1. The work done *by the system* on the environment is

$$W_{\text{env}} = +P(\Delta V) = \left(70.0\times10^3\ \text{Pa}\right)\left(-0.20\ \text{m}^3\right) = -14\times10^3\ \text{J} = -14\ \text{kJ}$$

and (c) is the correct choice.

2. When volume is constant, the work done on the gas is zero so the first law of thermodynamics gives the change in internal energy as $\Delta U = Q + W = 100\ \text{J} + 0 = 100\ \text{J}$, and (d) is the correct answer for this question.

7. From conservation of energy, the energy input to the engine must be

$$Q_h = W_{\text{eng}} + Q_c = 15\ \text{kJ} + 37\ \text{kJ} = 52\ \text{kJ}$$

so the efficiency is

$$e = \frac{W_{\text{eng}}}{Q_c} = \frac{15\ \text{kJ}}{52\ \text{kJ}} = 0.29 \quad \text{or} \quad 29\%$$

and the correct choice is (b).

8. The coefficient of performance of this refrigerator is

$$\text{COP} = \frac{|Q_c|}{W} = \frac{115\ \text{kJ}}{18\ \text{kJ}} = 6.4 \qquad \text{which is choice (d).}$$

2. Shaking opens up spaces between the jelly beans. The smaller ones have a chance of falling down into spaces below them. The accumulation of larger ones on top and smaller ones on the bottom implies an increase in order and a decrease in one contribution to the total entropy. However, the second law is not violated and the total entropy of the system increases. The increase in the internal energy of the system comes from the work required to shake the jar of beans (that is, work your muscles must do, with an increase in entropy accompanying the biological process) and also from the small loss of gravitational potential energy as the beans settle together more compactly.

4. Temperature = A measure of molecular motion. Heat = the process through which energy is transferred between objects by means of random collisions of molecules. Internal energy = energy associated with random molecular motions plus chemical energy, strain potential energy, and an object's other energy not associated with center of mass motion or location.

12.1 (a) The work done *on the gas* is

$$W = -P(\Delta V) = -(1.50\times10^5\ \text{Pa})(0.250\ \text{m}^2 - 0.750\ \text{m}^2) = \boxed{7.50\times10^4\ \text{J}}$$

(b) The work done by the gas on the environment is

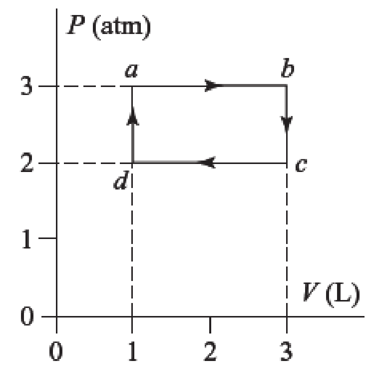
$$W_{\text{env}} = +P(\Delta V) = (1.50\times10^5\ \text{Pa})(0.250\ \text{m}^2 - 0.750\ \text{m}^2) = \boxed{-7.50\times10^4\ \text{J}}$$

(c) The work done on the gas is the negative of the work the gas does on the environment because of **Newton's third law**. When the environment exerts a force on the gas, the gas exerts an equal magnitude force in the opposite direction on the environment.

12.2 (a) $W_{ab} = P_a(V_b - V_a)$

$$= [3(1.013\times10^5\ \text{Pa})](3.0\ \text{L} - 1.0\ \text{L})\left(\frac{10^{-3}\ \text{m}^3}{1\ \text{L}}\right)$$

$$= \boxed{610\ \text{J}}$$



(b) $W_{bc} = P(V_c - V_b) = \boxed{0}$

(c) $W_{cd} = P_c(V_d - V_c)$

$$= [2(1.013\times10^5\ \text{Pa})](1.0\ \text{L} - 3.0\ \text{L})\left(\frac{10^{-3}\ \text{m}^3}{1\ \text{L}}\right)$$

$$= \boxed{-410\ \text{J}}$$

(d) $W_{da} = P(V_a - V_d) = \boxed{0}$

(e) $W_{\text{net}} = W_{ab} + W_{bc} + W_{cd} + W_{da} = +610\ \text{J} + 0 - 410\ \text{J} + 0 = \boxed{+200\ \text{J}}$

12.3 The constant pressure is $P = (1.5\ \text{atm})(1.013\times10^5\ \text{Pa/atm}) = 1.52\times10^5\ \text{Pa}$ and the work done on the gas is $W = -P(\Delta V)$.

(a) $\Delta V = +4.0\ \text{m}^3$ and

$$W = -P(\Delta V) = -(1.52\times10^5\ \text{Pa})(+4.0\ \text{m}^3) = \boxed{-6.1\times10^5\ \text{J}}$$

(b) $\Delta V = -3.0\ \text{m}^3$, so

$$W = -P(\Delta V) = -(1.52\times10^5\ \text{Pa})(-3.0\ \text{m}^3) = \boxed{+4.6\times10^5\ \text{J}}$$

12.5 In each case, the work done *on* the gas is given by the negative of the area under the path on the *PV* diagram. Along those parts of the path where volume is constant, no work is done. Note that $1 \text{ atm} = 1.013\times10^5 \text{ Pa}$ and $1 \text{ Liter} = 10^{-3} \text{ m}^3$.

(a) $W_{IAF} = W_{IA} + W_{AF} = -P_I\left(V_A - V_I\right) + 0$

$$= -\left[4.00\left(1.013\times10^5 \text{ Pa}\right)\right]\left[\left(4.00-2.00\right)\times10^{-3} \text{ m}^3\right] = \boxed{-810 \text{ J}}$$

(b) $W_{IF} = -\left(\text{triangular area}\right) - \left(\text{rectangular area}\right)$

$$= -\frac{1}{2}\left(P_I - P_B\right)\left(V_F - V_B\right) - P_B\left(V_F - V_B\right) = -\frac{1}{2}\left(P_I + P_B\right)\left(V_F - V_B\right)$$

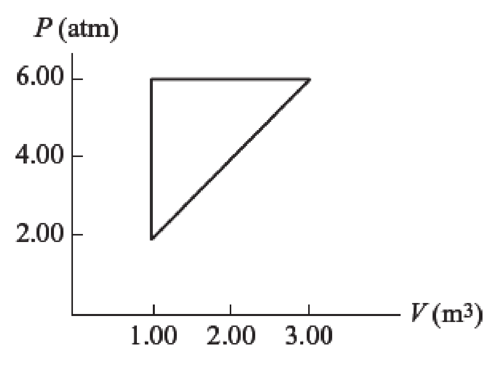
$$= -\frac{1}{2}\left[\left(4.00+1.00\right)\left(1.013\times10^5 \text{ Pa}\right)\right]\left(4.00-2.00\right)\times10^{-3} \text{ m}^3$$

$$= \boxed{-507 \text{ J}}$$

(c) $W_{IBF} = W_{IB} + W_{BF} = 0 - P_B\left(V_F - V_I\right)$

$$= -\left[1.00\left(1.013\times10^5 \text{ Pa}\right)\right]\left[\left(4.00-2.00\right)\times10^{-3} \text{ m}^3\right] = \boxed{-203 \text{ J}}$$

12.29 The net work done by a heat engine operating on the cyclic process shown in Figure P12.29 equals the triangular area enclosed by this process curve. Thus,



$$W_{\text{net}} = \frac{1}{2}\left(6.00 \text{ atm} - 2.00 \text{ atm}\right)\left(3.00 \text{ m}^3 - 1.00 \text{ m}^3\right)$$

$$= 4.00 \cancel{\text{atm}}\cdot\text{m}^3\left(\frac{1.013\times10^5 \text{ Pa}}{1 \cancel{\text{atm}}}\right) = 4.05\times10^5 \text{ J}$$

$$= 405\times10^3 \text{ J} = \boxed{405 \text{ kJ}}$$

12.31 The maximum possible efficiency for a heat engine operating between reservoirs with absolute temperatures of $T_c = 25° + 273 = 298 \text{ K}$ and $T_h = 375° + 273 = 648 \text{ K}$ is the Carnot efficiency

$$e_C = 1 - \frac{T_c}{T_h} = 1 - \frac{298 \text{ K}}{648 \text{ K}} = \boxed{0.540 \text{ or } 54.0\%}$$

12.33 (a) The efficiency of a heat engine is $e = W_{\text{env}}/|Q_h|$, where W_{env} is the work done by the engine and $|Q_h|$ is the energy absorbed from the higher temperature reservoir. Thus, if $W_{\text{env}} = |Q_h|/4$, the efficiency is $e = 1/4 = \boxed{0.25 \text{ or } 25\%}$.

(b) From conservation of energy, the energy exhausted to the lower temperature reservoir is $|Q_c| = |Q_h| - W_{\text{env}}$. Therefore, if $W_{\text{env}} = |Q_h|/4$, we have $|Q_c| = 3|Q_h|/4$ or $\boxed{|Q_c|/|Q_h| = 3/4}$.