

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

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

$$\text{PE} = mgz \quad (\text{kJ}) \quad \text{Potential energy}$$

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

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

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

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

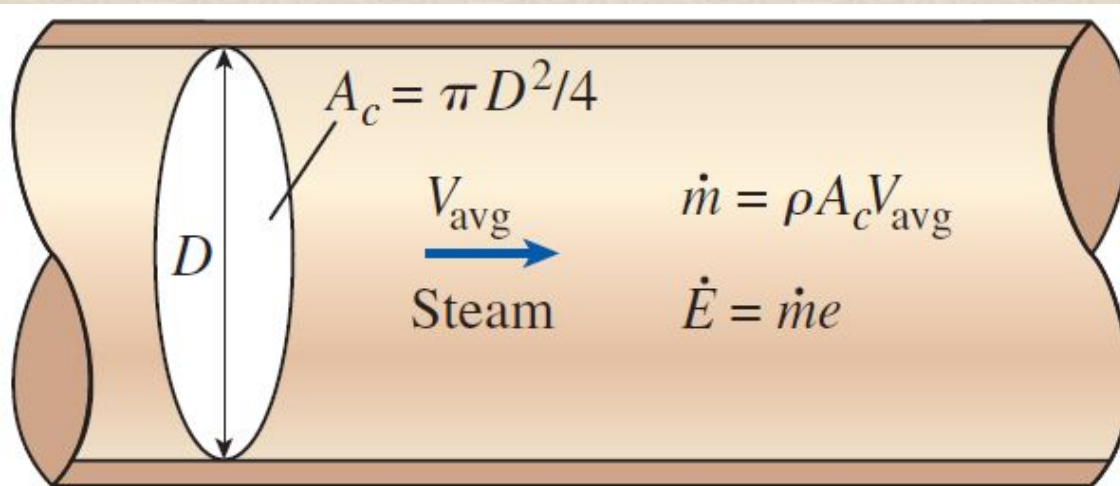


FIGURE 2–5

Mass and energy flow rates associated with the flow of steam in a pipe of inner diameter D with an average velocity of V_{avg} .

Mass flow rate: $\dot{m} = \rho \dot{V} = \rho A_c V_{\text{avg}} \quad (\text{kg/s})$

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

Some Physical Insight to Internal Energy

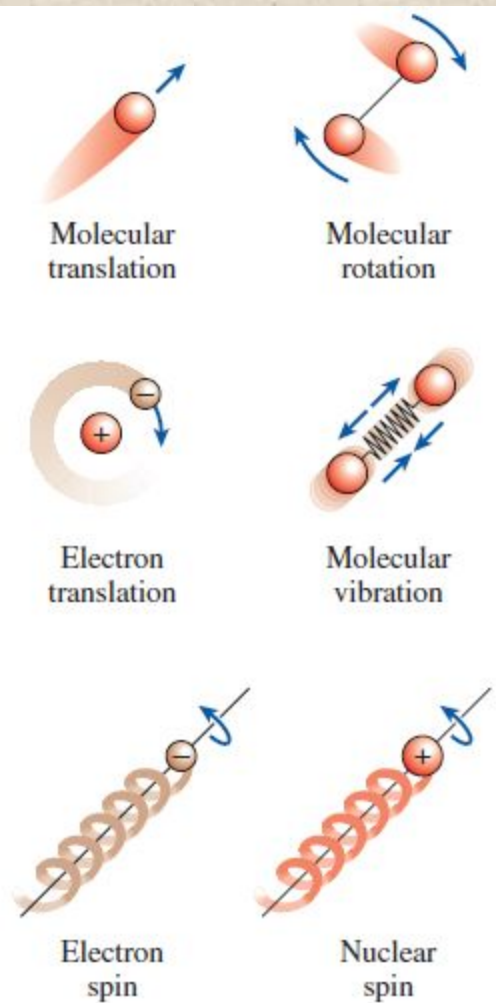


FIGURE 2-6

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

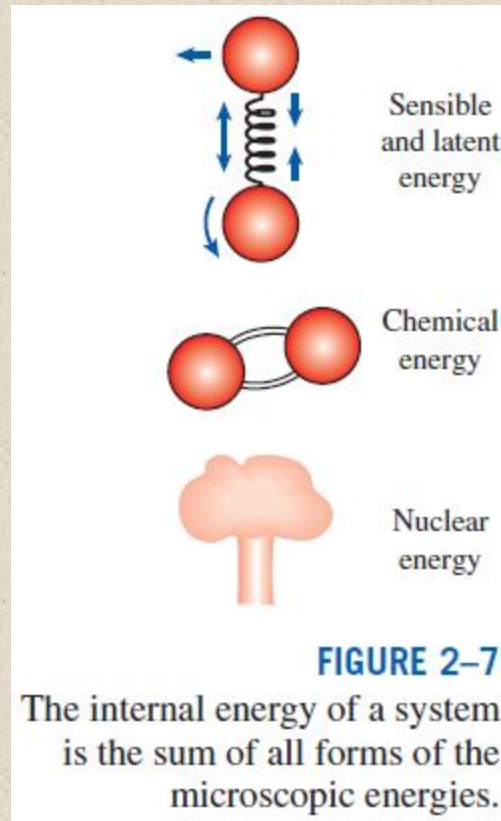


FIGURE 2-7

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

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

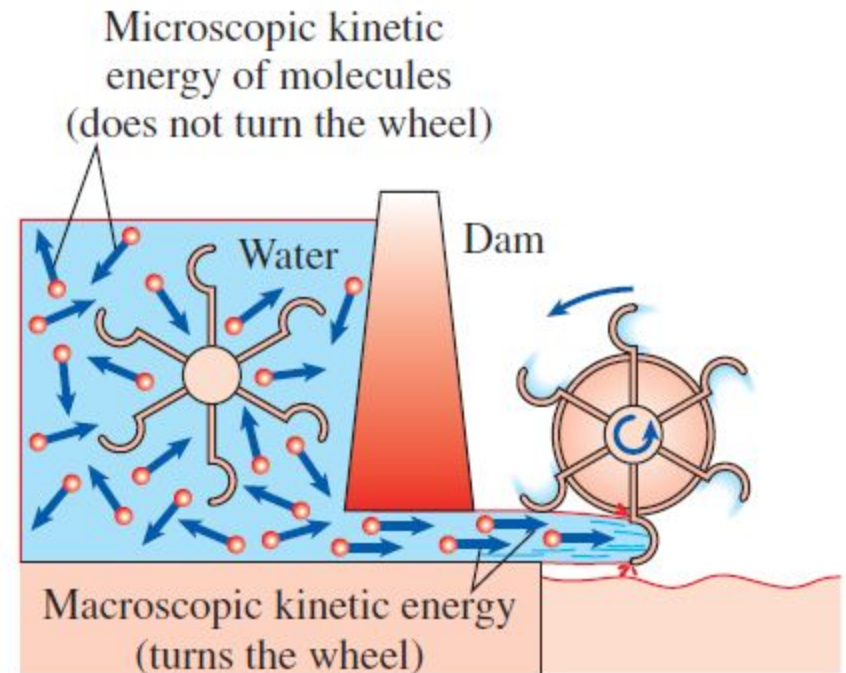


FIGURE 2-8

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

More on Nuclear Energy

- The best known **fission** reaction involves the split of the uranium atom (the U-235 isotope) into other elements and is commonly used to generate electricity in nuclear power plants (440 of them in 2004, generating 363,000 MW worldwide), to power nuclear submarines and aircraft carriers, and even to power spacecraft as well as building nuclear bombs.
- Nuclear energy by **fusion** is released when two small nuclei combine into a larger one.
- The uncontrolled fusion reaction was achieved in the early 1950s, but all the efforts since then to achieve controlled fusion by massive lasers, powerful magnetic fields, and electric currents to generate power have failed.

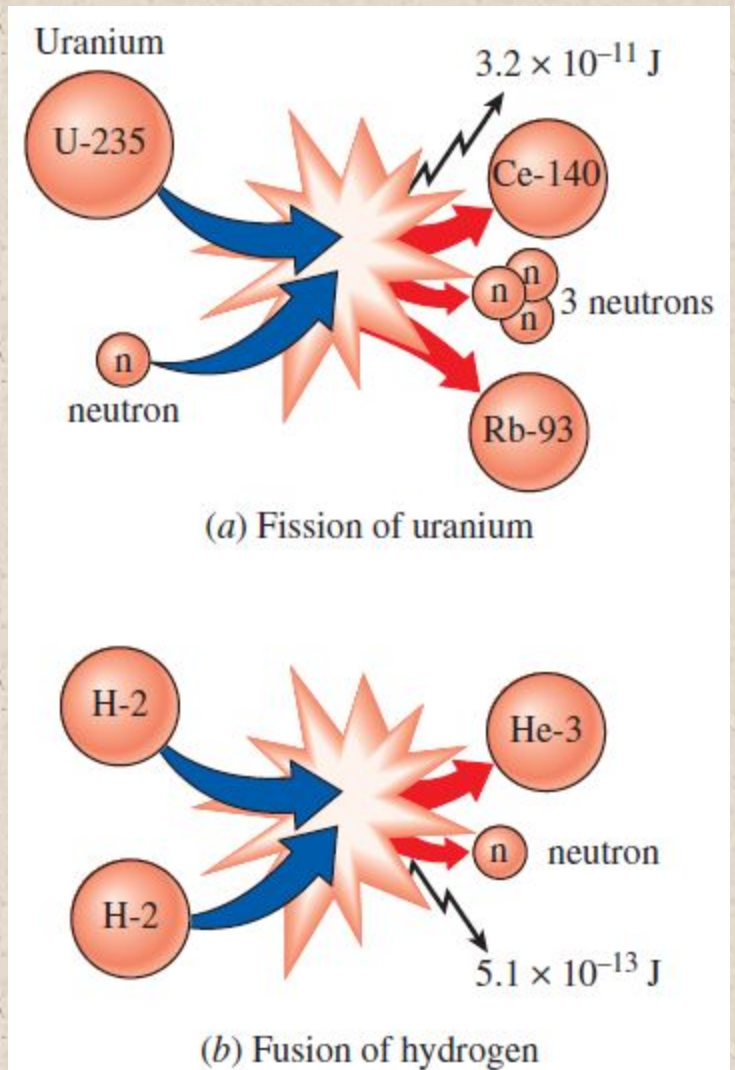


FIGURE 2-9

The fission of uranium and the fusion of hydrogen during nuclear reactions, and the release of nuclear energy.

Mechanical Energy

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

Kinetic and potential energies: The familiar forms of mechanical energy.

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

Mechanical energy of a flowing fluid per unit mass

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

Rate of mechanical energy of a flowing fluid

Mechanical energy change of a fluid during incompressible flow per unit mass

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

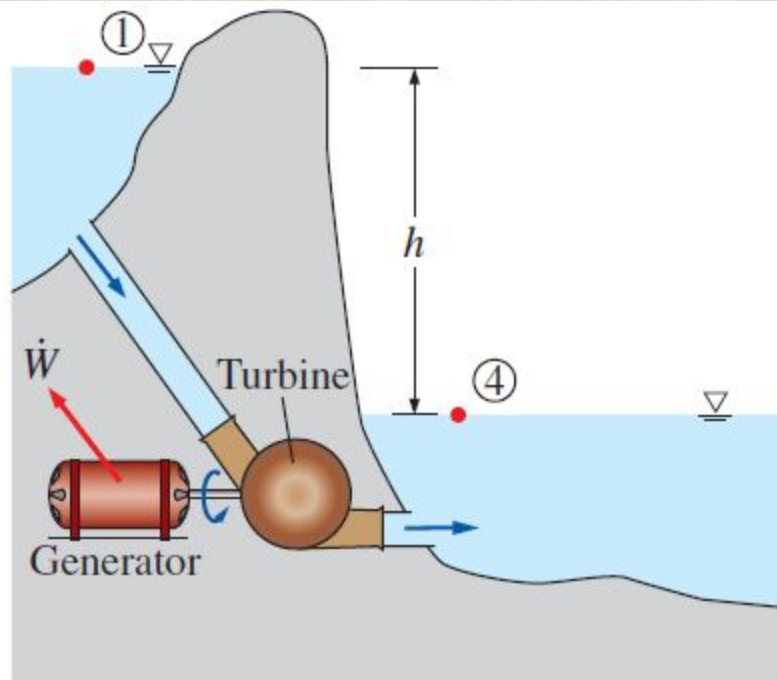
Rate of mechanical energy change of a fluid during incompressible flow

$$\Delta \dot{E}_{\text{mech}} = \dot{m}\Delta e_{\text{mech}} = \dot{m}\left(\frac{P_2 - P_1}{\rho} + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right) \quad (\text{kW})$$



FIGURE 2–11

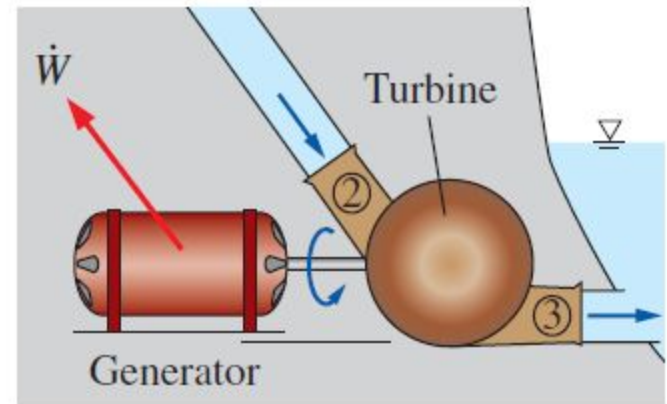
Mechanical energy is a useful concept for flows that do not involve significant heat transfer or energy conversion, such as the flow of gasoline from an underground tank into a car.



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

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

(a)



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

since $V_2 \approx V_3$ and $z_2 = z_3$

(b)

FIGURE 2–12

Mechanical energy is illustrated by an ideal hydraulic turbine coupled with an ideal generator. In the absence of irreversible losses, the maximum produced power is proportional to (a) the change in water surface elevation from the upstream to the downstream reservoir or (b) close-up view the drop in water pressure from just upstream to just downstream of the turbine.

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.

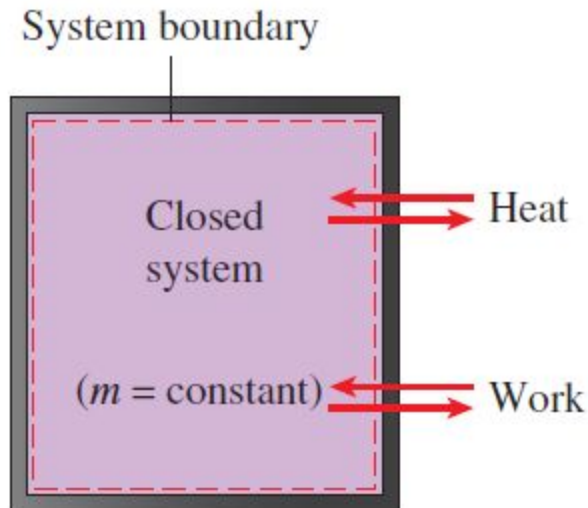


FIGURE 2-14

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

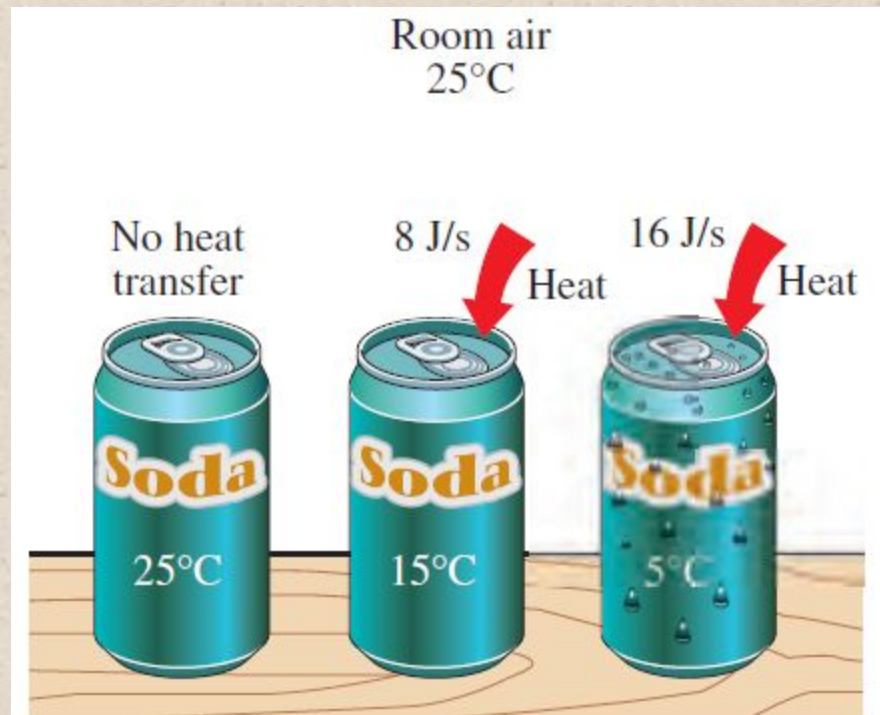


FIGURE 2-15

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

$$q = \frac{Q}{m} \quad (\text{kJ/kg})$$

Heat transfer
per unit mass

$$Q = \dot{Q} \Delta t \quad (\text{kJ})$$

Amount of heat transfer
when heat transfer rate
is constant

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

Amount of heat transfer
when heat transfer rate
changes with time

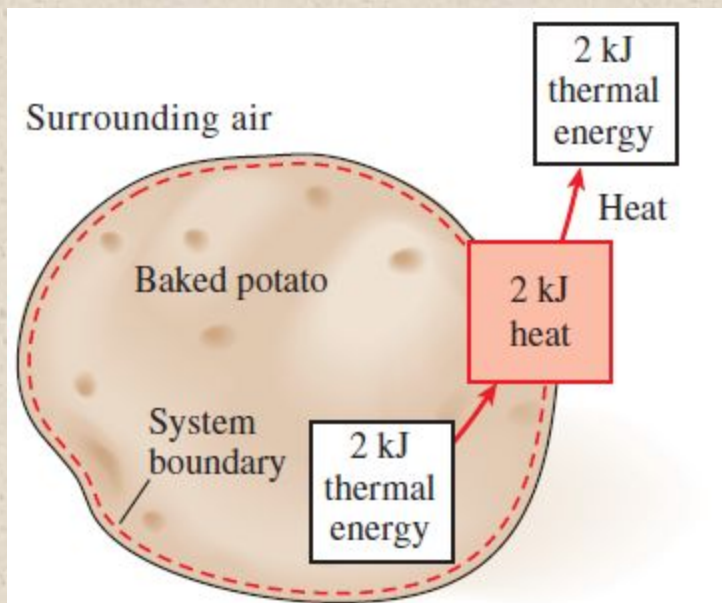


FIGURE 2-16

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

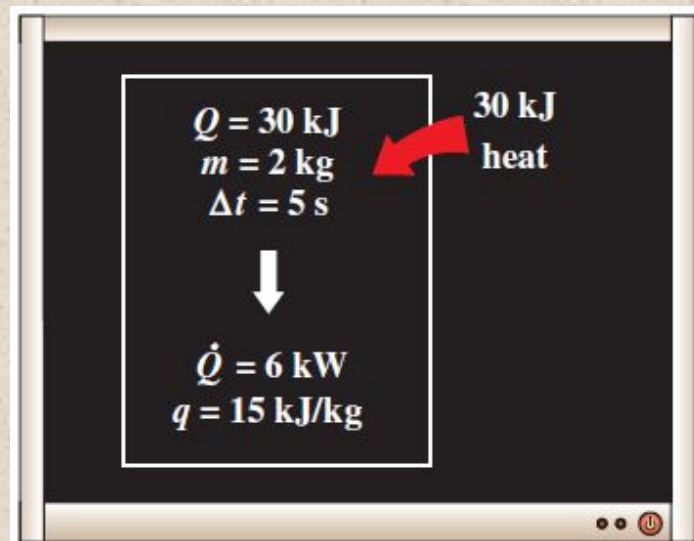


FIGURE 2-18

The relationships among q , Q , and \dot{Q} .

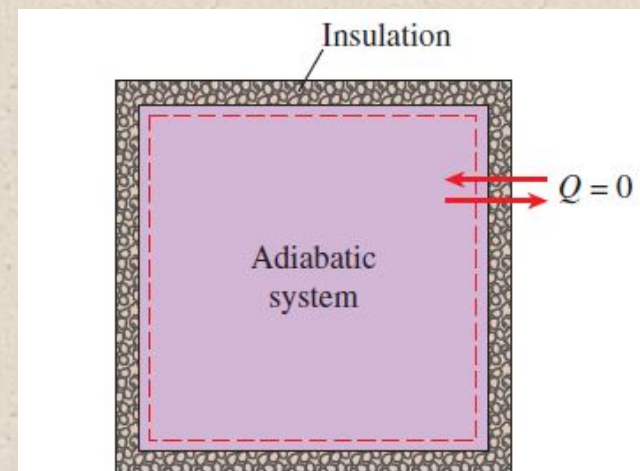


FIGURE 2-17

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

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).

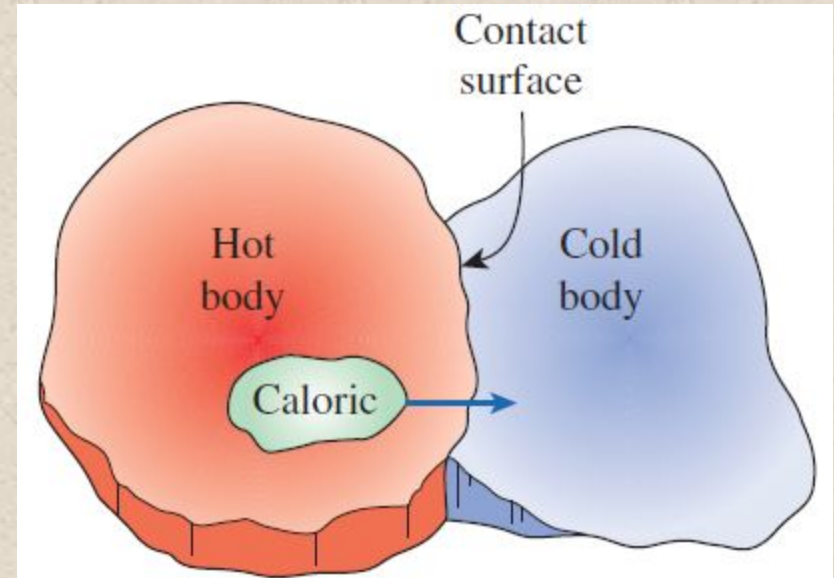


FIGURE 2-19

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.

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.**

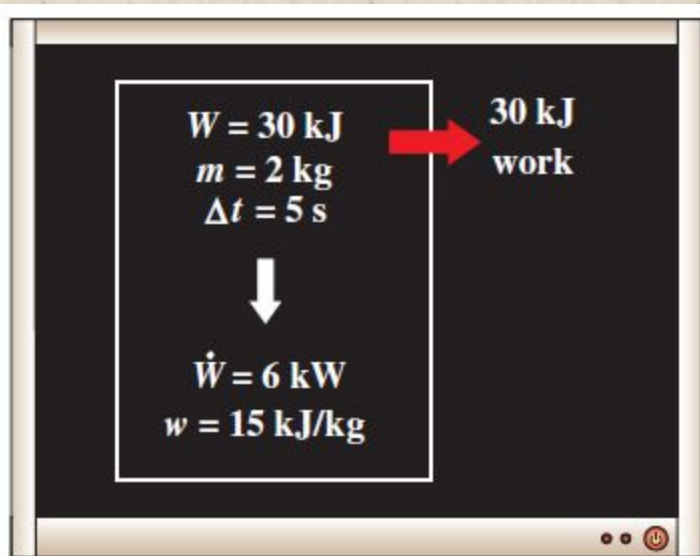


FIGURE 2-20

The relationships among w , W , and \dot{W} .

Work done per
unit mass

$$w = \frac{W}{m} \quad (\text{kJ/kg})$$

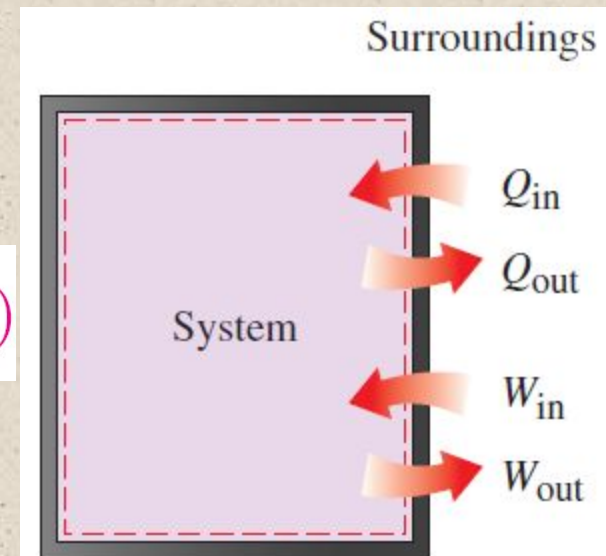


FIGURE 2-21

Specifying the directions
of heat and work.