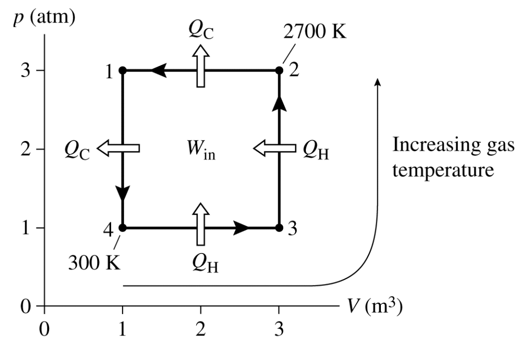
19.64. Model: Processes 2 → 1 and 4 → 3 are isobaric. Processes 3 → 2 and 1 → 4 are isobaric.

Visualize:



Solve: **(a)** Except in an adiabatic process, heat must be transferred into the gas to raise its temperature. Thus heat is transferred in during processes 4 → 3 and 3 → 2. This is the reverse of the heat engine in Example 19.2.

(b) Heat flows from hot to cold. Since heat energy is transferred into the gas during processes 4 → 3 and 3 → 2, which end with the gas at temperature 2700 K, the reservoir temperature must be $T > 2700$ K. This is the hot reservoir, so the heat transferred is Q_H. Similarly, heat energy is transferred out of the gas during processes 2 → 1 and 1 → 4. This requires that the reservoir temperature be $T < 300$ K. This is the cold reservoir, and the energy transferred during these two processes is Q_C.

(c) The heat energies were calculated in Example 19.2, but now they have the opposite signs.

$$Q_H = Q_{43} + Q_{32} = 7.09 \times 10^5 \text{ J} + 15.19 \times 10^5 \text{ J} = 22.28 \times 10^5 \text{ J}$$

$$Q_C = Q_{21} + Q_{14} = 21.27 \times 10^5 \text{ J} + 5.06 \times 10^5 \text{ J} = 26.33 \times 10^5 \text{ J}$$

(d) For a counterclockwise cycle in the pV diagram, the work is W_{in}. Its value is the area inside the curve, which is $W_{in} = (\Delta p)(\Delta V) = (2 \times 101{,}300 \text{ Pa})(2 \text{ m}^3) = 4.05 \times 10^5$ J. Note that $W_{in} = Q_C - Q_H$, as expected from energy conservation.

(e) Since $Q_C > Q_H$, more heat is exhausted to the cold reservoir than is extracted from the hot reservoir. In this device, work is used to transfer energy "downhill," from hot to cold. The exhaust energy is $Q_C = Q_H + W_{in} > Q_H$. This is the energy-transfer diagram of Figure 19.19.

(f) No. A refrigerator uses work input to transfer heat energy from the cold reservoir to the hot reservoir. This device uses work input to transfer heat energy from the hot reservoir to the cold reservoir.