# Physics 1114: Unit 7 Homework: Answers

## Problem set 1

1. When 7 kg (about 15 pounds) of fuel oil are burned ($H_{\mathrm{C}} = 43\,\mathrm{MJ/kg}$), the (heat) energy released is $Q = mH_{\mathrm{C}} = 301\,\mathrm{MJ}$.

2. The amount of cheese needed to provide 8.5 million joules of energy is $m = Q/H_{\mathrm{C}} = (8.5\,\mathrm{MJ})/(17\,\mathrm{MJ\,kg^{-1}}) = 0.52\,\mathrm{kg}$ (Over a pound of cheese! This is *not* a recommended diet!)

3. To find the energy (in kcal) to heat 72 kg of water from 20°C to 26°C, we start with

$$Q = mc\Delta T = (72\,\mathrm{kg})(1.0\,\mathrm{kcal\,kg^{-1}C^{\circ -1}})(26°\mathrm{C} - 20°\mathrm{C}) = 432\,\mathrm{kcal}$$

4. When 110 kilocalories are removed ($Q = -110$) from 62 kg of water at 85°C, the temperature drop comes from $Q = mc\Delta T$:

$$\Delta T = \frac{Q}{mc} = \frac{-110\,\mathrm{kcal}}{(62\,\mathrm{kg})(1.0\,\mathrm{kcal\,kg^{-1}C^{\circ -1}})} = -1.77\,\mathrm{C}^{\circ}$$

so that $T_f = T_i + \Delta T = 83.2°\mathrm{C}$.

5. Coal is being burned to heat 108 kg of water from 18°C to 65°C. The efficiency of the transfer process is 80%, meaning that $Q_{\mathrm{w}} = 0.8Q_{\mathrm{coal}}$, or

$$m_{\mathrm{w}}c_{\mathrm{w}}\Delta T = 0.8m_{\mathrm{coal}}H_C$$

Solve for $m_{\mathrm{coal}}$:

$$m_{\mathrm{coal}} = \frac{m_{\mathrm{w}}c_{\mathrm{w}}\Delta T}{H_C} = \frac{(108\,\mathrm{kg})(4186\,\mathrm{J\,kg^{-1}C^{\circ -1}})(65°\mathrm{C} - 18°\mathrm{C})}{0.8(3.3\times 10^{7}\,\mathrm{J\,kg^{-1}})} = 0.80\,\mathrm{kg}$$

6. What is the equilibrium temperature $T_e$ of 4.0 kg of aluminum at 80°C added to 10 kg of air at 20°C? [Specific heat capacity of air = 703 J/(kg C°) at constant volume.] We assume that no (heat) energy enters or leaves the air-metal system, so the heat lost by the aluminum is gained by the air: $0 = Q_{\mathrm{Al}} + Q_{\mathrm{air}}$

$$0 = m_{\mathrm{Al}}c_{\mathrm{Al}}\Delta T_{\mathrm{Al}} + m_{\mathrm{air}}c_{\mathrm{air}}\Delta T_{\mathrm{air}}$$

where $\Delta T_{\mathrm{Al}} = (T_e - 80°\mathrm{C})$, and $\Delta T_{\mathrm{air}} = (T_e - 20°\mathrm{C})$.

$$0 = m_{\mathrm{Al}}c_{\mathrm{Al}}(T_e - 80°\mathrm{C}) + m_{\mathrm{air}}c_{\mathrm{air}}(T_e - 20°\mathrm{C})$$

$$0 = (m_{\mathrm{Al}}c_{\mathrm{Al}} + m_{\mathrm{air}}c_{\mathrm{air}})T_e - m_{\mathrm{Al}}c_{\mathrm{Al}}(80°\mathrm{C}) - m_{\mathrm{air}}c_{\mathrm{air}}(20°\mathrm{C})$$

$$T_e = \frac{m_{\mathrm{Al}}c_{\mathrm{Al}}(80°\mathrm{C}) + m_{\mathrm{air}}c_{\mathrm{air}}(20°\mathrm{C})}{(m_{\mathrm{Al}}c_{\mathrm{Al}} + m_{\mathrm{air}}c_{\mathrm{air}})} = 40.6°\mathrm{C}$$

(using $c_{\mathrm{Al}} = 920\,\mathrm{J\,kg^{-1}}$).

7. What is the specific heat capacity of a 2.5 kg object if it causes a 12 C° temperature drop in 10.0 kg of water? The object is initially at 5.0°C, and the water is initially at 80°C. (Thus $T_e = 68°\text{C}$.) As for the previous problem,

$$0 = m_\text{w} c_\text{w} \Delta T_\text{w} + m_\text{o} c_\text{o} \Delta T_\text{o}$$

$$m_\text{o} c_\text{o} \Delta T_\text{o} = -m_\text{w} c_\text{w} \Delta T_\text{w}$$

$$c_\text{o} m_\text{o} \Delta T_\text{o} = \frac{-m_\text{w} c_\text{w} \Delta T_\text{w}}{m_\text{o} \Delta T_\text{o}} = \frac{-(10\,\text{kg})(4186\,\text{J}\,\text{kg}^{-1}\text{C}^{\circ -1})(-12\,\text{C}^\circ)}{(2.5\,\text{kg})(68°\text{C} - 5.0°\text{C})} = 3190\,\text{J}\,\text{kg}^{-1}\text{C}^{\circ -1}$$

**Problem set 2**

1. When 0.80 kg of glass is added to 2.0 kg of water, the temperature of the water falls from 92°C to 86°C. To find the initial temperature of the glass, we again start with

$$0 = m_\text{w} c_\text{w} \Delta T_\text{w} + m_\text{g} c_\text{g} \Delta T_\text{g}$$

$$m_\text{g} c_\text{g} \Delta T_\text{g} = -m_\text{w} c_\text{w} \Delta T_\text{w}$$

$$\Delta T_\text{g} = \frac{-m_\text{w} c_\text{w} \Delta T_\text{w}}{m_\text{g} c_\text{g}} = 74.7\,\text{C}^\circ$$

(using $c_\text{glass} = 840\,\text{J}\,\text{kg}^{-1}\text{C}^{\circ -1}$).

$$\Delta T_\text{g} = T_e - T_i = 74.7\,\text{C}^\circ$$

Since $T_e = 86°\text{C}$, Then $T_i = 11.3°\text{C}$.

2. On the phase diagram, the vertical axis is temperature, the horizontal axis is energy ($Q$). See the diagram in the book to get familiar with the specific heats, latent heats, and melting and boiling temperatures. What determines the slopes of the lines?

3. There are three steps to take 1.5 kg of water from 20°C to ice at $-12°\text{C}$: 1) Cool the water down to $0°\text{C}$ ($Q_1$), 2) freeze the water to ice ($Q_2$), then 3) cool the ice from 0 to $-12°\text{C}$ ($Q_3$). All the $Q$'s are negative since heat is removed:

$$Q_\text{tot} = Q_1 + Q_2 + Q_3$$

$$Q_\text{tot} = m_\text{w} c_\text{w} \Delta T_\text{w} - m_\text{w} L_\text{f} + m_\text{ice} c_\text{ice} \Delta T_\text{ice}$$

With $\Delta T_\text{w} = -20\,\text{C}^\circ$, $\Delta T_\text{ice} = -12\,\text{C}^\circ$, and $c_\text{ice} = 2100\,\text{J}\,\text{kg}^{-1}\text{C}^{\circ -1}$, we get $Q_\text{tot} = -6.6 \times 10^5\,\text{J}$

4. The heat energy needed to melt 13.00 kg of silver that is initially at 20°C is

$$Q = mc\Delta T + m_\text{Ag} L_\text{f} = 4.0 \times 10^6\,\text{J}$$

($c = 236\,\text{J}\,\text{kg}^{-1}\text{C}^{\circ -1}$), ($\Delta T = 961°\text{C} - 20°\text{C}$), ($L_f = 8.7990 \times 10^4\,\text{J}\,\text{kg}^{-1}$)

5. A soda biscuit has a mass of $8.2 \times 10^{-3}$ kg and a Heat of Combustion of $1.26 \times 10^{7}$ J/kg. How many such biscuits must a 90-kg man eat to supply sufficient energy for him to climb the stairs to the top of a building 80 m high assuming 20% of the energy is utilized for climbing?

   Here, we equate the change in gravitational potential energy ($mgh$) with 20% of the combustion energy ($0.2 m_b H_c$):

   $$mgh = 0.2 m_b H_c$$

   and solve for the mass of biscuits $m_b$:

   $$m_b = \frac{mgh}{0.2 m_b H_c} = \frac{(90\,\mathrm{kg})(9.8\,\mathrm{m\,s^{-2}})(80\,\mathrm{m})}{(0.2)(1.26 \times 10^{7}\,\mathrm{J\,kg^{-1}})} = 2.8 \times 10^{-2}\,\mathrm{kg}$$

   So the number of biscuits is $m_b/(8.2 \times 10^{-3}\,\mathrm{kg}) = 3.4$

**Problem set 3**

1. Name, define and give an example of the three methods of heat transfer. Use complete sentences: See your notes and the book on conduction, convection, and radiation.

2. State the First and Second Laws of Thermodynamics: See the sample test and the book.

The rest of the Set 3 problems were not covered in class due to lack of time. They will not appear on the test.