PHYS 328

Homework #1

Due : 3 Sept. 2013

Please submit answers to questions 1 - 3 in hard copy format at the beginning of class on 3 Sept. You may also submit the Mathematica based question in hard copy, or email it to me at dslavsk@luc.edu. Please send the .nb file through your Loyola email addy so I can verify authorship (and the time stamp of the email must be prior to the start of class.)

1. This question explores the relative cost of human vs. fossil fuel energy. A human being hard at work will expend approximately 100 W of power (if you use an exercise bike or treadmill that displays power, see how hard you have to work to expend 100 W). A small compact car traveling at highway speeds will expend approximately 100 kW. Use available data (such as the federal rate for reimbursing mileage) to determine how much money is required to operate a car for an hour. Now, suppose that the energy is provided by work study students pushing the car. How many students would you need to move the car at the same speed? Using the current U.S. minimum wage, how much would it cost to operate that car for an hour? Show all work and state explicitly all assumptions you make and values you use in your calculations.

2. Determine the number of molecules in a cubic meter of air at the surface of the Earth at room temperature and 1 atm of pressure.

3. The number density of the atmosphere decreases exponentially with height according to :

$$n(z) = n_0\, e^{-z/H}$$

where $n(z)$ is the number density at any height z above the surface of the Earth, n_o is the number density at the surface of the earth, and H is a constant called the scale height of the atmosphere. For the earth, the scale height is 8 km.

Find the total number of molecules in a 1 m^2 column reaching from the surface of the Earth to the "top" of the atmosphere, several hundred kilometers above the surface of the Earth. Assuming the Earth is a sphere of radius R (R = 6400 km), estimate the total number of molecules in the Earth' s atmosphere.

4. One of the most interesting aspects of an advanced course in thermodynamics is the introduction of probability theory to understand both macroscopic and microscopic systems. Since we will be dealing with systems containing an Avogadro' s number of particles, we will also have to learn the mathematics of *very* large numbers. So let' s get started understanding some of the basics of probability as it will apply to our thermodynamic systems.

Suppose we flip a fair coin N times (a fair coin is one that has a 1/2 probability of turning heads or tails on any individual flip) and want to know the likelihood of obtaining n heads. We can describe this probability as :

$$P(N, n) = \frac{N!}{n!\,(N-n)!}\, p^n\, q^{(N-n)}$$

where p is the probability of success (in this case = 0.5) and q is the probability of failure (in this case, also 0.5).

Let' s see how we can use this equation. Suppose we flip a coin 10 times, we expect that our most likely outcome is 5 heads and 5 tails. Let' s see what that probability is :

$$P(10, 5) = \frac{10!}{5!\quad 5!}\left(\frac{1}{2}\right)^5\left(\frac{1}{2}\right)^5 = 0.2461$$

Are you surprised that the most likely outcome has a probability less than 1/4?

Assignment to submit :

Write a short program(s) in Mathematica (and you must use Mathematica, not any other language) that will :

a) Calculate the probability of obtaining n heads out of N flips. Do not assume the coin is fair, in other words, p and q must be floating variables. Use this program to find the probability of obtaining 1, N/2, and N heads for a fair coin for N = 10, 100, 1000. (10 pts)

b) Produce a plot (remember you know about ListPlot) showing the variation of P (N, n) for the cases where N = 10, 100, 1000. (10 pts)

c) Describe how the height and sharpness of the probability curve vary as N increases? (10 pts)

d) Plot the P (N, n) vs. n distribution for the case N = 100 and p = 0.6 (q = 0.4). Explain why the peak occurs where it does. (5 pts)