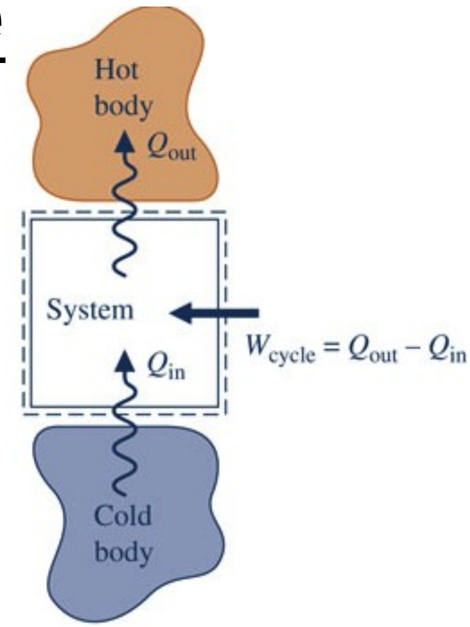
Chapter 2

Energy and the
First Law of Thermodynamics
Continued-5

Refrigeration Cycle

►A system undergoing a refrigeration cycle is shown at right.



Refrigeration Cycle

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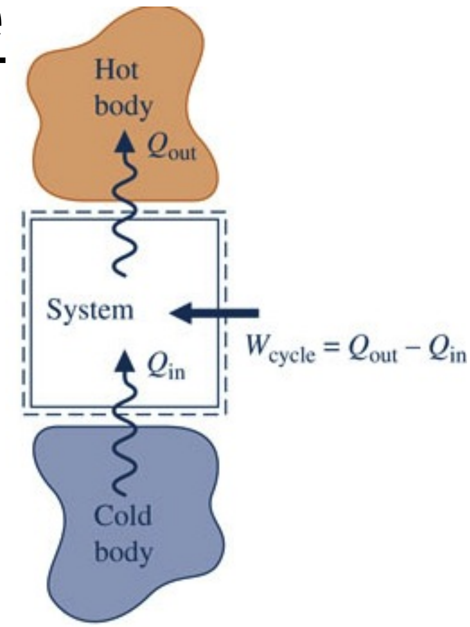
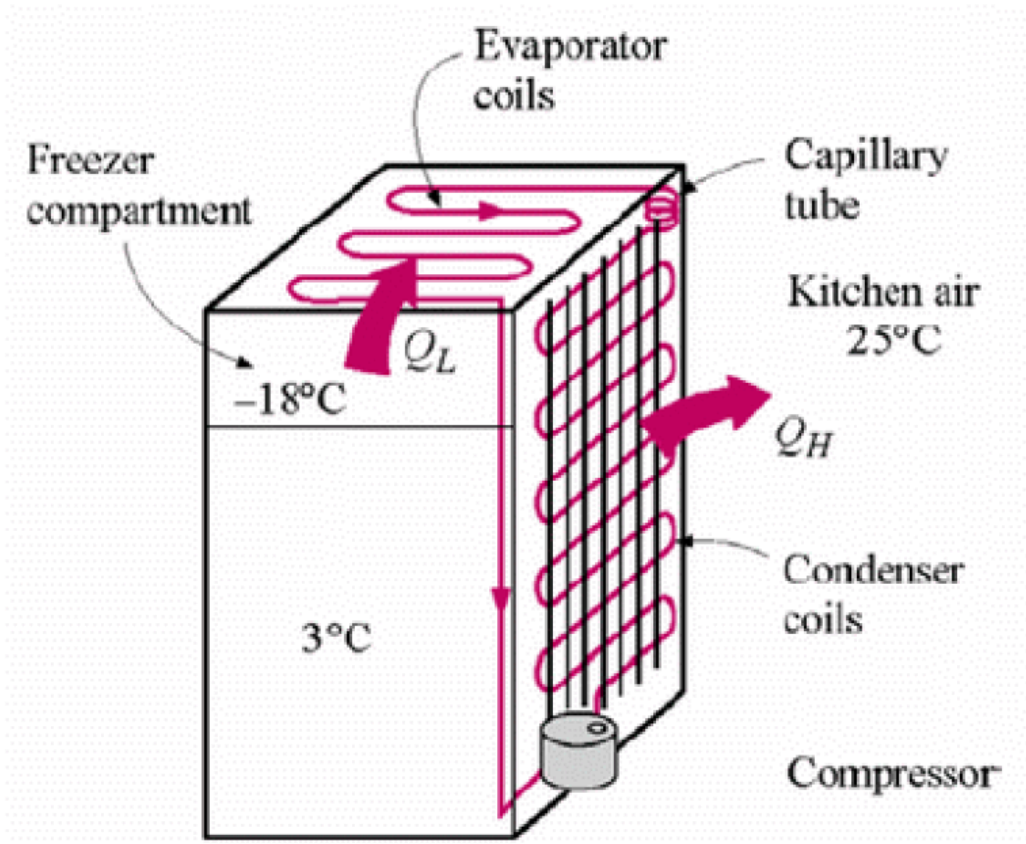
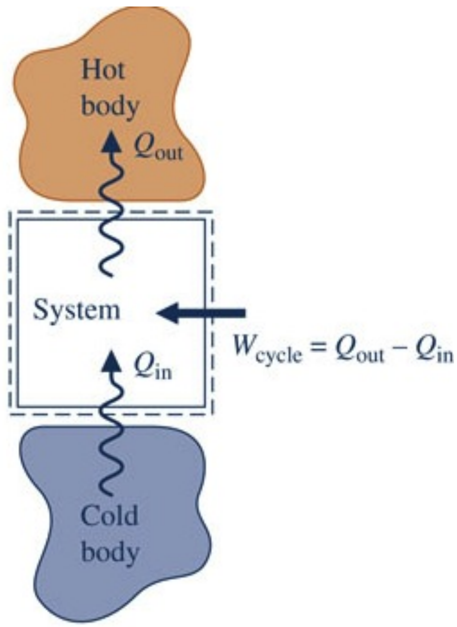




Refrigeration Cycle



► A system undergoing a refrigeration cycle is shown at right.

► As before, the energy transfers are each positive in the direction of the accompanying arrow.

- ► W_{cycle} is the **net energy transfer by work** to the system per cycle of operation, usually in the form of electricity.
- ► Q_{in} is the **heat transfer of energy to the system** per cycle from the cold body – drawn from a freezer compartment, for example.
- ► Q_{out} is the **heat transfer of energy from the system** per cycle to the hot body – discharged to the space surrounding the refrigerator, for instance.

Refrigeration Cycle

►Since the system returns to its initial state after each cycle, there is no net change in its energy: $\boldsymbol{\Delta E_{\text{cycle}} = 0}$, and the energy balance reduces to give

$$W_{\text{cycle}} = Q_{\text{out}} - Q_{\text{in}} \qquad \textbf{(Eq. 2.44)}$$

►In words, the ***net*** energy transfer by work to the system equals the ***net*** energy transfer by heat from the system, each per cycle of operation.

Refrigeration Cycle

► The performance of a system undergoing a refrigeration cycle is evaluated on an energy basis as the ratio of energy drawn from the cold body, Q_{in}, to the net work required to accomplish this effect, W_{cycle}:

$$\beta = \frac{Q_{\text{in}}}{W_{\text{cycle}}} \quad \text{(refrigeration cycle)} \qquad \textbf{(Eq. 2.45)}$$

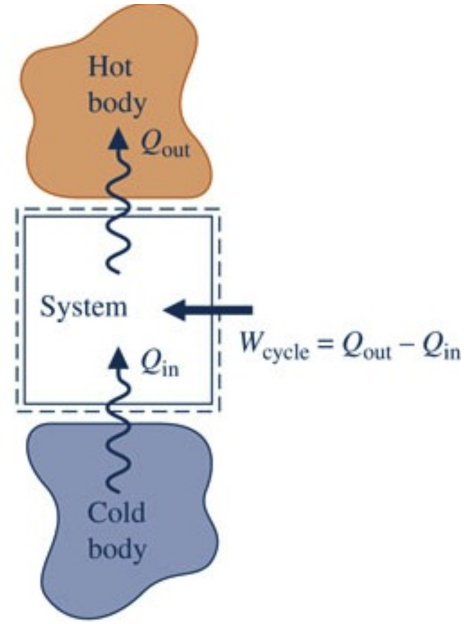
called the coefficient of performance for the refrigeration cycle.

► Introducing **Eq. 2.44**, an alternative form is obtained

$$\beta = \frac{Q_{\text{in}}}{Q_{\text{out}} - Q_{\text{in}}} \quad \text{(refrigeration cycle)} \qquad \textbf{(Eq. 2.46)}$$

Heat Pump Cycle

► The heat pump cycle analysis closely parallels that given for the refrigeration cycle. The same figure applies:



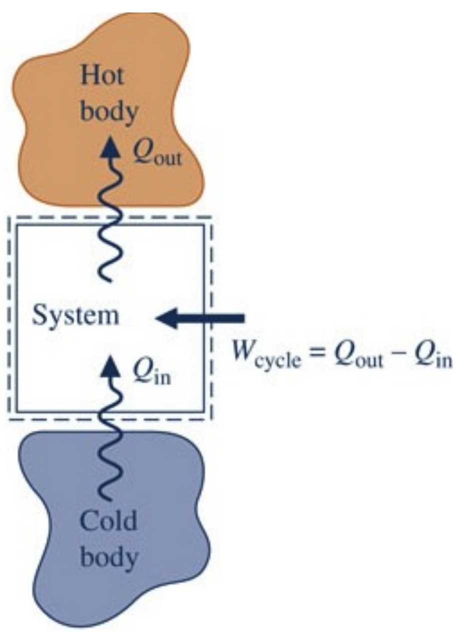
► But now the focus is on Q_{out}, which is the **heat transfer of energy from the system** per cycle to the hot body – such as to the living space of a dwelling.

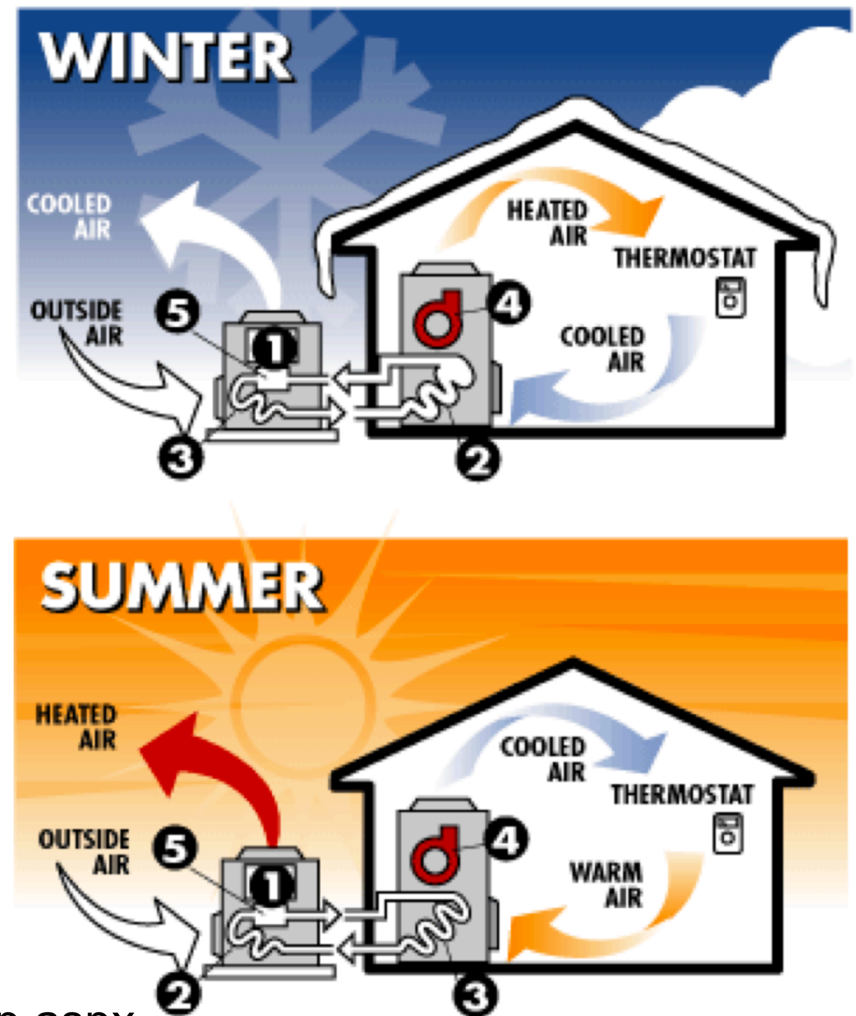
► Q_{in} is the **heat transfer of energy to the system** per cycle from the cold body – drawn from the surrounding atmosphere or the ground, for example.

Heat Pump Cycle

► The heat pump cycle analysis closely parallels that given for the refrigeration cycle.

The same figure applies:

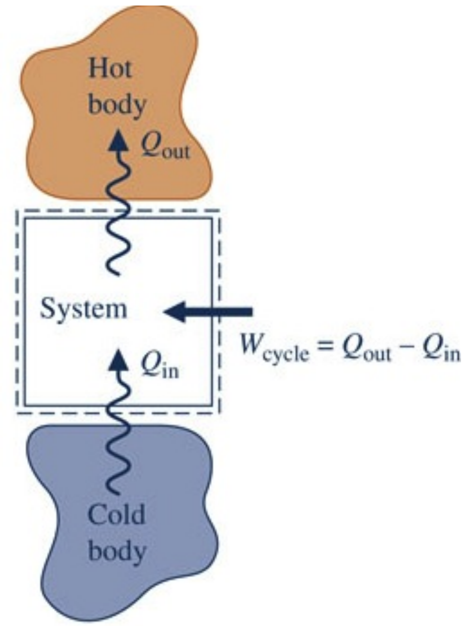




http://www.savewithsrp.com/advice/heatpump.aspx

Heat Pump Cycle

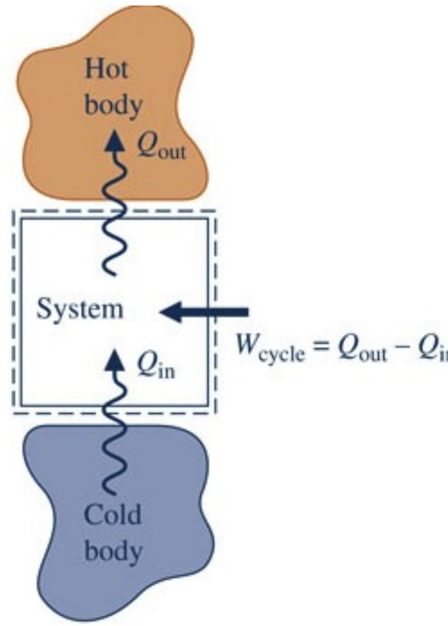
► The heat pump cycle analysis closely parallels that given for the refrigeration cycle. The same figure applies:



- ► But now the focus is on Q_{out}, which is the **heat transfer of energy from the system** per cycle to the hot body – such as to the living space of a dwelling.
- ► Q_{in} is the **heat transfer of energy to the system** per cycle from the cold body – drawn from the surrounding atmosphere or the ground, for example.

Heat Pump Cycle

►As before, W_{cycle} is the **net energy transfer by work** to the system per cycle, usually provided in the form of electricity.



►As for the refrigeration cycle, the energy balance reads

$$W_{cycle} = Q_{out} - Q_{in} \quad \textbf{(Eq. 2.44)}$$

Heat Pump Cycle

► The performance of a system undergoing a heat pump cycle is evaluated on an energy basis as the ratio of energy provided to the hot body, Q_{out}, to the net work required to accomplish this effect, W_{cycle}:

$$\gamma = \frac{Q_{out}}{W_{cycle}} \quad \text{(heat pump cycle)} \qquad \textbf{(Eq. 2.47)}$$

called the coefficient of performance for the heat pump cycle.

► Introducing **Eq. 2.44**, an alternative form is obtained

$$\gamma = \frac{Q_{out}}{Q_{out} - Q_{in}} \quad \text{(heat pump cycle)} \qquad \textbf{(Eq. 2.48)}$$

Heat Pump Cycle

Example: A system undergoes a heat pump cycle while discharging 900 kJ by heat transfer to a dwelling at 20^{o}C and receiving 600 kJ by heat transfer from the outside air at 5^{o}C. Taking the dwelling and outside air as the hot and cold bodies, respectively, determine for the cycle, the net work input, in kJ, and the coefficient of performance.

► Substituting into **Eq. 2.44**, W_{cycle} = **900 kJ – 600 kJ = <u>300 kJ</u>**.

► Then, with **Eq. 2.47**, γ = **900 kJ/300 kJ = <u>3.0</u>**. Note the coefficient of performance is reported as its numerical value, as calculated here.