Thermodynamics: An Engineering Approach, 7th Edition
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Chapter 2
ENERGY, ENERGY TRANSFER, AND GENERAL ENERGY ANALYSIS

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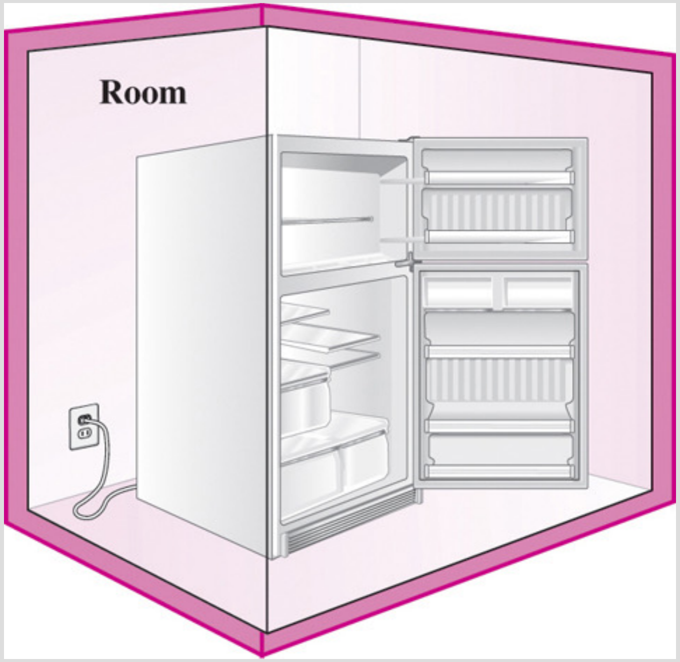
Objectives

- 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.
- Discuss the three mechanisms of heat transfer: conduction, convection, and radiation.
- 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.
- Discuss the implications of energy conversion on the environment.

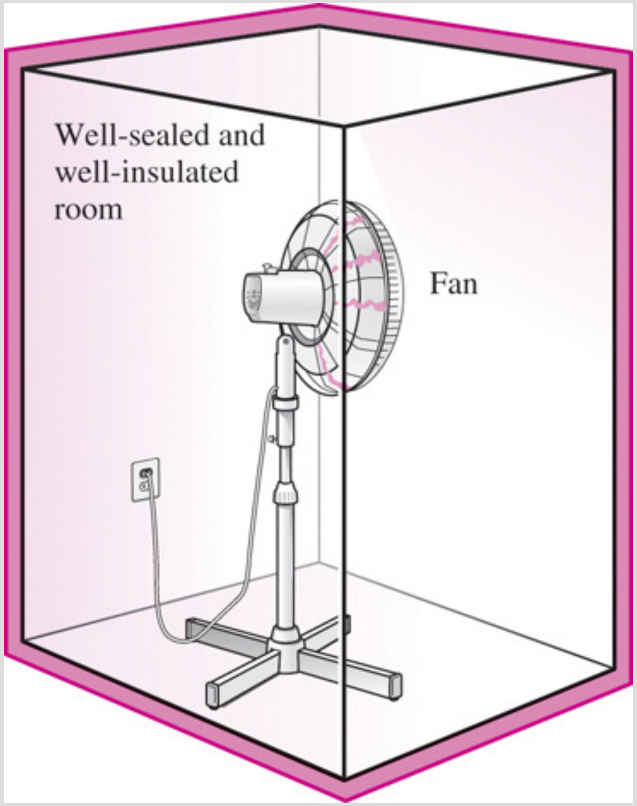
INTRODUCTION

- If we take the entire room—including the air and the refrigerator (or fan)—as the system, which is an adiabatic closed system (heat loss or gain through the walls is negligible. since the room is well-sealed and well-insulated, the only energy interaction involved is the electrical energy crossing the system boundary and entering the room.
- As a result of the conversion of electric energy consumed by the device to heat, **the room temperature will rise**.



A fan running in a well-sealed and well-insulated room will raise the temperature of air in the room.

A refrigerator operating with its door open in a well-sealed and well-insulated room



If we consider a refrigerator with its door open in a well-sealed and well-insulated room (an adiabatic closed system), the analysis of energy interactions within the system would focus on the electrical energy input and its conversion to heat. Here's how this situation can be understood:

System Definition

•**Adiabatic System**: No heat exchange occurs between the room and its external environment. The room is perfectly insulated.

•**Closed System**: No mass enters or leaves the system. The room is sealed.

•**Energy Interaction**: The only energy interaction is electrical energy crossing the system boundary to power the refrigerator.

Energy Interactions

1. **Electrical Energy Input**:
    1. The refrigerator draws electrical energy from an external power source. This energy crosses the system boundary as electrical work.

2. **Operation of the Refrigerator**:
    1. **Compressor Work**: The refrigerator's compressor uses electrical energy to perform work on the refrigerant, compressing it and increasing its temperature.
    2. **Evaporator and Condenser Functioning**:
        1. With the door open, the evaporator coil inside the refrigerator continuously absorbs heat from the room air (which now mixes freely with the air inside the refrigerator compartment).
        2. The condenser coil releases this heat, along with the additional heat generated by the compressor's work, back into the room air.

Implications

1.Energy Conversion:

1. The electrical energy entering the system is converted into mechanical work by the refrigerator’s compressor.
2. This mechanical work is used to circulate the refrigerant, causing it to absorb heat from the evaporator coil and reject it at the condenser coil.

2. Heat Addition to the Room:

1. The refrigerator absorbs heat from the room air at the evaporator and releases it at the condenser. With the door open, the heat absorbed at the evaporator is taken from the same air that the condenser releases the heat into.
2. Additionally, the work done by the compressor results in more heat being generated and released into the room.

3. Overall Heat Effect:

1. Since the system is adiabatic, no heat leaves the room. All the electrical energy input is eventually converted into heat.

2. The heat released into the room by the refrigerator’s condenser (which includes both the heat absorbed by the evaporator and the heat generated by the compressor’s work) increases the room’s internal energy.

Conclusion

In an adiabatic closed system where the room is well-sealed and well-insulated, and the refrigerator door is open, the electrical energy used by the refrigerator is converted into thermal energy. This thermal energy is released back into the room by the refrigerator's condenser. Consequently, the net effect is an increase in the room's temperature over time. This increase happens because the refrigerator, with its door open, cannot remove heat from the room without simultaneously adding a greater amount of heat back into it due to the inefficiency of the refrigeration cycle and the additional heat generated by the compressor's work.

FORMS OF ENERGY

- Energy can exist in numerous forms such as thermal, mechanical, kinetic, potential, electric, magnetic, chemical, and nuclear, and their sum constitutes the **total energy, *E*** of a system.
- Thermodynamics deals only with the ***change*** of the total energy.
- **Macroscopic forms of energy**: Those a system possesses as a whole with respect to some outside reference frame, such as kinetic and potential energies.
- **Microscopic forms of energy**: Those related to the molecular structure of a system and the degree of the molecular activity.
- **Internal energy, *U***: The sum of all the microscopic forms of energy.

- **Kinetic energy, KE**: The energy that a system possesses as a result of its motion relative to some reference frame.
- **Potential energy, PE:** The energy that a system possesses as a result of its elevation in a gravitational field.

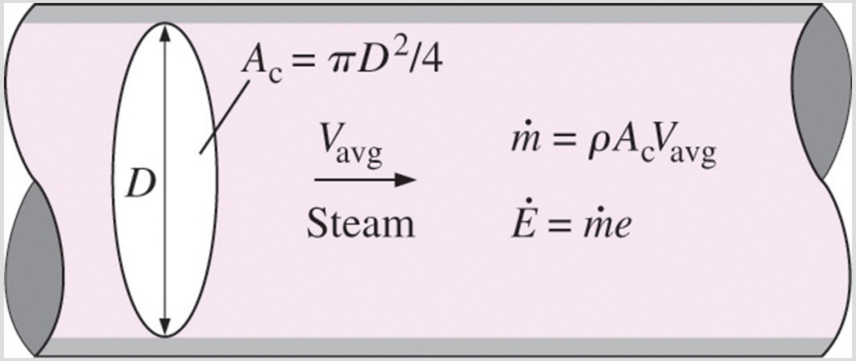
The macroscopic energy of an object changes with velocity and elevation.

$$KE = m\frac{V^2}{2} \quad (kJ)$$
Kinetic energy

$$ke = \frac{V^2}{2} \quad (kJ/kg)$$
Kinetic energy per unit mass

$$PE = mgz \quad (kJ)$$
Potential energy

$$pe = gz \quad (kJ/kg)$$
Potential energy per unit mass



Mass flow rate

$$\dot{m} = \rho \dot{V} = \rho A_c V_{avg} \quad (kg/s)$$

Energy flow rate

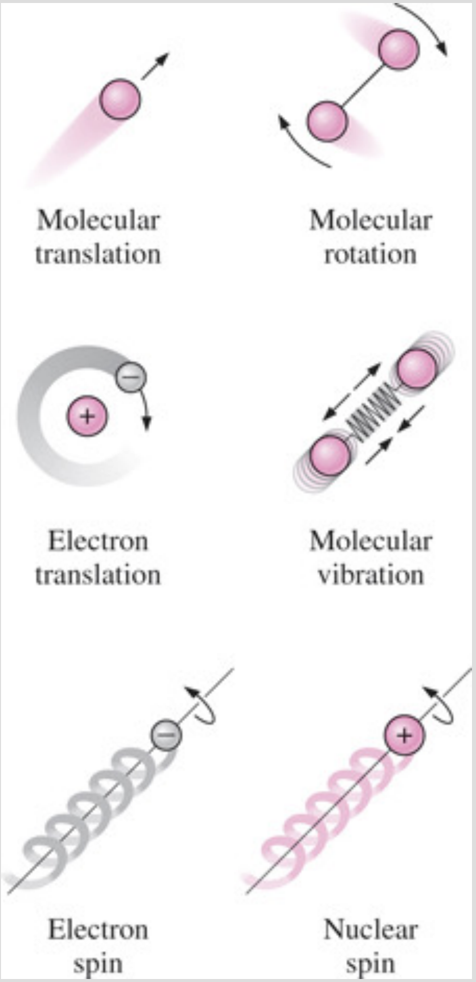
$$\dot{E} = \dot{m}e \quad (kJ/s \text{ or } kW)$$

$$E = U + KE + PE = U + m\frac{V^2}{2} + mgz \quad (kJ)$$
Total energy of a system

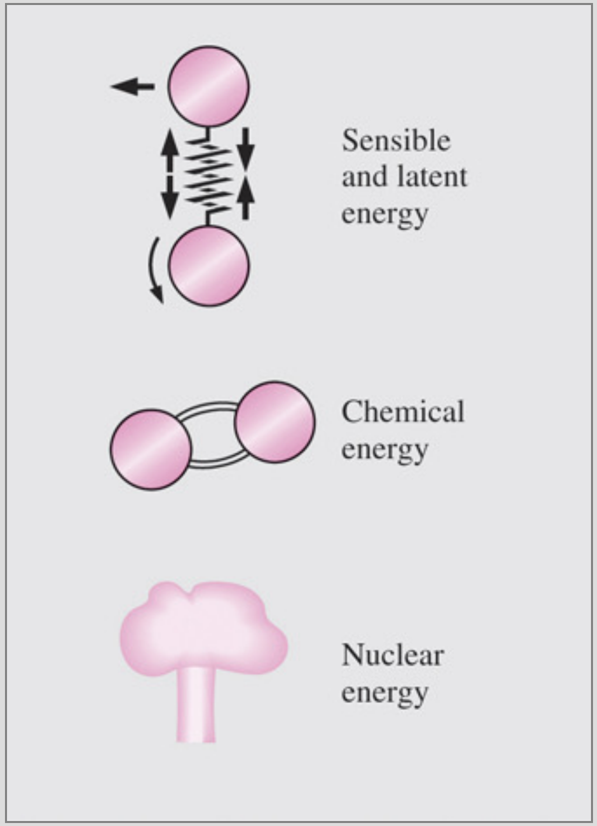
$$e = u + ke + pe = u + \frac{V^2}{2} + gz \quad (kJ/kg)$$
Energy of a system per unit mass

$$e = \frac{E}{m} \quad (kJ/kg)$$
Total energy per unit mass

Some Physical Insight to Internal Energy



The various forms of microscopic energies that make up *sensible* energy.



The internal energy of a system is the sum of all forms of the microscopic energies.

Sensible energy: The portion of the internal energy of a system associated with the kinetic energies of the molecules.

Latent energy: The internal energy associated with the phase of a system.

Chemical energy: The internal energy associated with the atomic bonds in a molecule.

Nuclear energy: The tremendous amount of energy associated with the strong bonds within the nucleus of the atom itself.

Thermal = Sensible + Latent

Internal = Sensible + Latent + Chemical + Nuclear