University of Anbar

Engineering Thermodynamics
CHE 215

Lecture # 04

Energy, Energy Transfer, and General Energy Analysis

Objectives of Lecture Note

- Define the concept of heat, work the terminology associated with energy transfer by heat and work.

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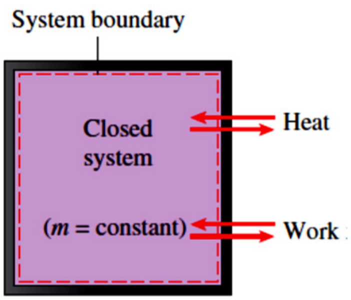
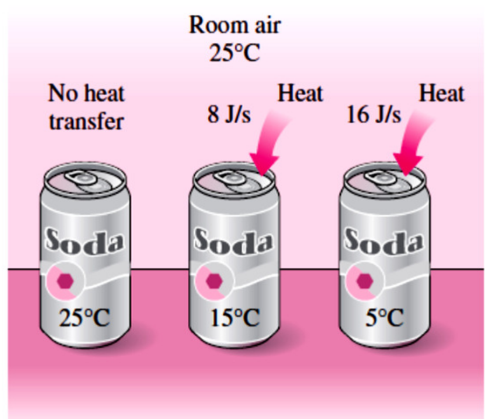
Energy Transfer By Heat

Heat: The form of energy that is transferred between two systems (or a system and its surroundings) by virtue of a *temperature difference*.



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.

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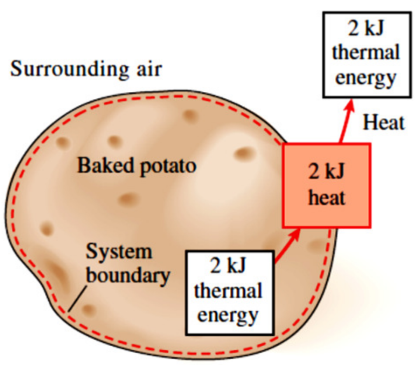
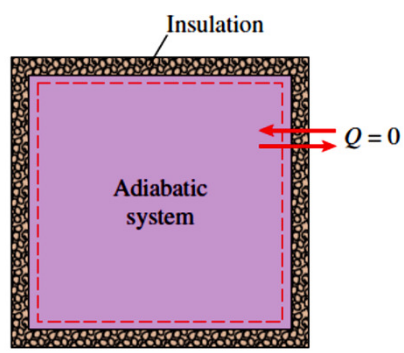


Energy is recognized as heat transfer only as it crosses the ***system boundary***.

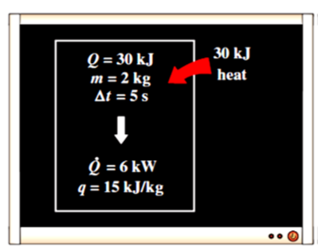


During an adiabatic process, a system exchanges **no heat** with its surroundings.

$$q = \frac{Q}{m} \qquad (\mathrm{kJ/kg})$$ Heat transfer per unit mass

$$Q = \dot{Q}\Delta t \qquad (\mathrm{kJ})$$ Amount of heat transfer when heat transfer rate is constant

$$Q = \int_{t_1}^{t_2} \dot{Q}\, dt \qquad (\mathrm{kJ})$$ Amount of heat transfer when heat transfer rate changes with time



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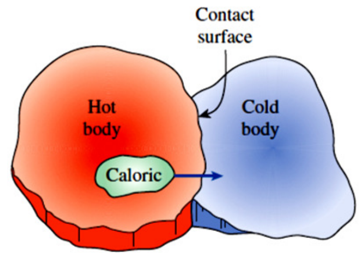
Historical Background on Heat

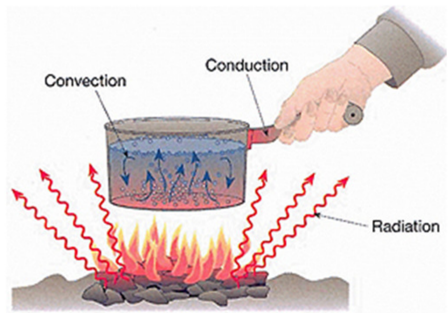
- **Kinetic theory:** Treats molecules as tiny balls that are in motion and thus possess kinetic energy.
- **Heat:** The energy associated with the random motion of atoms and molecules.

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.



Heat transfer by three mechanisms

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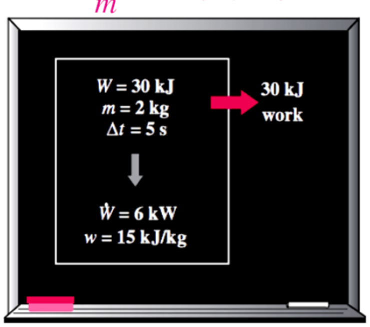
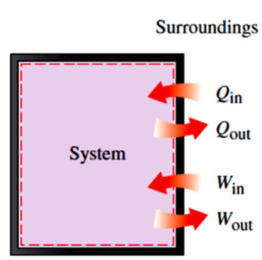
Energy Transfer By Work

- **Work:** The energy transfer associated with a force acting through a distance.
  - A rising piston, a rotating shaft, and an electric wire crossing the system boundaries are all associated with work interactions
- **Formal sign convention:** *Heat transfer to a system and work done by a system are positive; heat transfer from a system and work done on a system are negative*.
- Alternative to sign convention is to use the subscripts *in* and *out* to indicate direction. This is the primary approach in this text.

$$w = \frac{W}{m} \quad (\text{kJ/kg})$$ Work done per unit mass



Power is the work done per unit time (kW)



Specifying the directions of heat and work.

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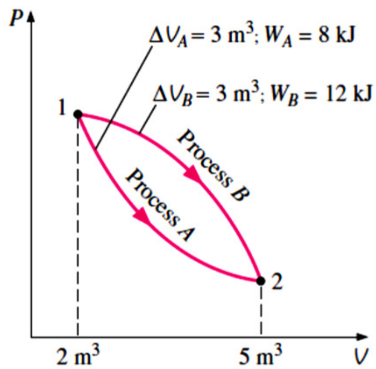
Heat vs. Work

1. **Both are recognized at the boundaries of a system as they cross the boundaries. That is, both heat and work are *boundary* phenomena.**
2. **Systems possess energy, but not heat or work.**
3. **Both are associated with a *process*, not a state. Unlike properties, heat or work has no meaning at a state.**
4. **Both are *path functions* (i.e., their magnitudes depend on the path followed during a process as well as the end states).**



Properties are point functions; but heat and work are path functions (their magnitudes depend on the path followed).

Properties are point functions have exact differentials (d).

$$\int_1^2 dV = V_2 - V_1 = \Delta V$$

Path functions have inexact differentials (δ)

$$\int_1^2 \delta W = W_{12} \qquad (not\ \Delta W)$$

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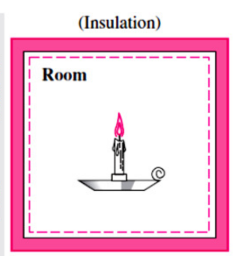
EXAMPLE 2–3 Burning of a Candle in an Insulated Room

A candle is burning in a well-insulated room. Taking the room (the air plus the candle) as the system, determine (*a*) if there is any heat transfer during this burning process and (*b*) if there is any change in the internal energy of the system.

Solution A candle burning in a well-insulated room is considered. It is to be determined whether there is any heat transfer and any change in internal energy.

Analysis (*a*) The interior surfaces of the room form the system boundary, as indicated by the dashed lines in Fig. 2–20. As pointed out earlier, heat is recognized as it crosses the boundaries. Since the room is well insulated, we have an adiabatic system and no heat will pass through the boundaries. Therefore, $Q = 0$ for this process.

(*b*) The internal energy involves energies that exist in various forms (sensible, latent, chemical, nuclear). During the process just described, part of the chemical energy is converted to sensible energy. Since there is no increase or decrease in the total internal energy of the system, $\Delta U = 0$ for this process.



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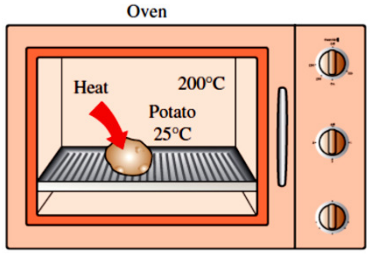
EXAMPLE 2–4 Heating of a Potato in an Oven

A potato initially at room temperature (25°C) is being baked in an oven that is maintained at 200°C, as shown in Fig. 2–21. Is there any heat transfer during this baking process?

Solution A potato is being baked in an oven. It is to be determined whether there is any heat transfer during this process.
Analysis This is not a well-defined problem since the system is not specified. Let us assume that we are observing the potato, which will be our system. Then the skin of the potato can be viewed as the system boundary. Part of the energy in the oven will pass through the skin to the potato. Since the driving force for this energy transfer is a temperature difference, this is a heat transfer process.



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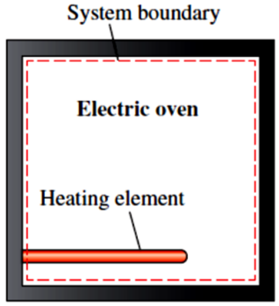
EXAMPLE 2–5 Heating of an Oven by Work Transfer

A well-insulated electric oven is being heated through its heating element. If the entire oven, including the heating element, is taken to be the system, determine whether this is a heat or work interaction.
Solution A well-insulated electric oven is being heated by its heating element. It is to be determined whether this is a heat or work interaction.
Analysis For this problem, the interior surfaces of the oven form the system boundary, as shown in Fig. 2–22. The energy content of the oven obviously increases during this process, as evidenced by a rise in temperature. This energy transfer to the oven is not caused by a temperature difference between the oven and the surrounding air. Instead, it is caused by *electrons* crossing the system boundary and thus doing work. Therefore, this is a work interaction.



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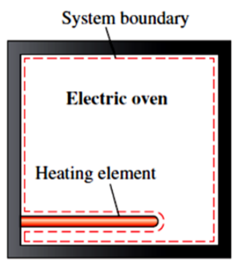
EXAMPLE 2–6 **Heating of an Oven by Heat Transfer**

Answer the question in Example 2–5 if the system is taken as only the air in the oven without the heating element.

Solution The question in Example 2–5 is to be reconsidered by taking the system to be only the air in the oven.

Analysis This time, the system boundary will include the outer surface of the heating element and will not cut through it, as shown in Fig. 2–23. Therefore, no electrons will be crossing the system boundary at any point. Instead, the energy generated in the interior of the heating element will be transferred to the air around it as a result of the temperature difference between the heating element and the air in the oven. Therefore, this is a heat transfer process.

Discussion For both cases, the amount of energy transfer to the air is the same. These two examples show that an energy transfer can be heat or work, depending on how the system is selected.



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