SCI-123 Spring 2020

Chapter Two Examples

1. Determine the amount of energy (in joules) consumed by a 75 watt light bulb while it is lit for 24 hours.

   Solution: A watt is a J/sec, so we need to determine the number of seconds in 24 hours: 24 hours $\times$ 60 minutes/hour $\times$ 60 seconds/munute = 86,400 seconds. The total energy consumed, at 75 joule per second, is 75 $\times$ 86,400 = $\boxed{\text{6,480,000 J}}$.

2. How high will one J of energy lift a one liter parcel of dry air assuming the density of the parcel is 1.22 g/L?

   Solution: The mass of the one-liter parcel, in kg, is 1.22/1000 = 0.00122 kg. Use the potential energy formula to determine the elevation z: $1 = 0.00122 \times 9.8 \times z \Rightarrow z = 1/(0.00122 \times 9.8) =$ $\boxed{\text{83.6 m}}$.

3. A 2-liter parcel of dry air is, initially, stationary at 1500m. It falls to the surface of the earth within the downdraft of a thunderstorm. Calculate the parcel's speed at the earth's surface assuming all PE is converted to KE. Take ρ_s =1.22 g/L.

   Solution: First, determine the potential energy (PE) of the parcel. For that, we need the mass of the parcel. The mass is determined from the volume and density. The density is given by $\rho(1500) = 1.22e^{-1500/8000} = 1.01$ g/L. The 2-liter parcel has a mass of 2 $\times$ 1.01 gm = 2.02 gm = 2.02/1000 = 0.00202 kg. Then, PE = 0.00202 $\times$ 9.8 $\times$ 1500 = 29.4 J. Assuming all of the 29.4 J of PE is converted to kinetic energy (KE), we have $\frac{1}{2}mv^2 = 29.4$. Solving for v gives $v = \sqrt{\frac{2\times 29.4}{0.002}}$ = $\boxed{\text{171 m/sec}} \approx \boxed{\text{377 mi/hr}}$.

4. One-half inch of rain collects in the bottom of a 12-inch diameter bucket during a summer rain shower. Calculate the amount of latent heat released to the air by the condensation associated with this volume of water.

   Solution: Calculate the volume of water in cubic centimeters (cc) by first calculating the volume in cubic inches and then converting to cc. The area of the bucket's bottom (radius = 6 inches) is $\pi 6^2 = 113.1$ square inches. The volume of water in cubic inches is 0.5 $\times$ 113.1 = 56.5. Each inch is 2.54 centimeters, so the water volume in cc is 56.5 $\times$ 2.54^3 = 926.7 cc. Each cc of water has a mass of 1 gram, so the mass of water is 926.7 g The heat of condensation for water is 600 cal/g, so the total energy liberated in the condensation of the water in the bucket is 600 $\times$ 926.7 = $\boxed{\text{555,999 cal}}$.

5. Suppose 0.01 gram of water condenses and the heat of condensation warms the dry mass of a three-liter parcel of air near the surface of the earth. Determine the temperature increase of the dry parcel.

   Solution: The 0.01 gram of water gives up 6 cal in condensation. The mass of the dry parcel is 3 $\times$ 1.22 g/l = 3.66 g. Use $\Delta Q = Cm\Delta T$ to give 6 cal = $0.24 \times 3.66 \times \Delta T$. Solving for ΔT gives a $\boxed{6.83\ C^\circ}$ increase in temperature.

6. Consider the volume of water given by an area of 1 square meter and a depth of 1 cm. Suppose this mass of water has a temperature increase of 2° C, between sun rise and 4:00 PM, due to the incident radiation of the sun. Calculate the resulted temperature rise in an equal mass of sand receiving an equal amount of radiant energy.

   Solution: Begin by calculating the mass of water based on the volume. One square meter = 100 cm × 100 cm = 10,000 cm^2, so the volume of water is 1 cm × 10,000 cm^2 = 10,000 cc = 10,000 grams (1 cc water = 1 gm water). Consequently, the amount of energy $\Delta Q = mC\Delta T = 10,000 \cdot 1 \cdot 2 = 20,000$ cal. Now, calculate the temperature increase for sand with the same increase of energy : $\Delta Q = mC\Delta T \Rightarrow \Delta T = \frac{\Delta Q}{mC} = \frac{20,000}{10,000 \cdot 0.19} = \frac{2}{0.19} = \boxed{10.5° \text{ C}}$. NOTE: The answer is easily determined without first calculating the amount of energy ΔQ involved. Because the heat capacity of sand is 0.19 that of water, the temperature increase for sand is $\Delta T_{sand} = \frac{\Delta T_{water}}{0.19} = \frac{2}{0.19} = 10.5$.

7. A toaster surface heats up to a temperature of 140° F while moderately toasting two slices of bread. Use Wien's Law to determine the wavelength of the radiation spectrum maximum.

   Solution: $\lambda_{max} = \dfrac{2897}{T}$ where the temperature T in this case is $T = \frac{5}{9}(140 - 32) + 273 = 333$ K. The radiation spectrum maximum has a wavelength of 2897/333 = $\boxed{8.7\ \mu\text{m}}$.

8. Suppose the same toaster, as above, has a surface area of 0.1 square meter, and it takes 2 minutes to toast two slice of bread. Determine the total radiative energy emitted from the toaster in joules.

   Solution: Use the Stefan-Boltzmann formula to first determine the number of watts per meter squared that were emitted from the toaster's surface. E = 5.67 $\times 10^{-8}$ × 333^4 = 697.2 watts per meter squared. Multiply this result by 0.1 to determine the wattage: 697.2 × 0.1 = 69.72 watts. One watt is a joule per second, so the total energy in joules is 69.72 J/sec × 120 seconds = $\boxed{8{,}366 \text{ J}}$. NOTE: This number is an over-estimation because we are assuming the toaster's surface temperature is a constant 140° F. The reality is that it will take a good portion of the 120 seconds for the toaster's surface to reach the temp of 140° .