REVIEW AND SYNTHESIS: CHAPTERS 13–15

Review Exercises

1. **Strategy** Assume no heat is lost to the air. The potential energy of the water is converted into heating of the water. The internal energy of the water increases by an amount equal to the initial potential energy.

   Solution Find the change in internal energy.
   $\Delta U = mgh = (1.00\text{ m}^3)(1.00\times10^3\text{ kg/m}^3)(9.80\text{ m/s}^2)(11.0\text{ m}) = \boxed{108\text{ kJ}}$

2. **Strategy** Use Eq. (13-22). Form a proportion.

   Solution Find the temperature of the nitrogen gas.
   $v_{\text{rms}} = \sqrt{\dfrac{3kT}{m}}$, so $\dfrac{v_{\text{N}}}{v_{\text{He}}} = 1 = \sqrt{\dfrac{m_{\text{He}}T_{\text{N}}}{m_{\text{N}}T_{\text{He}}}}$.
   Therefore, $T_{\text{N}} = \dfrac{m_{\text{N}}}{m_{\text{He}}}T_{\text{He}} = \dfrac{2\times14.00674}{4.00260}(273.15\text{ K}+20.0\text{ K}) = 2052\text{ K} = \boxed{1779°\text{C}}$.

3. **Strategy** Set the sum of the heat flows equal to zero. Use Eqs. (14-4) and (14-9).

   Solution

   (a) Find the mass of ice required.
   $0 = Q_{\text{w}} + Q_{\text{ice}} = m_{\text{w}}c_{\text{w}}\Delta T_{\text{w}} + m_{\text{ice}}L_{\text{f}} + m_{\text{ice}}c_{\text{ice}}\Delta T_{\text{ice}} = m_{\text{w}}c_{\text{w}}\Delta T_{\text{w}} + m_{\text{ice}}(L_{\text{f}} + c_{\text{ice}}\Delta T_{\text{ice}})$, so
   $$m_{\text{ice}} = -\frac{m_{\text{w}}c_{\text{w}}\Delta T_{\text{w}}}{L_{\text{f}} + c_{\text{ice}}\Delta T_{\text{ice}}} = -\frac{(0.250\text{ kg})[4.186\text{ kJ/(kg}\cdot\text{K)}](-25.0\text{ K})}{333.7\text{ kJ/kg} + [2.1\text{ kJ/(kg}\cdot\text{K)}](10.0\text{ K})} = \boxed{74\text{ g}}.$$

   (b) Find the final temperature of the water, T, which includes the melted ice.
   $$0 = Q_{\text{w}} + Q_{\text{ice}}$$
   $$0 = m_{\text{w}}c_{\text{w}}\Delta T_{\text{w}} + m_{\text{ice}}L_{\text{f}} + m_{\text{ice}}c_{\text{ice}}\Delta T_1 + m_{\text{ice}}c_{\text{w}}\Delta T_2$$
   $$0 = m_{\text{w}}c_{\text{w}}(T - T_{\text{w}}) + m_{\text{ice}}L_{\text{f}} + m_{\text{ice}}c_{\text{ice}}\Delta T_{\text{ice}} + m_{\text{ice}}c_{\text{w}}(T - 273.15\text{ K})$$
   $$0 = (m_{\text{w}} + m_{\text{ice}})c_{\text{w}}T + m_{\text{ice}}(L_{\text{f}} + c_{\text{ice}}\Delta T_{\text{ice}}) - c_{\text{w}}[m_{\text{w}}T_{\text{w}} + m_{\text{ice}}(273.15\text{ K})]$$
   $$T = \frac{c_{\text{w}}[m_{\text{w}}T_{\text{w}} + m_{\text{ice}}(273.15\text{ K})] - m_{\text{ice}}(L_{\text{f}} + c_{\text{ice}}\Delta T_{\text{ice}})}{(m_{\text{w}} + m_{\text{ice}})c_{\text{w}}}$$
   $$T = \frac{\begin{array}{l}[4.186\text{ kJ/(kg}\cdot\text{K)}][(0.250\text{ kg})(273.15\text{ K}+25.0\text{ K}) + (0.037\text{ kg})(273.15\text{ K})] \\ -\ (0.037\text{ kg})\{333.7\text{ kJ/kg} + [2.1\text{ kJ/(kg}\cdot\text{K)}](10.0\text{ K})\}\end{array}}{(0.250\text{ kg} + 0.037\text{ kg})[4.186\text{ kJ/(kg}\cdot\text{K)}]} - 273.15\text{ K} = \boxed{11°\text{C}}$$

4. **Strategy** Determine how much larger the volume of the Pyrex container is than the volume of the water after the temperature decrease. Use Eq. (13-7).

   Solution Find the amount of water that can be added.
   $\dfrac{\Delta V}{V_0} = \beta\Delta T$, so $\Delta V_{\text{Pyrex}} - \Delta V_{\text{water}} = V_0(\beta_{\text{Pyrex}} - \beta_{\text{water}})\Delta T$
   $= (40.0\text{ L})(9.75\times10^{-6}\text{ K}^{-1} - 207\times10^{-6}\text{ K}^{-1})(20.0°\text{C} - 90.0°\text{C}) = \boxed{0.552\text{ L}}$.

5. Strategy Use the ideal gas law.

Solution Find the number of moles of air when the balloon is at 40.0°C.

$$PV = nRT,\ \text{so}\ n_2 = \frac{PV}{RT_2} = \frac{(1.00\ \text{atm})(1.013\times 10^5\ \text{Pa/atm})(12.0\ \text{m}^3)}{[8.314\ \text{J/(mol}\cdot\text{K)}](273.15\ \text{K} + 40.0\ \text{K})} = \boxed{467\ \text{mol}}.$$

6. (a) Strategy The maximum power emission is inversely proportional to the absolute temperature. Use Wien's law.

Solution Compute the surface temperature of the star.

$$T = \frac{2.898\times 10^{-3}\ \text{m}\cdot\text{K}}{\lambda_{\text{max}}} = \frac{2.898\times 10^{-3}\ \text{m}\cdot\text{K}}{700.0\times 10^{-9}\ \text{m}} = \boxed{4140\ \text{K}}$$

(b) Strategy Use Stefan's law of blackbody radiation.

Solution Compute the power radiated.

$$3 = \sigma A T^4 = [5.670\times 10^{-8}\ \text{W/(m}^2\cdot\text{K}^4)][4\pi(7.20\times 10^8\ \text{m})^2](4140\ \text{K})^4 = \boxed{1.09\times 10^{26}\ \text{W}}$$

(c) Strategy Intensity is power radiated per unit area.

Solution Compute the intensity measured by the Earth-based observer.

$$I = \frac{3}{A} = \frac{1.085\times 10^{26}\ \text{W}}{4\pi(9.78\ \text{ly})^2(9.461\times 10^{15}\ \text{m/ly})^2} = \boxed{1.01\times 10^{-9}\ \text{W/m}^2}$$

7. (a) Strategy Use Eqs. (14-12) and (14-13).

Solution Find the thermal resistance for each material.

$$R_{\text{wood}} = R_{\text{w}} = \frac{d_{\text{w}}}{\kappa_{\text{w}} A}\ \text{and}\ R_{\text{insulation}} = R_{\text{i}} = \frac{d_{\text{i}}}{\kappa_{\text{i}} A}.$$

Compute the rate of heat flow.

$$3 = \frac{\Delta T}{R_{\text{w}} + R_{\text{i}}} = \frac{A\Delta T}{\frac{d_{\text{w}}}{\kappa_{\text{w}}} + \frac{d_{\text{i}}}{\kappa_{\text{i}}}} = \frac{(2.74\ \text{m})(3.66\ \text{m})[23.0°\text{C} - (-5.00°\text{C})]}{\frac{0.0100\ \text{m}}{0.13\ \text{W/(m}\cdot\text{K)}} + \frac{0.0300\ \text{m}}{0.038\ \text{W/(m}\cdot\text{K)}}} = \boxed{320\ \text{W}}$$

(b) Strategy The area of the insulated wall has been reduced by half, so the rate of heat flow through it is reduced by half. The other half is glass. The total rate of heat flow is the sum of the two rates.

Solution Find the rate of heat flow.

$$3_{\text{g}} = \frac{\Delta T}{R_{\text{g}}} = \frac{A\Delta T}{\frac{d_{\text{g}}}{\kappa_{\text{g}}}} = \frac{\kappa_{\text{g}} A\Delta T}{d_{\text{g}}},\ \text{so}$$

$$3_{\text{total}} = \frac{\kappa_{\text{g}} A\Delta T}{d_{\text{g}}} + \frac{3}{2} = \frac{[0.63\ \text{W/(m}\cdot\text{K)}](1/2)(2.74\ \text{m})(3.66\ \text{m})[23.0°\text{C} - (-5.00°\text{C})]}{0.00500\ \text{m}} + \frac{324\ \text{W}}{2} = \boxed{18\ \text{kW}}.$$

8. (a) Strategy The net work done in one cycle is equal to the area inside the graph.

Solution Compute the net work done per cycle.

$$W = (4.00\text{ atm} - 1.00\text{ atm})(1.013\times 10^5\text{ Pa/atm})(0.800\text{ m}^3 - 0.200\text{ m}^3) = \boxed{182\text{ kJ}}$$

(b) Strategy and Solution The net heat flow into the engine is equal to the work done per cycle, so $Q_{\text{net}} = \boxed{182\text{ kJ}}$.

9. (a) Strategy Use the ideal gas law.

Solution Find the pressure at point *A*, which is the same as the pressure at point *D*.

$$P_D = P_A = \frac{nRT_A}{V_A} = \frac{(2.00\text{ mol})[8.314\text{ J/(mol}\cdot\text{K)}](800.0\text{ K})}{1.50\text{ m}^3} = \boxed{8.87\text{ kPa}}$$

Find the temperature at point *D*.

$$T_D = \frac{P_D V_D}{nR} = \frac{(8.87\times 10^3\text{ Pa})(2.25\text{ m}^3)}{(2.00\text{ mol})[8.314\text{ J/(mol}\cdot\text{K)}]} = \boxed{1200\text{ K}}$$

(b) Strategy The net work done on the gas is equal to the area inside the graph.

Solution Find the net work done on the gas as it is taken though four cycles.

$$W = 4(8.87\text{ kPa} - 1.30\text{ kPa})(2.25\text{ m}^3 - 1.50\text{ m}^3) = \boxed{23\text{ kJ}}$$

(c) Strategy The internal energy of an ideal monatomic gas is given by $U = \frac{3}{2}nRT$.

Solution Compute the internal energy of the gas at point *A*.

$$U = \frac{3}{2}nRT = \frac{3}{2}(2.00\text{ mol})[8.314\text{ J/(mol}\cdot\text{K)}](800.0\text{ K}) = \boxed{20.0\text{ kJ}}$$

(d) Strategy and Solution The total change in internal energy in four complete cycles is $\boxed{0}$, since the change in temperature is zero.

10. Strategy The temperature is constant and the heat entering the system is $Q = mL_\text{f}$.

Solution Find the change in entropy of the ice.

$$\Delta S = \frac{Q}{T} = \frac{mL_\text{f}}{T} = \frac{(2.00\text{ kg})(333.7\text{ kJ/kg})}{273.15\text{ K} + 0.0\text{ K}} = \boxed{2.44\text{ kJ/K}}$$

11. Strategy The gravitational potential energy of the steel ball is converted into heat. Set the sum of the heat flows equal to zero.

Solution Find the final temperature of the system, T.

$$0 = U_s + Q_s + Q_w$$
$$0 = -m_s gh + m_s c_s \Delta T_s + m_w c_w \Delta T_w$$
$$0 = -m_s gh + m_s c_s (T - T_s) + m_w c_w (T - T_w)$$
$$0 = -m_s (gh + c_s T_s) + (m_s c_s + m_w c_w)T - m_w c_w T_w$$
$$T = \frac{m_w c_w T_w + m_s (gh + c_s T_s)}{m_s c_s + m_w c_w}$$
$$T = \frac{(4.50\text{ L})(1\text{ kg/L})[4186\text{ J/(kg}\cdot\text{K)}](10.1°\text{C}) + (7.30\text{ kg})\{(9.80\text{ m/s}^2)(10.0\text{ m}) + [450\text{ J/(kg}\cdot\text{K)}](15.2°\text{C})\}}{(7.30\text{ kg})[450\text{ J/(kg}\cdot\text{K)}] + (4.50\text{ L})(1\text{ kg/L})[4186\text{ J/(kg}\cdot\text{K)}]}$$
$$= \boxed{10.9°\text{C}}$$

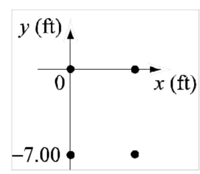
12. (a) Strategy Use the definition of pressure.

Solution Find the weight of the car.

$$P = \frac{F}{A},\text{ so } F = PA = (36.0\text{ lb/in}^2)(2\times 24.0\text{ in}^2 + 2\times 20.0\text{ in}^2) = \boxed{3170\text{ lb}}.$$

(b) Strategy Since the contact areas of the front tires are greater than those of the back tires, the front half of the car weighs more than the back half. Use the definition of center of mass.

Solution Compute the y-coordinate of the car's center of mass. Since $F = ma = PA$, the mass each tire supports is proportional to the contact area, so the contact areas can be used instead of the masses when computing the center of mass. Due to symmetry, the front tires can be combined, as well as the rear tires.



$$y_{CM} = \frac{m_{front} y_{front} + m_{rear} y_{rear}}{m_{front} + m_{rear}} = \frac{A_{front} y_{front} + A_{rear} y_{rear}}{A_{front} + A_{rear}}$$
$$= \frac{(48.0\text{ in}^2)(0) + (40.0\text{ in}^2)(-7.00\text{ ft})}{48.0\text{ in}^2 + 40.0\text{ in}^2} = \boxed{-3.18\text{ ft}}$$

13. Strategy Use Fourier's law of heat conduction for the copper rod and the heat of fusion for the ice.

Solution Find the rate of melting.

$$\frac{Q}{\Delta t} = \frac{mL_f}{\Delta t} = \kappa A\frac{\Delta T}{d},\text{ so } \frac{m}{\Delta t} = \frac{\kappa A \Delta T}{L_f d} = \frac{[401\text{ W/(m}\cdot\text{K)}]\pi(0.0100\text{ m})^2(100.0\text{ K})}{(333.7\text{ J/g})(1.00\text{ m})}\left(\frac{3600\text{ s}}{1\text{ h}}\right) = \boxed{136\text{ g/h}}.$$

14. (a) Strategy and Solution

The boiling temperature of water varies with pressure. If the pressure is high, the water molecules are pushed close together, making it harder for them to form a gas. (Gas molecules are farther apart from each other than are liquid molecules.) A higher pressure raises the temperature at which the coolant fluid will boil.

(b) Strategy and Solution

If you were to remove the cap on your radiator without first bringing the radiator pressure down to atmospheric pressure, the fluid would suddenly boil, sending out a jet of hot steam that could burn you.

15. Strategy The work done per stroke (cycle) is equal to the average pressure times the change in volume. The average power output is equal to the operating frequency times the work per stroke.

Solution Find the operating frequency *f*. Let p_{av} be the average power output.

$$fW_{stroke} = fP_{av}\Delta V = p_{av},\ \text{so}\ f = \frac{p_{av}}{P_{av}\Delta V} = \frac{27.6\times10^3\ \text{W}}{(1.3\times10^5\ \text{Pa})\pi(0.150\ \text{m}/2)^2(0.200\ \text{m})} = \boxed{60\ \text{Hz}}.$$

16. Strategy and Solution

(a) Since the blocks are made of the same material and are at the same temperature, they will have the same internal energy $\boxed{\text{if they have the same mass}}$.

(b) $\boxed{\text{Since they are at the same temperature, there is no net energy transfer between the two blocks}}$.

(c) $\boxed{\text{The blocks need not touch each other in order to be in thermal contact. They can be in thermal contact due to convection and radiation.}}$

17. (a) Strategy The maximum possible efficiency is that of a reversible engine.

Solution Compute the maximum possible efficiency.

$$e_r = 1 - \frac{T_C}{T_H} = 1 - \frac{323\ \text{K}}{535\ \text{K}} = 0.396\ \text{or}\ \boxed{39.6\%}$$

(b) Strategy Use energy conservation and the definition of efficiency of an engine.

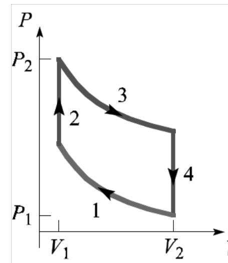
Solution Find the rate at which heat must be removed by means of a cooling tower.

$$\frac{W_{net}}{\Delta t} = \frac{Q_H}{\Delta t} - \frac{Q_C}{\Delta t} = \frac{W_{net}/e}{\Delta t} - \frac{Q_C}{\Delta t},\ \text{so}$$

$$\frac{Q_C}{\Delta t} = \frac{W_{net}}{e\Delta t} - \frac{W_{net}}{\Delta t} = \frac{W_{net}}{\Delta t}\left(\frac{1}{0.500e_r} - 1\right) = (1.23\times10^8\ \text{W})\left(\frac{1}{0.500(0.396)} - 1\right) = \boxed{4.98\times10^8\ \text{W}}.$$

18. (a) Strategy Use the ideal gas law, $PV = nRT$. Draw a qualitative diagram.

Solution First, the temperature is constant, so $P \propto V^{-1}$. Since the volume is reduced to one-eighth of its initial size, the pressure increases by a factor of eight. Next, the volume is constant, while the temperature and pressure increases. Then, the temperature is again constant. Finally, the volume is constant as the temperature and pressure decreases. The *P*-*V* diagram is shown.



(b) Strategy Refer to the diagram in part (a). Calculate the quantities for each step in the cycle. Note that the gas is diatomic.

Solution Step 1, isothermal process:

The work done on the gas is $W = nRT\ln\frac{V_i}{V_f} = (2.00\text{ mol})[8.314\text{ J/(mol}\cdot\text{K)}](325\text{ K})\ln 8 = 11.2\text{ kJ}.$

The change in the internal energy of the gas is 0 for an isothermal process.
The heat transferred is $Q = -W = -11.2$ kJ.

Step 2, isochoric process:
Without a displacement, work cannot be done, so $W = 0$.
The change in the internal energy of the gas is equal to the heat that enters the system, so the change in internal energy and the heat transferred are

$$\Delta U = Q = nC_V\Delta T = n\left(\frac{5}{2}R\right)\Delta T = \frac{5}{2}(2.00\text{ mol})[8.314\text{ J/(mol}\cdot\text{K)}](985\text{ K} - 325\text{ K}) = 27.4\text{ kJ}.$$

Step 3, isothermal process:

The work done on the gas is $W = nRT\ln\frac{V_i}{V_f} = (2.00\text{ mol})[8.314\text{ J/(mol}\cdot\text{K)}](985\text{ K})\ln\frac{1}{8} = -34.1\text{ kJ}.$

The change in the internal energy of the gas is 0 for an isothermal process.
The heat transferred is $Q = -W = 34.1$ kJ.

Step 4, isochoric process:
Without a displacement, work cannot be done, so $W = 0$.
The change in the internal energy of the gas is equal to the heat that enters the system, so the change in internal energy and the heat transferred are

$$\Delta U = Q = nC_V\Delta T = n\left(\frac{5}{2}R\right)\Delta T = \frac{5}{2}(2.00\text{ mol})[8.314\text{ J/(mol}\cdot\text{K)}](325\text{ K} - 985\text{ K}) = -27.4\text{ kJ}.$$

The results of the processes and the totals are shown in the table. (Note that the totals for work and heat differ slightly from the sums of the values for each step due to round-off error.)

Process	W (kJ)	ΔU (kJ)	Q (kJ)
Step 1	11.2	0	−11.2
Step 2	0	27.4	27.4
Step 3	−34.1	0	34.1
Step 4	0	−27.4	−27.4
Total	−22.8	0	22.8

(c) Strategy The efficiency is equal to the ratio of the net work done by the gas to the heat transferred into the gas.

Solution The work done by the gas is negative the work done on the gas.
$W_{net} = -(-22.8 \text{ kJ}) = 22.8 \text{ kJ}$ and the heat transferred into the gas is $Q_{in} = 27.4 \text{ kJ} + 34.1 \text{ kJ} = 61.5 \text{ kJ}$.

The efficiency of the engine is $e = \dfrac{W_{net}}{Q_{in}} = \dfrac{22.8 \text{ kJ}}{61.5 \text{ kJ}} = \boxed{0.371 \text{ or } 37.1\%}$.

(d) Strategy Use Eq. (15-17).

Solution Compute the efficiency of a Carnot engine operating at the same extreme temperatures.
$e_r = 1 - \dfrac{T_C}{T_H} = 1 - \dfrac{325 \text{ K}}{985 \text{ K}} = \boxed{0.670 \text{ or } 67.0\%}$

19. Strategy Use the ideal gas law and Hooke's law.

Solution Find the final pressure in terms of the initial pressure.
$\dfrac{P_2V_2}{P_1V_1} = \dfrac{nRT}{nRT} = 1$, so $P_2 = \dfrac{V_1}{V_2}P_1 = \dfrac{\frac{1}{4}\pi d^2 h}{\frac{1}{4}\pi d^2(h+\Delta x)}P_1 = \dfrac{h}{h+\Delta x}P_1.$
The magnitudes of the forces due to the spring, on the outside of the piston, and on the inside of the piston are $k\Delta x$, $k\Delta x + P_{atm}A$, and P_2A, respectively. Set the forces equal, substitute for P_2, and solve for Δx.

$k\Delta x + P_{atm}A = P_2A = \dfrac{h}{h+\Delta x}P_1A$, so $k(\Delta x)^2 + (kh + P_{atm}A)\Delta x - Ah(P_1 - P_{atm}) = 0.$

Thus, $\Delta x = \dfrac{-(kh + P_{atm}A) \pm \sqrt{(kh + P_{atm}A)^2 + 4kAh(P_1 - P_{atm})}}{2k}.$

Substituting $k = 1.00\times10^3$ N/m, $h = 0.100$ m, $P_{atm} = 1.013\times10^5$ Pa, $A = \dfrac{1}{4}\pi d^2 = \dfrac{1}{4}\pi(0.0500 \text{ m})^2$, and

$P_1 = 5.00\times10^5$ Pa, we find that $\Delta x = \boxed{0.168 \text{ m}}$, where -0.467 m is extraneous, since the gas expands.

MCAT Review

1. Strategy and Solution According to the second law of thermodynamics, heat never flows spontaneously from a colder body to a hotter body, therefore, heat will not flow from bar A to bar B. The correct answer is $\boxed{\text{C}}$.

2. Strategy Assume that the specific heat capacity of seawater is approximately the same at 0°C and 5°C.

Solution Find the approximate temperature *T*.
$0 = Q_0 + Q_5 = mc(T - 0°\text{C}) + mc(T - 5°\text{C})$, so $2T = 5°\text{C}$ or $T = 2.50°\text{C}$.

The correct answer is $\boxed{\text{B}}$.

3. Strategy Use the latent heat of fusion for water.

Solution The heat gained by the ice when melting is $Q = mL_f = (0.0180 \text{ kg})(333.7 \text{ kJ/kg}) = 6.01 \text{ kJ}$.

The correct answer is $\boxed{\text{C}}$.

4. **Strategy and Solution** Since $e = 1 - Q_C/Q_H = 1 - T_C/T_H$, decreasing the exhaust temperature will increase the steam engine's efficiency. The correct answer is $\boxed{\text{B}}$.

5. **Strategy and Solution** Since refrigerators remove heat by transferring it to a liquid that vaporizes, refrigerators are primarily dependent upon the heat of vaporization of the refrigerant liquid. The correct answer is $\boxed{\text{A}}$.

6. **Strategy and Solution** Steam is generally at a higher temperature than water and the specific heat of steam is lower than that of water, so water would be more effective than steam for changing steam to water. Circulating water brings more mass of water in contact with the condenser than stationary water, so it can carry away heat at a faster rate, therefore, it would be more effective for changing steam to water. The correct answer is $\boxed{\text{D}}$.

7. **Strategy and Solution** Since it is not possible to convert all of the input heat into output work, the amount of useful work that can be generated from a source of heat can only be less than the amount of heat. The correct answer is $\boxed{\text{A}}$.

8. **Strategy and Solution** The internal energy of the steam is converted into mechanical energy as it expands and moves the piston of the steam engine to the right, therefore, the correct answer is $\boxed{\text{C}}$.

9. **Strategy and Solution** The refrigerant must be able to vaporize (boil) at temperatures lower than the freezing point of water so that it can carry away heat (as a gas) from the contents of the refrigerator (which contain water) to cool and possibly freeze the contents. The correct answer is $\boxed{\text{B}}$.

10. **Strategy** The heat transferred to the water by the heaters was $Q_w = m_w c_w \Delta T_w$. The heat required for the oil is $Q_o = m_o c_o \Delta T_o$.

Solution Form a proportion and use the temperature changes of the oil and water and the specific heat and the specific gravity of the oil to obtain a ratio of heat required for the oil to that transferred to the water.

$$\frac{Q_o}{Q_w} = \frac{m_o c_o \Delta T_o}{m_w c_w \Delta T_w} = \frac{(0.7m_w)(0.60c_w)(60-20)}{m_w c_w (100-20)} = 0.21$$

So, 21% of the amount of heat transferred to the water is required to heat the oil to 60°C. Assuming the heaters work at the same rate for both the water and the oil, the time required to raise the temperature of the oil from 20°C to 60°C is $0.21(15\text{ h}) = 3.2\text{ h}$. The correct answer is $\boxed{\text{A}}$.

11. **Strategy and Solution** The high pressure would increase the pressure on the plug, making it more difficult to lift. The pressure difference between the air in the tank and the air outside of the tank would increase the fluid velocity when the tank is drained, thus, decreasing the time required to drain the tank. The time required to heat the oil would be the least likely affected, since the oil is fairly incompressible. The correct answer is $\boxed{\text{A}}$.