Ch. 18: The Laws of Thermodynamics

Sec 18-2: The First Law of Thermodynamics

The internal energy, *U*, of a thermodynamic system is the sum of all kinetic and potential energies of all the particles.

Consider adding heat to a gas in a sealed, rigid container. The gas cannot expand, so all the heat added must go into increasing the internal energy.

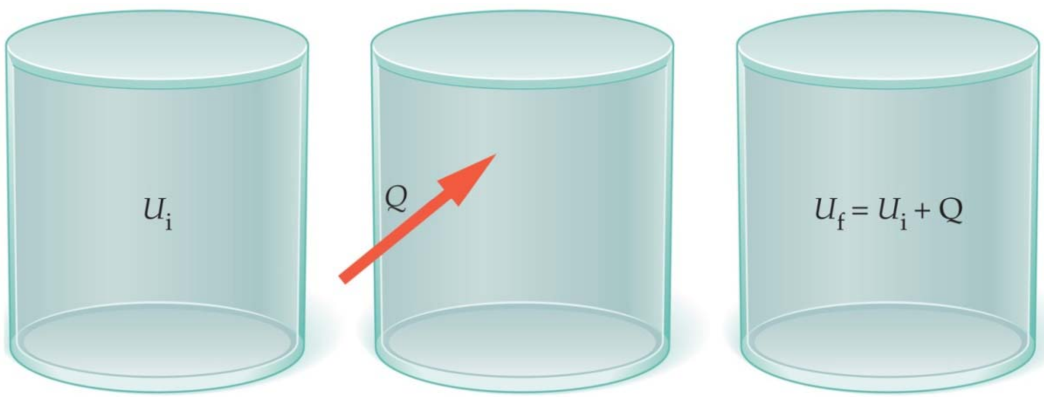
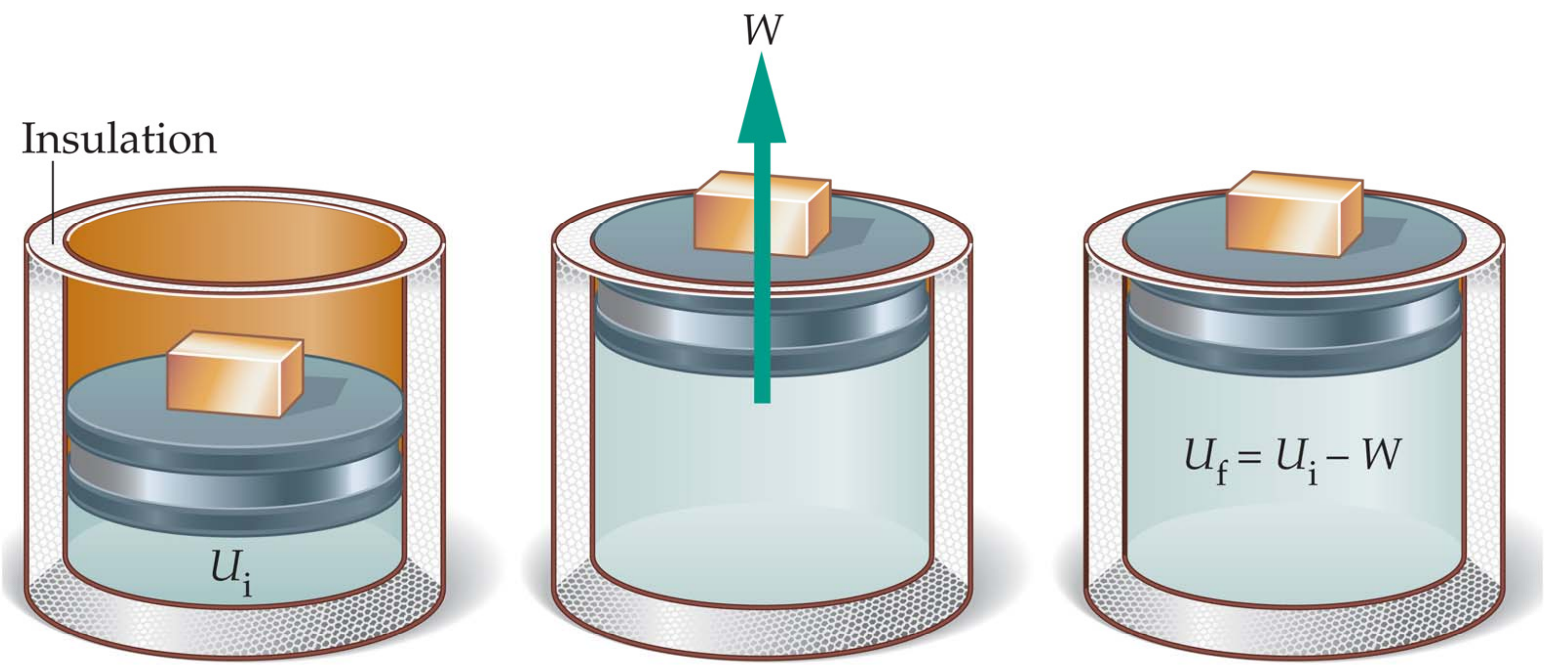


Fig. 18-1: The Internal Energy of a System

Now consider allowing a hot gas in an insulated container to expand against a piston, doing work on its surroundings. If the container is insulated, no heat *Q* is supplied, so the work done must come at the expense of some internal energy.

Fig. 18-2: Work and Internal Energy



If heat is exchanged *and* work is done, then:

$$\Delta U = Q - W$$

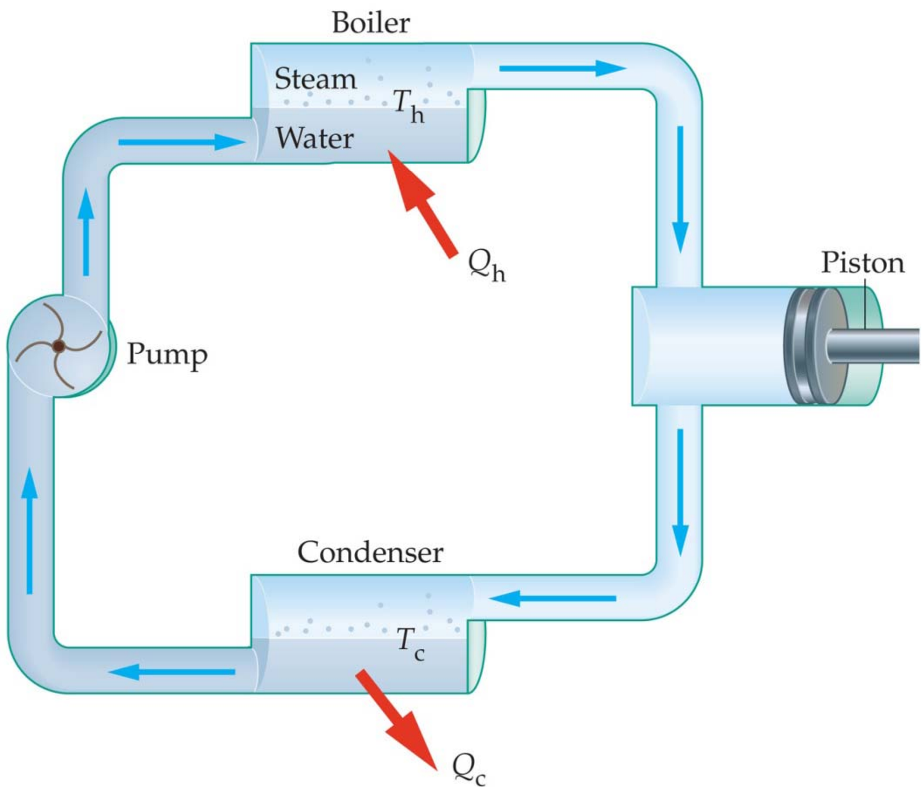
This is called the first law of thermodynamics. It is really just energy conservation, extended to include this new kind of energy called internal energy.

Sec 18-5: The Second Law of Thermodynamics

When objects of different temperatures are brought into thermal contact, the spontaneous flow of heat that results is always from the high-temperature object to the low-temperature object. *Spontaneous* heat flow never proceeds in the reverse direction.

Sec 18-6: Heat Engines and the Carnot Cycle

Fig. 18-15: A schematic steam engine



$$\Delta U = 0$$

$$Q - W = 0$$

$$(Q_h - Q_c) - W = 0$$

$$W = Q_h - Q_c$$

Efficiency of a Heat Engine

$$e \equiv \frac{W}{Q_h}$$

$$e = \frac{Q_h - Q_c}{Q_h}$$

$$e = 1 - \frac{Q_c}{Q_h}$$

Carnot's Theorem: If an engine operating between two constant-temperature reservoirs is to have maximum efficiency, it must be an engine in which all processes are *reversible*.

In addition, *all* reversible engines operating between the same two temperatures, T_c and T_h, have the same efficiency.

Since the efficiency depends only on the temperatures T_c and T_h, Kelvin proposed defining a temperature scale so that:

$$\frac{Q_c}{Q_h} = \frac{T_c}{T_h}$$

This is the kelvin scale. So if the temperatures are expressed in kelvins, the efficiency of a *reversible* engine, called a *Carnot engine*, would be:

$$e_{\max} = 1 - \frac{T_c}{T_h}$$

This is the maximum efficiency a heat engine can have.

The Second Law of Thermodynamics

Kelvin-Planck Statement ("engine" statement): It is impossible for any system to undergo a process in which it absorbs heat from a reservoir at a single temperature and converts the heat completely into mechanical work, with the system ending in the same state in which it began.

Clausius Statement ("refrigerator" statement): It is impossible for any process to have as its sole result the transfer of heat from a cooler body to a hotter body.