Chapter 2 Heat, Temperature, and the First Law of Thermodynamics

2.1. Temperature and the Zeroth Law of Thermodynamics

2.2. Thermal Expansion

2.3. Heat and the Absorption of Heat by Solids and Liquids

2.4. Work and Heat in Thermodynamic Processes

2.5. The First Law of Thermodynamics and Some Special Cases

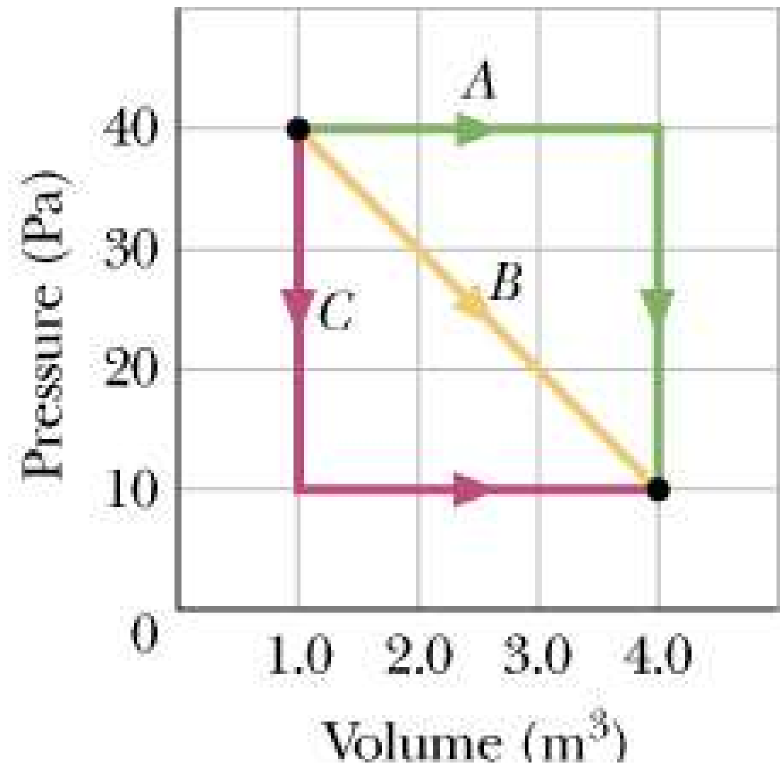
2.6. Heat Transfer Mechanisms

Homework:

Problems 43, 45, 46, 48, 49, 50, 51, 54, 60 in Chapter 18, Textbook

43. A gas sample expands from 1.0 m^3 to 4.0 m^3 while its pressure decreases from 40 Pa to 10 Pa. How much work is done by the gas if its pressure changes with volume via (a) path A, (b) path B, and (c) path C?

$$W = \int p\,dV$$



(a) $W = p\Delta V + 0$

$$W = 40 \times 3 = 120(J)$$

(b) $W = \frac{1}{2}(10+40)3 = 75(J)$

or you can use

$$W = \int p\,dV = \int_1^4 (50 - 10V)\,dV$$

$$W = (50V - 5V^2)\Big|_1^4 = 75(J)$$

(c) $W = 0 + p\Delta V = 10 \times 3 = 30(J)$

46. Suppose 200 J of work is done on a system and 80.0 cal is extracted from the system as heat. In the sense of the first law of thermodynamics, what are the values (including algebraic signs) of (a) W, (b) Q, and (c) ΔE_{int}?

$$W_{on} = 200\,J$$

(a) Work done on the gas = - work done by the gas

$$W_{on} = -W$$

$$W = -W_{on} = -200\,(J)$$

(b) the gas released energy as heat, so Q<0:

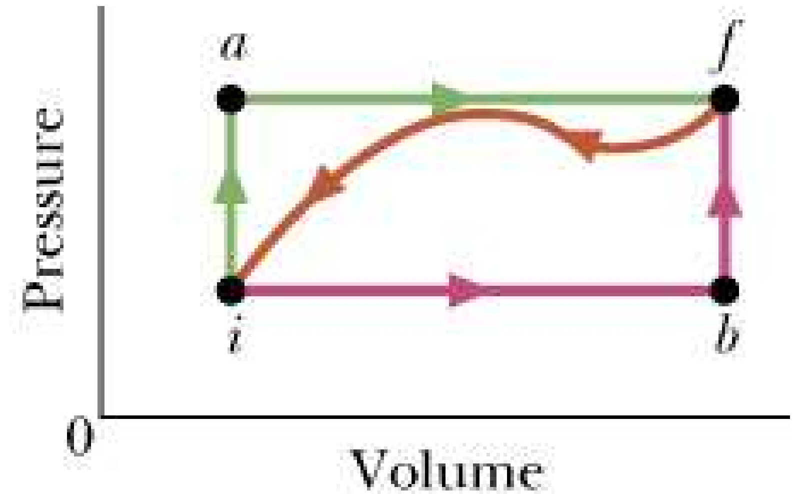
$$Q = -80\,cal = -80 \times 4.19 = -335.2(J)$$

(c) the first law of thermodynamics:

$$\Delta E_{int} = Q - W$$

$$\Delta E_{int} = -335.2 - (-200) = -135.2(J)$$

47. When a system is taken from state i to state f along path iaf in the figure below, Q = 50 cal and W = 20 cal. Along path ibf, Q = 36 cal. (a) What is W along path ibf? (b) If W = -13 cal for the return path fi, what is Q for this path? (c) If $E_{int,i}$ = 10 cal, what is $E_{int,f}$? If $E_{int,b}$ = 22 cal, what is Q for (d) path ib and (e) path bf?



$$\Delta E_{int} = Q - W$$

(a) For path iaf:

$$\Delta E_{int,iaf} = E_{int,f} - E_{int,i} = Q_{iaf} - W_{iaf}$$

For path ibf:

$$\Delta E_{int,ibf} = E_{int,f} - E_{int,i} = Q_{ibf} - W_{ibf} = \Delta E_{int,iaf}$$

$$W_{ibf} = Q_{ibf} - (Q_{iaf} - W_{iaf}) = 36 - (50 - 20) = 6(\text{cal})$$

(b) For path fi:

$$\Delta E_{int,fi} = E_{int,i} - E_{int,f} = -\Delta E_{int,if} = -30(cal)$$

$$Q_{fi} = \Delta E_{int,fi} + W = -30 - 13 = -43(cal)$$

(c) For path fi:

$$E_{int,f} = E_{int,i} - \Delta E_{int,fi} = 10 - (-30) = 40(cal)$$

(d) For path ibf:

$$W_{ibf} = W_{ib} = 6\,(cal)\ \text{as}\ W_{bf} = 0\,(\text{constant volume})$$

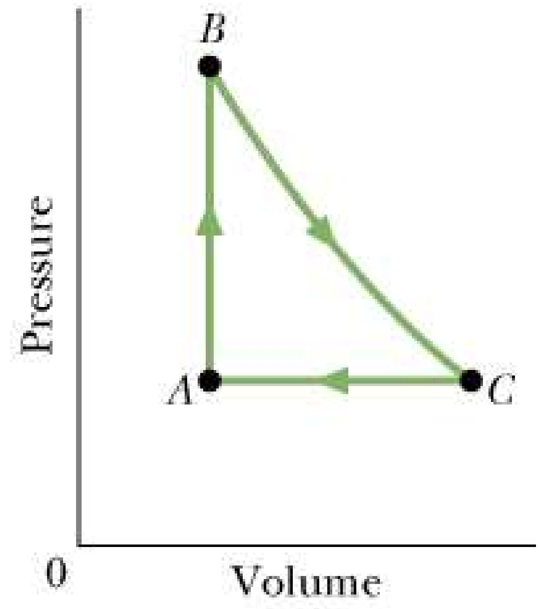
$$\Delta E_{int,ib} = E_{int,b} - E_{int,i} = 22 - 10 = 12(cal)$$

$$Q_{ib} = \Delta E_{int,ib} + W_{ib} = 12 + 6 = 18(cal)$$

(e) For path ibf:

$$Q_{bf} = Q_{ibf} - Q_{ib} = 36 - 18 = 18(cal)$$

48. Gas within a chamber passes through the cycle shown in the figure below. Determine the energy transferred by the system as heat during process *CA* if the energy added as heat Q_{AB} during process *AB* is 25.0 J, no energy is transferred as heat during process *BC*, and the net work done during the cycle is 15.0 J.



$$\Delta E_{int} = Q - W$$

For the ABCA closed cycle:

$$\Delta E_{int} = 0$$

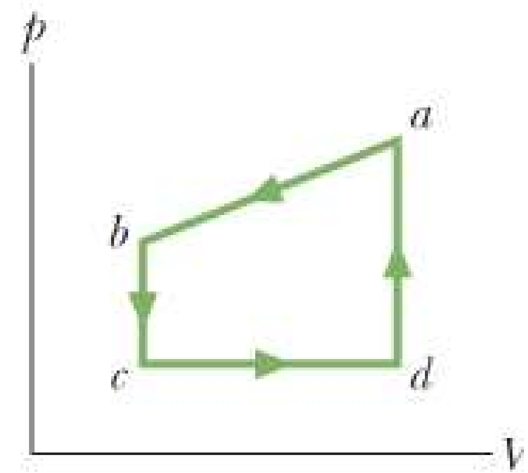
$$Q_{AB} + Q_{BC} + Q_{CA} = W$$

$$Q_{CA} = W - Q_{AB} - Q_{BC}$$

$$Q_{CA} = 15 - 25 - 0 = -10 \text{ (J)}$$

49. The figure below displays a closed cycle for a gas (the figure is not drawn to scale). The change in the internal energy of the gas as it moves from *a* to *c* along the path *abc* is -200 J. As it moves from *c* to *d*, 180 J must be transferred to it as heat. An additional transfer of 80 J as heat is needed as it moves from *d* to *a*. How much work is done by the gas as it moves from *c* to *d*?

$$\Delta E_{int} = Q - W$$



For a closed cycle: $\Delta E_{int} = 0$

$$\Delta E_{abc} + \Delta E_{cd} + \Delta E_{da} = 0$$

$$\Delta E_{abc} = -200\ (J)$$

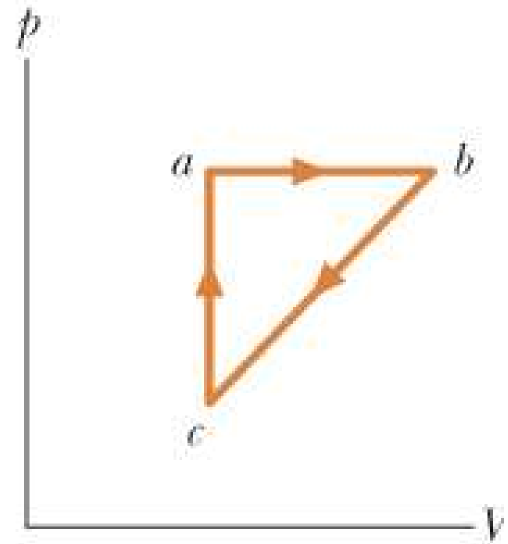
For process da:

$$\Delta E_{da} = Q_{da} - W_{da} = 80 - 0 = 80\ (J)$$

$$\Delta E_{cd} = -\Delta E_{abc} - \Delta E_{da} = 200 - 80 = 120\ (J)$$

$$\rightarrow W_{cd} = Q_{cd} - \Delta E_{cd} = 180 - 120 = 60\ (J)$$

50. A sample of gas is taken through cycle *abca* shown in the p-V diagram (see figure). The net work done is +1.5 J. Along path *ab*, the change in the internal energy is +3.0 J and the magnitude of the work done is 5.0 J. Along path *ca*, the energy transferred to the gas as heat is 2.5 J. How much energy is transferred as heat along (a) path *ab* and (b) path *bc*?



$$\Delta E_{int} = Q - W$$

(a) This process a→b is an expansion ($V_b > V_a$):

$$W > 0 \text{ and } W = 5 \text{ J}$$

$$Q_{ab} = \Delta E_{int} + W = 3 + 5 = 8 \text{ (J)}$$

(b) We consider a closed cycle abca:

$$\Delta E_{int} = Q - W = 0$$

$$Q_{ab} + Q_{bc} + Q_{ca} = W_{net}$$

$$Q_{bc} = W_{net} - Q_{ab} - Q_{ca} = 1.5 - 8 - 2.5 = -9.0 \text{ (J)}$$

51. A sphere of radius 0.500 m, temperature 27.0^{0}C, and emissivity 0.850 is located in an environment of temperature 77.0^{0}C. At what rate does the sphere (a) emit and (b) absorb thermal radiation? (c) What is the sphere's net rate of energy exchange?

(a) $$P_{rad} = \sigma\varepsilon A T^4$$

$$A = 4\pi R^2; T = 273 + 27 = 300\ (K)$$

$$P_{rad} \approx 1.23 \times 10^3\ (W)$$

(b) $$P_{abs} = \sigma\varepsilon A T_{env}^4$$

$$T_{env} = 273 + 77 = 350\ (K)$$

$$P_{abs} \approx 2.27 \times 10^3\ (W)$$

(c) $$P_{net} = P_{abs} - P_{rad} = 2.27 \times 10^3 - 1.23 \times 10^3 = 1.04 \times 10^3\ (W)$$

54. If you were to walk briefly in space without a spacesuit while far from the Sun (as an astronaut does in the movie 2001), you would feel the cold of space – while you radiated energy, you would absorb almost none from your environment. (a) At what rate would you lose energy? (b) How much energy would you lose in 30 s? Assume that your emissivity is 0.90, and estimate other data needed in the calculations.

(a) The heat transfer mechanism is radiation:

$$P_{rad} = \sigma\varepsilon A T^4$$

$$P_{rad} = 5.67\times10^{-8}\times0.9\times2.0\times310^4 = 9.4\times10^2 \text{ (W)}$$

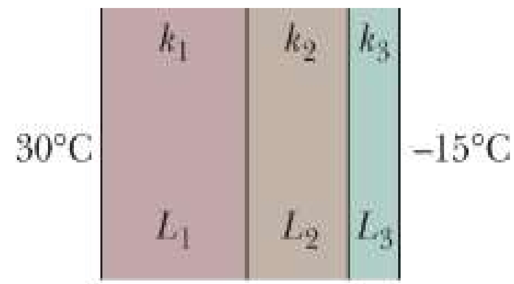
(b) The energy lost in 30 s is:

$$E = P_{rad}\times t = 9.4\times10^2\times30 = 2.8\times10^4 \text{ (J)}$$

60. The figure below shows the cross section of a wall made of three layers. The thicknesses of the layers are L_1, $L_2=0.750L_1$, and $L_3=0.350L_1$. The thermal conductivities are k_1, $k_2=0.900k_1$, and $k_3=0.800k_1$. The temperatures at the left and right sides of the wall are 30.0^0C and -15.0^{0}C, respectively. Thermal conduction through the wall has reached the steady state. (a) What is the temperature difference ΔT_2 across layer 2 (between the left and right sides of the layer)? If k_2 were, instead, equal to $1.1k_1$, (b) would the rate at which energy is conducted through the wall be greater than, less than, or the same as previously, and (c) what would be the value of ΔT_2?

(a) $$P_{cond} = \frac{A(T_H - T_C)}{\sum(L/k)} = \frac{A\Delta T_2}{L_2/k_2}$$

$$\Delta T_2 = \frac{(L_2/k_2)(T_H - T_C)}{\sum(L/k)} \approx 16.5^0 C$$



(b) conductivity k increases → conduction rate increases.

(c) Repeat the calculation in part (a): $\Delta T_2 \approx 14.5^0 C$