ANSWERS TO MULTIPLE CHOICE QUESTIONS

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

$$W_{\text{env}} = +P\ \Delta V = 70.0 \times 10^3\ \text{Pa}\quad -0.20\ \text{m}^3 = -14 \times 10^3\ \text{J} = -14\ \text{kJ}$$

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.

3. For a monatomic ideal gas, the internal energy is $U = \frac{3}{2} nRT$ and the change in internal energy is $\Delta U = \frac{3}{2} nR(\Delta T)$. From the ideal gas law, $PV = nRT$, observe that $nR(\Delta T) = nRT_f - nRT_i = P_f V_f - P_i V_i$. When the pressure is constant, $P_f = P_i = P$, this reduces to $\Delta U = \frac{3}{2}[P(V_f - V_i)] = \frac{3}{2} P(\Delta V)$, so the change in internal energy for this gas is $\Delta U = \frac{3}{2}(2.00 \times 10^5\ \text{Pa})(+1.50\ \text{m}^3) = 4.50 \times 10^5\ \text{J}$ making (c) the correct answer.

4. The work an ideal gas does on the environment during an isothermal expansion is $W_{\text{env}} = nRT \ln\ V_f/V_i$, so for the given process,

$$W_{\text{env}} = 3.9 \times 10^2\ \text{mol}\quad 8.31\ \text{J/mol}\cdot\text{K}\quad 850\ \text{K}\ \ \ln\ 2 = 1.9 \times 10^6\ \text{J}$$

and (a) is the correct choice.

5. For an adiabatic process, $PV^{\gamma} = \text{constant}$, where $\gamma = c_p/c_{\text{v}} = 1.4$ for diatomic gases (See Table 12.1 in the textbook.) Thus, $P_f V_f^{1.4} = P_i V_i^{1.4}$, or the final pressure will be

$$P_f = P_i \left(\frac{V_i}{V_f}\right)^{1.4} = 1.00 \times 10^5\ \text{Pa}\ \left(\frac{1.00\ \text{m}^3}{3.50\ \text{m}^3}\right)^{1.4} = 1.73 \times 10^4\ \text{Pa}$$

and the correct response is (e).

6. In a cyclic process, the net work done equals the area enclosed by the process curve in a *PV* diagram. Thus,

$$W_{\text{net}} = \left[\ 4.00 - 1.00\ \times 10^5\ \text{Pa}\right]\left[\ 2.00 - 1.00\ \ \text{m}^3\right] + \left[\ 2.00 - 1.00\ \times 10^5\ \text{Pa}\right]\left[\ 3.00 - 2.00\ \ \text{m}^3\right] = 4.00 \times 10^5\ \text{J}$$

and (d) is the correct answer.

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

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

9. The maximum theoretical efficiency (the Carnot efficiency) of a device operating between absolute temperatures $T_c < T_h$ is $e_C = 1 - T_c/T_h$. For the given steam turbine, this is

$$e_C = 1 - \frac{3.0 \times 10^2\text{ K}}{450\text{ K}} = 0.33 \quad \text{or} \quad 33\%$$

and (c) is the correct answer.

10. At a pressure of 1.0 atm, ice melts at absolute temperature $T_K = 0° + 273.15 = 273.15\text{ K}$. The thermal energy this block of ice must absorb to fully melt is

$$Q_r = mL_f = (1.00\text{ kg})(3.33 \times 10^5\text{ J/kg}) = 3.33 \times 10^5\text{ J}$$

so the change in entropy of the ice is

$$\Delta S = \frac{Q_r}{T_K} = \frac{+3.33 \times 10^5\text{ J}}{273.15\text{ K}} = +1.22 \times 10^3\text{ J/K} = +1.22\text{ kJ/K}$$

and (d) is the correct choice.

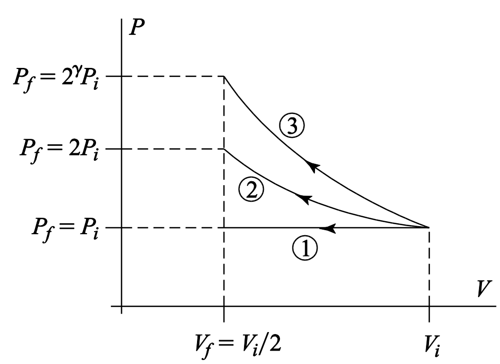
11. In an ideal gas, the internal energy is directly proportional to the absolute temperature. Thus, in an isothermal process (constant temperature process) the internal energy of the ideal gas is constant. Choice (d) is the only true statement among the listed choices. In the compression, work is done *on the gas* while the internal energy is constant. The first law of thermodynamics then says that energy must be transferred *from the gas* by heat. Also, by the ideal gas law, when the volume decreases while temperature is constant, the pressure must increase.

12. By definition, in an adiabatic process, no energy is transferred to or from the gas by heat. Thus, (c) is a true statement. All other choices are false. In an expansion process, the gas does work on the environment. Since, there is no energy input by heat, the first law of thermodynamics says that the internal energy of the ideal gas must decrease, meaning the temperature will decrease. Also, in an adiabatic process, $PV^{\gamma} = \text{constant}$ meaning that the pressure must decrease as the volume increases in this adiabatic expansion.

13. In an isobaric process on an ideal gas, pressure is constant while the gas either expands or is compressed. Since the volume of the gas is changing, work is done either on or by the gas, so choice (b) is a true statement. Also, from the ideal gas law with pressure constant, $P(\Delta V) = nR(\Delta T)$. Thus, the gas must undergo a change in temperature having the same sign as the change in volume. If $\Delta V > 0$, then both ΔT and the change in the internal energy of the gas are positive $(\Delta U > 0)$. However, when $\Delta V > 0$, the work done *on the gas* is negative $(W < 0)$, and the first law of thermodynamics says that there must be a positive transfer of energy by heat to the gas $(Q = \Delta U - W > 0)$. When $\Delta V < 0$, a similar argument shows that $(\Delta U < 0)$, $(W > 0)$, and $Q = \Delta U - W < 0$. Thus, all of the other listed choices are false statements.

14. Choice (c) is a statement of the first law of thermodynamics, *not* the second law, and hence is the correct answer to this question. Choices (a), (b), (d) and (e) are alternative statements of the second law, (a) being the Kelvin-Planck formulation, (b) the Carnot statement, (d) the Clausius statement, and (e) summarizes the primary consequence of all these various statements.

15. First, eliminate choice (d) since the work involved in an isovolumetric process is zero, and by definition, one cannot have an isovolumetric process when the volume is changing. In the other processes, the work done on the gas equals the area under the process curve in a *PV* diagram. In an isobaric process, the pressure is constant, so $P_f = P_i$ and the work done is the area under curve 1 in the sketch at the right. For an isothermal process, the ideal gas law gives $P_f V_f = P_i V_i$, so $P_f = (V_i/V_f)P_i = 2P_i$ and the work done is the area under curve 2 in the sketch. Finally, for an adiabatic process, $P_f V_f^{\gamma} = P_i V_i^{\gamma} = \text{constant}$, so



$P_f = (V_i/V_f)^{\gamma} P_i$ and $P_f = 2^{\gamma} P_i > 2P_i$ since $\gamma > 1$ for all ideal gases (See Table 12.1 in the textbook). The work done in an adiabatic process is the area under curve 3, which exceeds that done in either of the other processes. Thus, the correct choice is (b), the adiabatic process involves the most work.

16. With this method of using an air conditioner, the average temperature in the room will increase, and choice (a) is the correct answer. The air conditioner operates on a cyclic process so the change in the internal energy of the refrigerant is zero. Then, the conservation of energy gives the thermal energy exhausted to the room as $Q_h = Q_c + W_{\text{eng}}$ where Q_c is the thermal energy the air conditioner removes from the room and W_{eng} is the work done to operate the device. Since $W_{\text{eng}} > 0$, the air conditioner is returning more thermal energy to the room than it is removing, so the average temperature in the room will increase.

17. The correct choice is (d). The second law basically says that you must put in some work to transfer energy by heat from a lower-temperature to a higher-temperature location. But it can be very little work if the two temperatures are very nearly equal. Still, in the coefficient of performance for a refrigerator, $\text{COP} = |Q_c|/W$, W can never be zero and the result must be finite in all cases.

18. The Clausius statement of the second law of thermodynamics says that in any thermodynamics process, reversible or irreversible, the total entropy of the universe must either remain constant (reversible process) or increase (irreversible process). Thus, if in a thermodynamics process, the entropy of a system changes by –6 J/K, the entropy of the environment (i.e., the rest of the universe) must increase by +6 J/K or more. The correct choice here is (e).