Thermodynamics

WORKSHEET #1

Name: ______________________

1. A pigeon flying horizontally at a speed of 16.0 m/s drops a stolen Rolex watch. The timepiece falls to the ground in 2.90 s. (a) What was the watch's altitude when it was dropped? (b) how far horizontally did it travel before it smashed into the deck?

a. $x = x_o + v_o t + \frac{1}{2} at^2 = 0.5 \cdot 9.8\ m/s^2 \cdot 2.90^2\ s^2 = 41.209\ m =$ **41.2 m**

b. $d = v \cdot t = 16.0\ m/s \cdot 2.90\ s =$ **46.4 m**

2. How much heat is required to raise the temperature of 235 g of iron from 22.5°C to 234°C (the specific heat of iron is 0.45 J/g·K)?

$Q = mc\Delta T = 235\ g \cdot 0.45\ J/g{\cdot}K \cdot 211.5\ K = 22{,}366\ J =$ **22 400 J or 22.4 kJ**

3. You attend a birthday party and cram an enormous amount of cake and ice cream into your stressed digestive system. You find out that this little snack amounted to over 1500 food Calories. To work this food off, how much equivalent mechanical work would you have to do (in Joules please)? *(Note: 4.186 J = 1 cal. The definition of a "cal" is the amount of heat required to raise 1 g of water 1 degree celsius*–i.e. *the specific heat. Memorize this number.)*

1500 Cal · (1000 cal/1 Cal) · (4.186 J/1cal) = 6 279 000 J = **6 300 000 J or 6.3 MJ**

4. A 56.0 Ω resistor is placed into 350 g of water. It is hooked up to a 12 V battery. If the current flows for 15 minutes, we ignore the mass of the resistor, it is entirely immersed in the H_2O, by how many degrees would the water temperature increase?

$P = V^2/R = 12^2/56 = 2.57\ W$

$E = 2.57\ W \cdot 900\ s = 2314.3\ J$

$Q = mc\Delta T$

$\Delta T = Q/mc = 2314.3\ J/(350\ g \cdot 4.186\ J/g{\cdot\cdot}K) = 1.57961914\ °C =$ **1.6 °C**

5. A 345 g chunk of gold at 98.5°C is dropped into 656 g of H_2O at 22.5°. (a) What will the final temperature of the gold be after the system reaches equilibrium (c_{gold} = 0.13 J/g·K)? (b) What is the apparent weight of the gold in the water?

a. energy lost by gold = energy gained by water
$mc(T_i - T_f) = mc(T_f - T_i)$
$345\ g \cdot 0.13\ J/g{\cdot}K \cdot (98.5\ °C - T_f) = 656\ g \cdot 4.186\ J/g{\cdot}K \cdot (T_f - 22.5\ °C)$
$4417.725\ J - 44.85\ J/K \cdot T_f = 2746.016\ T_f - 61785.36\ J$
$66203.085\ J = 2790.866\ J/K \cdot T_f$
$T_f = 66203.085/2790.866\ °C = 23.7213413\ °C = \boxed{23.7\ °C}$

b. Need to do fluids first to be able to do this one.
$w_{app} = mg - F_{buoy}$
$= mg - \rho V_{gold} g$
$= mg - \rho(m/D_{gold})g = mg(1-\rho/D_{gold})$
$= 0.345\ kg \cdot 9.8\ m/s^2\ (1 - 1/19.3) = 3.2058\ N = \boxed{3.21\ N}$

6. Buffy the Vampire slayer is, as a change of pace, after a werewolf. Her weapon? A 9 mm Glock firing silver bullets! Anyway she spots one of the fearsome beasts and fires off a round, but misses! The bullet drills into a thick slab of insulating material. If the bullet has a mass of 3.50 g and a speed of 225 m/s, what is its final temperature when it comes to rest (c_{silver} = 0.23 J/g·K)?

Assuming all of the kinetic energy is converted to heat, AND assuming that all of the heat goes into the bullet...

$KE = \frac{1}{2} mv^2 = 0.5 \cdot 0.0035\ kg \cdot 225^2\ m^2/s^2 = 88.59375\ J$
$Q = mc\Delta T$
$\Delta T = Q/mc = 88.59375\ J/(3.5\ g \cdot 0.23\ J/gK) = 110.0543478110\ °C = \boxed{110\ °C}$

so, the final temp is 110 °C hotter than what its original temp was.

7. How much heat is required to melt 455 g of silver that is at a temperature of 25.9°C (melting point for silver: 961 °C, H_f for silver: 88.0 J/g)?

First you need to raise the silver to its melting point, then melt it.
$Q = mc\Delta T = 455\ g \cdot 0.23\ J/gK \cdot 935.1\ °C = 97{,}858\ J$
$Q = H_f \cdot m = 88.0\ J/g \cdot 455\ g = 40{,}040\ J$
$Q_{total} = 97{,}858\ J + 40{,}040\ J = 137{,}898\ J = \boxed{137\ 900\ J \text{ or } 137.9\ kJ}$

8. You have two samples of water at different temperatures. The 265 g sample is at 22.5°C. It is mixed with 385 g of water at 87.0°C. What is the final equilibrium temperature of the system after it is mixed?

Solution 1:

Energy lost by hot water = energy gained by cooler water

$m_{hot}c(T_i - T_f) = m_{cool}c(T_f - T_i)$

$m_{hot}(T_i - T_f) = m_{cool}(T_f - T_i)$

$385\ g\ (87\ °C - T_f) = 265\ g\ (T_f - 22.5\ °C)$

$33495\ g{\cdot}°C - 385\ g\ T_f = 265\ g\ T_f - 5962.5\ g{\cdot}°C$

$39457.5\ g{\cdot}°C = 650\ g\ T_f$

$T_f = \boxed{60.7\ °C}$

Solution 2:

If both materials are the same material in the same phase, then you can just do a weighted average of the temperatures.

$T_f = 87\ °C \cdot 385/(385+265) + 22.5\ °C \cdot 265/(385+265) = \boxed{60.7\ °C}$