Physics 2A
Chapter 11/12 HW Solutions

Chapter 11
Conceptual Questions: 1, 7
Problems: 4, 11, 18, 40

Chapter 12
Conceptual Questions: 6, 16
Problems: 11, 16, 34, 37, 45, 54, 57, 62, 98

Q11.1. Reason: The friction between your hands increases the kinetic energies in molecules of your hands, and this exhibits itself as an increase in thermal energy of your hands. The temperature of your hands goes up.
Assess: Thermal energy is related to molecular kinetic energies.

Q11.7. Reason: Refer to Equation 11.12, the first law of thermodynamics.
(a) The space shuttle gets hotter, and its thermal energy increases, but it isn't heated in the sense of being in thermal contact with a hotter object. Instead, it gets hot by the other method of changing the thermal energy: work. As the shuttle slams into air molecules in the upper atmosphere, work is done on them by the shuttle and work is done on the shuttle by them. The atoms in the shuttle jiggle more vigorously.
(b) Since energy must be conserved but the shuttle is slowing down, that kinetic energy decrease must be balanced by an increase in another form of energy. In this case the shuttle's initial kinetic energy is decreased while the thermal energy of the shuttle is increased.
Assess: In the microscopic view, even heating by contact with a hotter object is work as the faster molecules collide with (and do work on) the slower molecules. But work and heat appear as separate terms in Equation 11.12.

P11.4. Prepare: $e = 0.20$
Solve: Each LED provides $(1.0\,\text{W})(0.20) = 0.20\,\text{W}$ of visible light. We therefore need eight of them to give 1.6 W of visible light power. Since each of them uses 1.0 W then the total power necessary is 8.0 W.
Assess: This is a factor of five better than the incandescent bulb.

P11.11. Prepare: A typical efficiency for climbing stairs is about 25%, so we can assume that 25% of the chemical energy in the candy bar is transformed to increased potential energy.

$$\Delta U_g = (0.25)(400\,\text{Cal})\left(\frac{1\,\text{kcal}}{1\,\text{Cal}}\right)\left(\frac{1000\,\text{cal}}{1\,\text{kcal}}\right)\left(\frac{4.2\,\text{J}}{1\,\text{cal}}\right) = 4.2\times10^5\,\text{J}$$

Solve: Since $\Delta U_g = mg\Delta y$, the height gained is

$$\Delta y = \frac{\Delta_g}{mg} = \frac{4.2\times10^5\,\text{J}}{(60\,\text{kg})(9.8\,\text{m/s}^2)} = 710\,\text{m}$$

If we assume that each flight of stairs has a height of 2.7 m (as is done in Example 11.5), this gives

$$\text{Number of flights} = \frac{710\,\text{m}}{2.7\,\text{m}} \approx 260\text{ flights}$$

Assess: This is more than enough to get to the top of the Empire State Building twice—all fueled by one candy bar! This is a remarkable result.

P11.18. Prepare: Solve $\Delta E_{\text{th}} = \frac{3}{2} N k_{\text{B}} \Delta T$ for ΔT.

Solve:

$$\Delta T = \frac{2}{3}\frac{\Delta E_{\text{th}}}{N k_{\text{B}}} = \frac{2}{3}\frac{-4.3\,\text{J}}{(2.2\times 10^{22})(1.38\times 10^{-23})} = -9.4\,\text{K} = -9.4^{\circ}\text{C}$$

$$T_{\text{f}} = T_{\text{i}} + \Delta T = 20^{\circ}\text{C} - 9.4^{\circ}\text{C} = 11^{\circ}\text{C}$$

Assess: We expected the temperature to drop from the removed thermal energy.

P11.40. Prepare: We consult Table 11.2 to see that we will need to assume a *large* size meal of burger, fries, and drink which has an energy content of 1350 Cal = 5670 kJ. In addition, we consult Table 11.4 to see that swimming at a fast crawl requires about 800 W of metabolic power for a 68 kg individual.
We will also estimate the efficiency of the swimmer to be 25% (see Problem 11.43).
Solve: Use energy = power × time, modified to account for the efficiency of $e = 25\%$. Here the energy (in the burger, fries, and drink) is what you had to "pay," and the power × time in swimming is what you get. So energy × e = power × time.

$$\text{time} = \frac{\text{energy} \times e}{\text{power}} = \frac{(5670\text{ kJ})(0.25)}{800\text{ J/s}} = 1770\text{ s} = 30\text{ min}$$

Assess: Fast swimming is strenuous exercise and uses up the metabolic energy fairly quickly, so 30 min for a large junk food meal is about right.

Q12.6. Reason: Note that N/V and v_{rms} are the same for both gases.
(a) In the process of deriving the ideal gas law we saw that

$$p = \frac{1}{3}\frac{N}{V} m v_{\text{rms}}^2$$

or that $p \propto m$, so given the conditions above, the gas with the more massive molecules (gas 2) will have the higher pressure.

$$p_2 > p_1$$

(b) The ideal gas law can be rearranged as

$$p = \frac{N}{V} k_{\text{B}} T$$

which shows that $p \propto T$, so given the answer to part **(a)** the temperature of gas 2 must be greater than the temperature of gas 1.

$$T_2 > T_1$$

Assess: We conclude that, other things being equal, the gas with the more massive molecules will have a greater pressure and a greater temperature.

Q12.16. Reason: Since A and B are in a well-insulated container, any heat leaving B goes entirely into raising the temperature of A so

$$mc_{\text{A}}(T_{\text{f}} - 0°\text{C}) + mc_{\text{B}}(T_{\text{f}} - 200°\text{C})$$

Solving for the final temperature,

$$T_{\text{f}} = \frac{200°\text{C}}{1 + c_{\text{A}}/c_{\text{B}}}$$

Since the specific heat of A is larger than the specific heat of B, the final temperature is less than 100°C.
Assess: As expected, if the specific heats of the two materials are equal, the final temperature will be 100°C. Note that the temperature change depends only on the mass of material, not the density.

P12.11. Prepare: In order to use the ideal gas law (Equation 12.11) we need to know the number of helium atoms in the gas.

$$N = nN_A = (7.5\text{ mol})(6.02\times10^{23}\text{ mol}^{-1}) = 4.52\times10^{24}$$

$$V = 15\text{L}\left(\frac{1\text{m}^3}{1000\text{L}}\right) = 0.015\text{m}^3$$

As a further preliminary calculation add 1 atm to the gauge pressure to give the absolute pressure and convert the pressure to SI units.

$$p = p_g + 1\text{ atm} = 65\text{ psi} + 14.7\text{ psi} = 79.7\text{ psi}\left(\frac{1\text{ atm}}{14.7\text{ psi}}\right)\left(\frac{101.3\text{ kPa}}{1\text{ atm}}\right) = 549\text{ kPa}$$

Solve: **(a)** Solve Equation 12.11 for T.

$$T = \frac{pV}{Nk_B} = \frac{(549\text{ kPa})(0.015\text{ m}^3)}{(4.52\times10^{24})(1.38\times10^{-23}\text{ J/K})} = 132\text{ K} = -105°\text{ C}$$

(b) Now use Equation 12.5 for K_{ave}.

$$K_{ave} = \frac{3}{2}k_BT = \frac{3}{2}(1.38\times10^{-23}\text{ J/K})(132\text{ K}) = 2.7\times10^{-21}\text{ J}$$

Assess: The answer to part **(a)** is a cold temperature, but it needs to be to get that much gas in that volume.

P12.16. Prepare: The gas is assumed to be ideal. As a general rule, we must convert all quantities into SI units. In the present case, however, we will be dealing with the ratio of the final and the initial value of V, so we do not have to convert L into m^3.
Solve: The before-and-after relationship of an ideal gas is

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2} \Rightarrow p_2 = p_1\frac{V_1}{V_2}\cdot\frac{T_2}{T_1} = (2.4\text{ atm})\left(\frac{3.0\text{ L}}{9.0\text{ L}}\right)\left(\frac{600\text{ K}}{300\text{ K}}\right) = 1.6\text{ atm}$$

P12.34. Prepare: The mass of the mercury is 20 g = 2.0×10^{-2} kg and its specific heat from Table 12.4 is c_{Hg} = 140 J/kg K. The mass of the water is 20 g = 2.0×10^{-2} kg and its specific heat from Table 12.4 is c_{water} = 4190 J/kg K. We will use Equation 12.22 to obtain the needed heats.
Solve: **(a)** The heat needed to change the mercury's temperature is

$$\text{Q} = \text{Mc}_{\text{Hg}}\Delta T \Rightarrow \Delta T = \frac{Q}{Mc_{\text{Hg}}} = \frac{100\text{ J}}{(0.020\text{ kg})(140\text{ J/(kg}\cdot\text{K))}} = 35.7\text{ K} = 35.7°\text{C, which will be reported as }36°\text{C.}$$

(b) The amount of heat required to raise the temperature of the same amount of water by the same number of degrees is

$$Q = Mc_{water}\Delta T = (0.020\text{ kg})(4190\text{ J/(kg}\cdot\text{K))}(35.7\text{ K}) = 3000\text{ J}$$

Assess: Q is directly proportional to c_{water} and the specific heat for water is much higher than the specific heat for mercury. This explains why $Q_{water} > Q_{mercury}$.

P12.37. Prepare: Water in the body is converted to water vapor. Equation 12.22 applies.
Solve: Each breath converts 25 mg of water to water vapor. The heat required for this is

$$Q = ML_v = (2.5\times10^{-5}\text{ kg})(24\times10^5\text{ J/kg}) = 60\text{ J}$$

At 12 breaths/min, there are 0.2 breaths/s. Multiplying by the above result of 60 J/breath we obtain that P = 12 J/s or P = 12 W is the rate of heat loss.
Converting to Calories/day, we have

$$P = (12\text{ W})\left(\frac{1\text{ Calorie}}{4190\text{ J}}\right)\left(\frac{60\text{ s}}{\text{min}}\right)\left(\frac{60\text{ min}}{\text{h}}\right)\left(\frac{24\text{ h}}{\text{d}}\right) = 250\ \text{Calorie}$$

Assess: This seems reasonable since it is a small fraction of a person's daily caloric intake of about 2000 calories.

P12.45. Prepare: Problem-Solving Strategy 12.1 will be useful. Assume the heat is transferred entirely from the coffee to the ice since the container is well-insulated. All the ice melts and is converted to water at 0°C, otherwise the leftover ice would continue to cool the coffee. The coffee transfers additional heat to the water to raise its temperature to 30°C.
Solve: The ice is at its melting temperature when it's put in the coffee. The heat required to melt the ice is $Q_{\text{melt}} = M_{\text{ice}}L_{\text{f}}$. Once the ice melts, heat goes into the water that results in raising its temperature to 30°C. The heat required is $Q_{\text{water}} = M_{\text{ice}}c_{\text{water}}(T_{\text{f}} - T_{\text{i}}) = M_{\text{ice}}c_{\text{water}}(T_{\text{f}} - 0°\text{C}) = M_{\text{ice}}c_{\text{water}}T_{\text{f}}$.
The temperature of the coffee decreases as a result of the ice melting and the heating of the resulting water. The mass of the coffee is $M_{\text{coffee}} = \rho V$. The density of the coffee is $\rho = 1000\text{ kg/m}^3$. The volume of the coffee is

$$V = 200\text{ mL} = (200\times10^{-3}\text{ L})\left(\frac{1\text{ m}^3}{1000\text{ L}}\right) = 2.00\times10^{-4}\text{ m}^3$$

Three significant figures have been assumed in the volume of coffee.
Energy conservation gives

$$M_{\text{ice}}L_{\text{f}} + M_{\text{ice}}c_{\text{water}}T_{\text{f}} + \rho V c_{\text{water}}(T_{\text{f}} - T_{\text{i}}) = 0$$

Where T_{i} is the initial temperature of the coffee. Solving for the mass of ice required,

$$M_{\text{ice}} = \frac{-\rho V c_{\text{water}}(T_{\text{f}} - T_{\text{i}})}{L_{\text{f}} + c_{\text{water}}T_{\text{f}}} = \frac{-(1000\text{ kg/m}^3)(2.00\times10^{-4}\text{ m}^3)(4190\text{ J/(kg}\cdot\text{K))}(-50\text{ K})}{(3.33\times10^5\text{ J/kg}) + (4190\text{ J/(kg}\cdot\text{K))}(30\text{ K})} = 9.1\times10^{-2}\text{ kg}$$

It takes 91 g of ice to cool the coffee.
Assess: About half the mass of the coffee in ice has to be added to cool the coffee, as we might expect.

P12.54. Prepare: The bottom of the interior of the kettle is the same temperature of the boiling water, 100°C. Equation 12.31 can be used.
Solve: Solving Equation 12.31 for the temperature difference,

$$\Delta T = \left(\frac{Q}{\Delta t}\right)\left(\frac{L}{kA}\right) = (800\text{ W})\left(\frac{3.0\times10^{-3}\text{ m}}{(400\text{ W/(m}\cdot\text{K))}\pi(0.12\text{ m})^2}\right) = 1.3\times10^{-1}\text{ K}$$

The bottom of the kettle is only 0.13 K hotter than the interior.
Assess: This result makes sense.

P12.57. Prepare: The rate of net energy loss by radiation is given by Equation 12.34.

$$\frac{Q_{\text{net}}}{\Delta t} = e\sigma A(T^4 - T_0^4)$$

where T_0 is the termperature of the surroundings.
We are given $T = 30°\text{C} = 303\text{ K}$, $T_0 = -10°\text{C} = 263\text{ K}$, and $A = 0.030\text{ m}^2$. We are told to assume the emissivity of seal skin is the same as human skin; the text gives this vaule as $e = 0.97$.
The textbook gives Stefan's constant as $\sigma = 5.67\times10^{-8}\text{ W/(m}^2\cdot\text{K}^4)$.
Solve:

$$\frac{Q_{\text{net}}}{\Delta t} = e\sigma A\left(T^4 - T_0^4\right) = (0.97)(5.67\times10^{-8}\text{ W/(m}^2\cdot\text{K}^4))(0.030\text{ m}^2)[(303\text{ K})^4 - (263\text{ K})^4] = 6.0\text{ W}$$

Assess: 6 W isn't a lot, but it is sufficient to cool the seal when the surroundings are very cool. If there were no thermal windows the seal would have difficulty regulating its temperature.

P12.62. Prepare: Treat the air in the compressed-air tank as an ideal gas and use Equation 12.12 to find n. We will, however, need to convert pressure and temperature to SI units using 1 atm = 1.013×10^5 Pa and T (in K) = T (in °C) + 273. Also note that $\pi r^2 h$ is the volume of a cylinder.

Solve: **(a)** From the ideal-gas law $pV = nRT$, the number of moles n is

$$n = \frac{pV}{RT} = \frac{p(\pi r^2 h)}{RT} = \frac{(150\ \text{atm})(1.013\times10^5\ \text{Pa/1 atm})[\pi(0.075\ \text{m})^2(0.50\ \text{m})]}{(8.31\ \text{J/(mol}\cdot\text{K))}[(273+20)\ \text{K}]} = 55.1\ \text{mol}$$

which will be reported as 55 mol.

(b) At STP, the ideal-gas law yields

$$V = \frac{nRT}{p} = \frac{(55.1\ \text{mol})(8.31\ \text{J/(mol}\cdot\text{K))}(273\ \text{K})}{1.013\times10^5\ \text{Pa}} = 1.2\ \text{m}^3$$

Assess: The volume of the compressed air tank is $(\pi r^2)h = 8.84 \times 10^{-3}\ \text{m}^3$. The volume at STP is 140 times the volume of the tank. That is, the air is compressed 140 times compared to STP values, which does not look unreasonable.

P12.98. Prepare: Assume all the insulation comes from the air layer. Assume the value for the thermal conductivity of air in Table 12.7 is a good approximation for these conditions. Equation 12.31 applies.

Solve: Using Equation 12.31,

$$\frac{Q}{\Delta t} = \left(\frac{kA}{L}\right)\Delta T = \frac{(0.026\ \text{W/(m}\cdot\text{K)})(1.1\ \text{m}^2)}{0.025\ \text{m}}(34°\text{C} - (-20°\text{C})) = 62\ \text{W}$$

Assess: This is a large amount of power, even though air has the lowest thermal conductivity of all the materials in Table 12.7.