SCI-123	Spring 2026

Chapter Two Exercises

Directions: Solve the assigned exercises on a separate sheet of paper. Be sure to show intermediate steps. You may work cooperatively, but each student must turn in her or his own work.

1. A single 100-watt bulb is lit for 1 hour.
   (a) Determine the amount of energy, in joules, consumed by the bulb in one hour.
   (b) Calculate the vertical distance, in meters, this amount of energy would lift a 150-pound person.
2. A motionless (so KE = 0) two-liter parcel of dry air starts at an elevation of 1200 meters.
   (a) Calculate the mass of the air parcel in kilograms. Assume $\rho_s = 1.22$ gm/L.
   (b) Calculate the potential energy (PE) of the parcel.
   (c) The parcel falls to the surface (where its PE is now zero) and its vertical speed reaches 20 m/s. Calculate the kinetic energy (KE) of the parcel.
   (d) Note that the gain in KE of the parcel is less than the loss in PE of the parcel. How would you account for (explain) the difference in these numbers? Consider the other "form" of energy the parcel has, as well as possible mechanisms that may cause a net loss of energy of the parcel.
3. A 100 L parcel of air has an initial horizontal speed of 10 m/s. As it moves along the surface of the earth, friction slows the parcel to 5 m/s. If half of the KE lost by the parcel heats the parcel, determine the temperature increase of the parcel in ° C. Assume the parcel's density is 1.22 gm/L.
4. Suppose 500 gm of water vapor condenses to make a cloud about the size of an average room.
   (a) Assuming the latent heat of condensation is 600 cal/gm, how much energy would be released to the dry air in the room?
   (b) If the total mass of dry air is 100 kg, calculate the change in temperature (ΔT) of the dry air in degrees C.
5. A summer thunderstorm dumps a uniform 1 inch of rain on the area within the city limits of Decorah.
   (a) Calculate the volume of water (in cubic centimeters) in this rainfall. (NOTE: The area within the city limits of Decorah is roughly 6.4 square miles.)
   (b) Estimate the amount of latent heat (in joules) released into the atmosphere during such an event. Assume all of the rainfall mass began as water vapor and condensed into raindrops.
   (c) The atomic bomb that destroyed Hiroshima near the end of World War II is estimated to be equivalent to 20 kilotons of TNT. Calculate the ratio of energies (thunderstorm energy /bomb energy) of these events given that a kiloton of TNT is equivalent to 4.2×10^{12} joules.
6. (a) The average surface temperature for Decorah on June 21 is 65° F. Use the Stefan-Boltzmann formula to determine the total energy, in Joules, that earth's surface will radiate from a one-meter square area over a 24-hour period.

(b) The U.S. Energy Information Administration reports that the average daily electricity use by an American household is approximately 30 kilowatt-hours (kWh). Converting this to the number Joules is done by multiplying by 1000 (kilowatts to watts) and then by 3600 (watt = J/sec times 3600 sec per hour) resulting in an energy use of 108 million Joules. What percentage of this number could be supplied by the Earth's long wave radiation assuming perfect efficiency in capturing and converting the energy for household use?

7. Planet A and planet B belong to a distant solar system.

   (a) A astrophysicist determines the wavelength of maximum energy emission is 7.2425 μm for planet A. Determine the surface temperature of the planet A in Kelvins.

   (b) The total power emitted from the surface of planet B is 459,279 watts. The surface temperature of the planet is 300K. Determine the surface area of the planet B in m^2.

8. The purpose of this exercise is to determine the net thermal radiation loss or gain of the human body on a daily basis. The skin surface of a human body is a boundary between two objects that emit thermal EMR throughout the day. One object, of course, is the human body. The other is the atmosphere that surrounds the human. The magnitude of each surface area is that of the human because the atmosphere surrounds the human.

   Suppose the surface temperature of a human body averages 90° F, and the atmospheric temperature surrounding the human is a constant 70° F. Use the Stefan-Boltzmann formula to calculate the total net radiation, in large calories, for the human body on a 24-hour basis. Assume a total body surface area of 1.7 m^2 (The average is 1.8 for males and 1.6 for females[1].)

9. If you were to design a thermal imaging device for the detection of human bodies, for what approximate range of wavelengths, in μm, should the device be most able to detect?

10. A very simple energy balance model for estimating the Earth's average global annual temperature is

$$I_{in} = I_{out} \Rightarrow \pi r^2(1-\alpha)E_{solar} = 4\pi r^2 \epsilon\sigma T_{earth}^4$$

   where r is the Earth's radius, $\alpha = 0.33$ is the Earth's albedo, $\sigma = 5.67 \times 10^{-8}$ is the Stefan-Boltzmann constant, $E_{solar} = 1367$ is the solar constant and ϵ is the Earth's emissivity.

   (a) T_{earth} is known to be 15° C. Determine the Earth's emissivity.

   (b) Data suggest that since 1972, Arctic ice has been decreasing at an average rate of about 3 percent per decade, while Antarctic ice has increased by about 0.8 percent per decade[2]. The net loss of polar ice results in a decrease in the Earth's albedo. Using the value for ϵ found in part (a), estimate the Earth's average surface temperature if the earth's average albedo decreased to 30%.

[1] Bender, Arnold E. & David A. Bender. Body Surface Area. A Dictionary of Food and Nutrition. New York: Oxford University Press, 1995.

[2] National Snow and Ice Data Center (https://nsidc.org/)