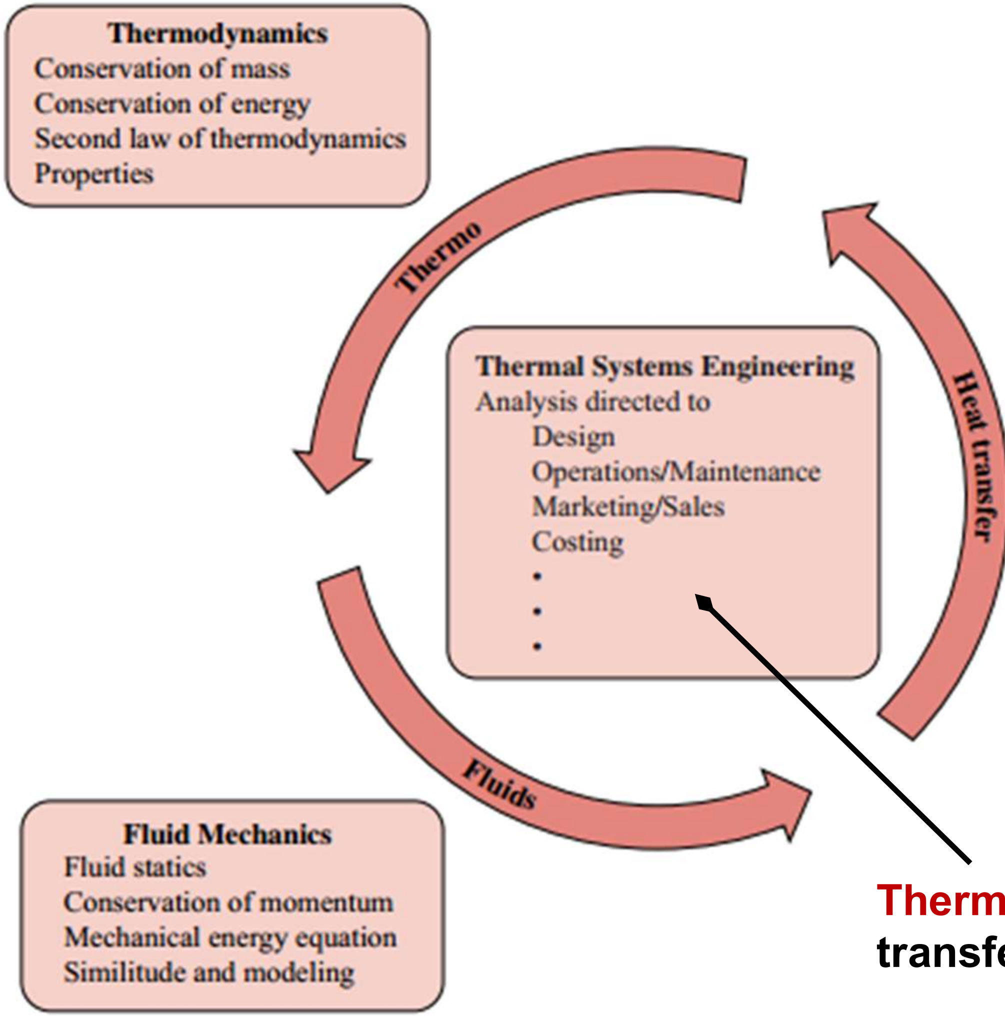
4.1.1 Fundamentals: Thermodynamics VS Heat Transfer

Examples→	Nuclear PP*	Atomic Bomb*
Thermodynamics	Similar	Similar
Heat Transfer	Takes years together for heat release Synonymous to life	Takes a few seconds for releasing same amount of heat Synonymous to death

* Considering that both systems have the same quantity of fissile material and release same amount of heat due to nuclear chain reactions.

4.1 Introduction to Heat Transfer

4.1.1 Fundamentals



Thermal systems that involve storage, transfer and conversion of energy

Ref: Moran et al. Introduction to Thermal Systems Engineering. c 2003, John Wiley & Sons

4.1 Introduction to Heat Transfer

4.1.2 Applications of Heat Transfer

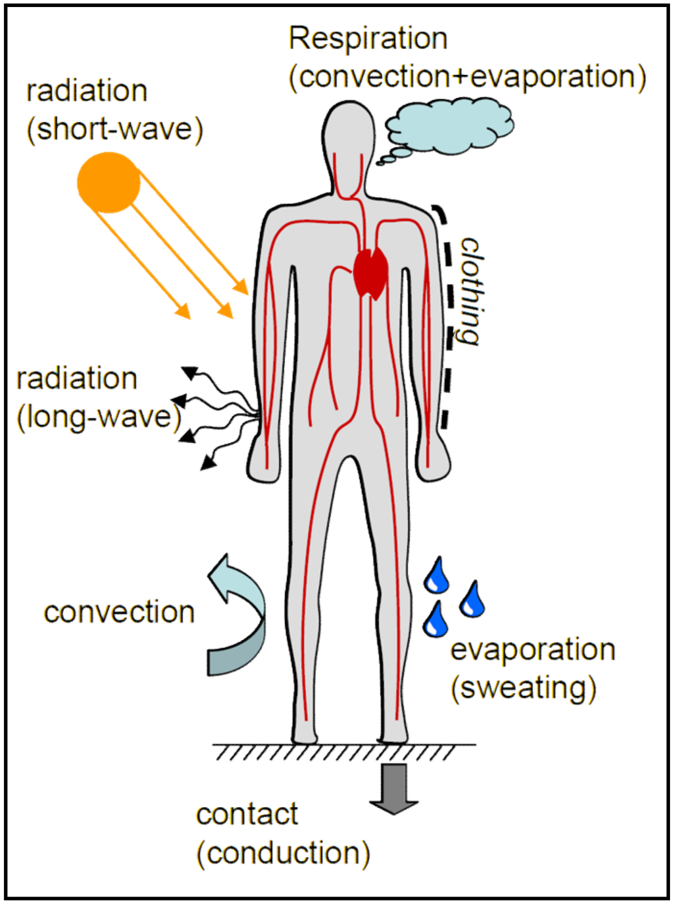
Thermal Systems in	**Examples**
Industry	Power plants, Chemical processing plants, and manufacturing facilities
Transportations	Engines, power converters, and cooling equipment.
Home	Ovens, refrigerators, and furnaces represent thermal systems. Ice rinks, snow-making machines, and other recreational uses involve thermal systems.
Living things	The respiratory and circulatory systems are thermal systems, as are equipment for life support and surgical procedures.

Ref: Moran et al. Introduction to Thermal Systems Engineering. c 2003, John Wiley & Sons

4.1 Introduction to Heat Transfer

4.1.2 Applications of Heat Transfer

Heat sinks for electronic devices



Power plant

Radiator

Refrigerator

Ref: Google images

4.1.2 Applications—Hi Tech

Electronics cooling:

We know that heat is “generated” within an electronic equipment, and the electronic equipment work only if they are maintained at or near room temperature (that is why computers are generally kept in an air conditioned room, AC is not for the white-collar job operator!).

Controlling the temperature of computer chips is a highly challenging task in the era of miniaturization. A futuristic *palm top* or a *wrist top* would not be a reality unless until a heat transfer specialist makes them cool!

4.1 Introduction to Heat Transfer

4.1.2 Applications—Hi Tech

Satellites and Spacecraft:
Just think of a satellite or a spacecraft whose temperature can exceed 120^{o}C because of solar heating. On the other hand, in the absence of solar heating, the temperature may be close to –269^{o}C (cold space temperature= 4 K).

We can read the title of this paragraph as a "fried" and/or "frozen" *Space Junk*, unless until a heat transfer specialist designs a proper Spacecraft Temperature Control System (for both heating and cooling).

4.1.3 Heat and Associated properties

- Energy is a fundamental concept of thermodynamics and is viewed as the ability to cause changes/effects
- It can be stored within systems in two general forms as follows:
  - **Macroscopic forms of energy**—related to motion and the influence of some external effects such as gravity, magnetism, electricity, and surface tension.

    Energy related to motion: Kinetic energy, KE = $mv^2/2$

    Energy under influence of gravity: Potential energy, PE = $m\ g\ z$

  - **Microscopic forms of energy** — related to molecular structure of a system and the degree of molecular activity. Example includes Sensible energy, latent energy, chemical energy, nuclear energy.

    All microscopic energy are termed as internal energy, U

Total Energy, E = U + PE + KE

PE + KE: Macroscopic

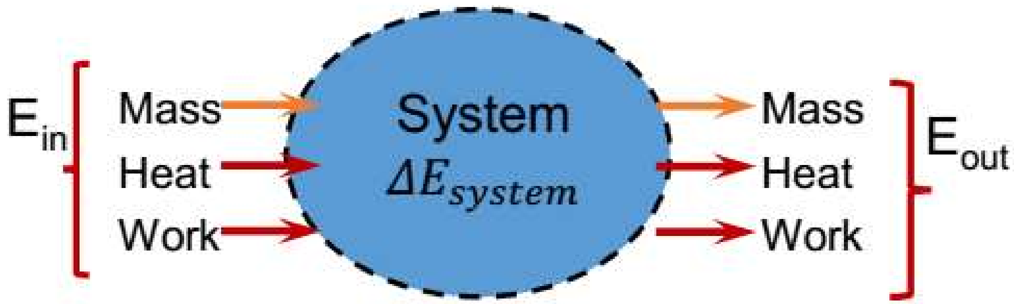
U: Microscopic

4.1 Introduction to Heat Transfer

4.1.3 Heat and Associated properties

Mechanism of Energy Transfer across a system boundary:

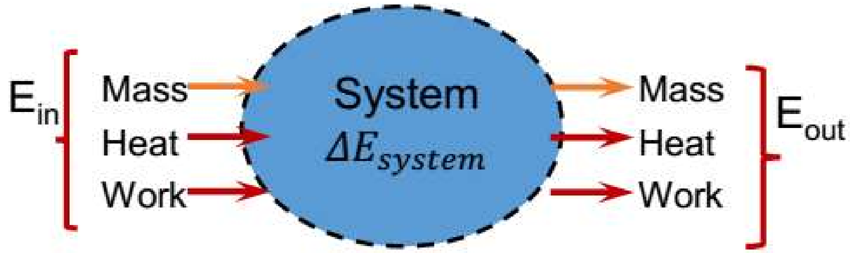
- Work, W due to boundary movement and others (electrical)
- Heat, Q due to temperature diff between system and surrounding
- Mass flow, m—flow work



$$E_{in} - E_{out} = \Delta E_{system}$$

$$\dot{E}_{in} - \dot{E}_{out} = dE_{system}/dt$$

4.1.3 Heat and Associated properties



$$E_{in} - E_{out} = \Delta E_{system}$$
$$\dot{E}_{in} - \dot{E}_{out} = dE_{system}/dt$$

For closed system: $Q - W = \Delta U + \Delta KE + \Delta PE$

For control volume at steady flow condition:

$$\dot{Q} - \dot{W} = \dot{m}(h_2 - h_1) + \dot{m}\left(\frac{V_2^2 - V_1^2}{2}\right) + \dot{m}g\,(z_2 - z_1)$$

NB: Heat supplied to the system and work done by the system are considered positive

For systems with ΔKE=0, ΔPE=0,

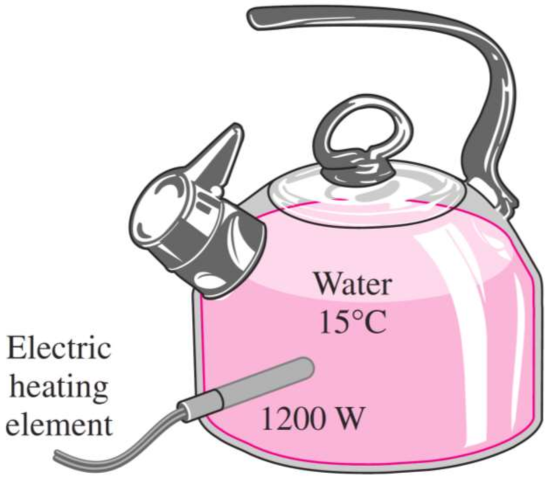
$$Q - W = m\,c_v(T_2 - T_1) \quad \dots\dots \textit{ For Closed system}$$

$$\dot{Q} - \dot{W} = \dot{m}\,c_p(T_2 - T_1) \quad \dots\dots \textit{ For Open system}$$

4.1 Introduction to Heat Transfer

EP#1.1: Heating of Water in an Electric Teapot

1.2 kg of liquid water initially at 15°C is to be heated to 95°C in a teapot equipped with a 1200-W electric heating element inside. The teapot is 0.5 kg and has an average specific heat of 0.7 kJ/kg°C. Taking the specific heat of water to be 4.18 kJ/kg°C and disregarding any heat loss from the teapot, determine how long it will take for the water to be heated.



4.1 Introduction to Heat Transfer

Next Class:

4.1.4 Modes of Hear Transfer