Homework set #2 (assigned 24 September, due 3 October)

Instructions. As before, these questions have many parts to them. Please make sure you read all of each of these questions, and answer all the questions I ask you. Please remember that, while I do not officially "count off" for grammar, spelling, and overall writing style, I do care about such things deeply. You should *definitely* proofread your homeworks not only to see if your answers make sense and have the correct units labeled, but also to see if your wording and spelling are correct.

Some of the math questions here are pretty straightforward and some require more creative thinking. I want to see how well you can do at each of those things. It will definitely help me to see what you have done if you write, in words, what it is that you are doing and trying to do (in addition to writing mathematical formulae).

There is lots of other useful advice in the solution set to homework 1. I suggest you read it and take it to heart – especially the part about starting this homework *early*. There are more questions in this homework than in the first one, but the questions are generally simpler. Problems 1 and 2 will require the most mathematical analysis. Other problems require simpler math, or just discussion of a concept.

1) Your weight is really the product of your mass and the acceleration due to gravity where you are, i.e., on the surface of the Earth (check out Newton's Second Law). In other words, weight is a **force**. Mass, in English units, is expressed in a unit called the slug. (a) What is your mass, in slugs? [Note: Acceleration due to gravity at the Earth's surface is around 32 feet/sec^2.] Now consider Newton's universal law of gravity, and switch to metric units (1 slug = 14.6 kg). (b) What is your mass in kg? (c) What is your mass 1000 km above the Earth's surface? (The radius of the Earth is around 6400 km, and the mass of the Earth is around 6×10^{24} kg.) (d) What is your weight, in Newtons, at 1000 km above the Earth's surface? Note that 1 Newton (the metric unit of force) is the amount of force required to accelerate 1 kg by 1 m/sec^2.

Now you can figure out how much you would weigh on the moon. (e) What is your mass (in kg) on the moon? (f) Now find your weight (in Newtons) on the moon, using $M_{moon} = 7 \times 10^{22}$ kg and $r_{moon} = 1700$ km. (g) What would your weight be, in pounds, on the Moon?

Lastly, here are the same questions for Mars: (h) What would your weight be, in pounds and in Newtons, on Mars? The mass of Mars is around 6×10^{23} kg and its radius is around 3400 km.

2) It turns out that the mass of 1 **mole** of a substance is simply the *atomic weight*, expressed in grams. The *atomic weight* of an atom is the simply the number of protons plus the number of neutrons of that atom. Examples: one mole of hydrogen has a mass of 1 g; one mole of helium has a mass of 4 g (because the atomic weight of helium is 4: two protons and two neutrons, each of which has an atomic weight of 1).

The amount of energy released by metabolizing one mole of glucose ($C_6H_{12}O_6$) is 2870 kJ (a Joule (J) is the metric unit of energy; 1 J is equal to 1 Newton times 1 meter or 1 Newton meter or 1 kg m^2/sec^2; and 1 kiloJoule is equal to 1000 Joules).

To climb a set of stairs is to do **work** (in the technical, mechanical definition; vertical motion turns out to be the only part that matters, not horizontal distance). Work is defined this way: $W = F \times d$ where W is the amount of work done (units: Joules), F is the force (units: Newtons), and d is the distance (units: meters) over which the force is applied.

The US RDA (Recommended Dietary Allowance, published by the Food and Drug Administration) suggests that young, active, adult males and females require something like 2500 and 2000 calories, respectively, for their daily intakes (your mileage may vary, of course). These FDA/RDA calories are actually kilocalories by the scientific definition, and 1 calorie (really kilocalorie) is equal to 4.184 kJ or 4184 J.

What percentage of your RDA do you expend climbing the stairs to my office? You can assume that all your caloric intake for the day is in pure glucose, which is (probably) not true, but makes the problem easier. How many grams of glucose do you have to eat to power the climb to my office? How much of a candy bar is this?

Other information you might want to know: 1 slug is equal to 14.6 kg. I have given you a lot of different kinds of information here without a specific road map. I want to see how you take apart this problem. I suggest you start by writing down what you know and what you are trying to find, identify the steps you need to take, and proceed from there.

3) Domain Archaea is vastly underknown: there are many organisms that belong in Domain Archaea that have not yet been identified. Why is this? Where and how would you look for Archaea organisms, and why? I am looking for a fairly complete discussion here – more like a paragraph than a sentences.

4) Most telecommunications satellites are in geostationary orbits, that is, they are always above the same place on the Earth. That is why satellite dishes don't have to track back and forth across the sky to find their satellites. How far above the Earth's surface do geostationary satellites orbit? Another kind of satellite orbit is called LEO (low Earth orbit). Some weather satellites and the space station occupy these orbits. Their orbital periods are around 90 minutes. How far above the Earth's surface are these satellites? For problems like this (actually, for every problem), a great way to start is to write down what you know, and what you are trying to find out. Oftentimes, this simple step can take you a long way toward figuring out how to do a problem. You must show your work for this problem; it is not acceptable to just look up the answer.

5) The relationship between temperature and distance from the Sun in the Solar nebula probably followed a relation something like this:

$$T(r) = T_1 \sqrt{\frac{1\ \mathrm{AU}}{r}}$$

where T_1 is the temperature at 1 AU (assume $T_1 = 273$ K), r is distance from the Sun in AUs, and $T(r)$ is the temperature at some distance r. Write down what the temperatures in the Solar nebula would have been at the current orbital distances of the planets. Also write down, for each planet, the density of the planet.

Chemical species in the Solar nebula could only condense where temperatures were cooler than the species' condensation temperatures. Where in the Solar nebula could the following species (with their condensation temperatures in parentheses) have condensed? These species are listed in decreasing order of density. The species of interest are nickel (1300 K), iron (1300 K), calcium (1400 K), silicon (1200 K), aluminium (1400 K), magnesium (1200 K), sodium (600 K), water (150 K), ammonia (75 K), and methane (30 K). How do the condensation locations of these species correlate to planetary densities? Why is this? Do the densities and condensation temperatures exactly correlate, why or why not?

6) The magnitude of the tides raised on the Earth by the Moon and by the Sun is proportional to m^2/r^6, where m is the mass of the other body and r is the distance to the other body. Which is greater, tides raised on the Earth by the Moon or by the Sun? How much bigger? Explain, using this information, the difference between neap and spring tides.

7) The planet Uranus has an unusual orientation: its rotation pole is in the ecliptic plane[1]. What are seasons like on Uranus? Feel free to draw some pictures in your answer. I am looking for a fairly complete discussion here (more like a paragraph than a sentence, though you shouldn't feel like this guideline is absolute). Additional fact if you feel like doing a calculation: Uranus' orbital distance from the Sun is around 19 AU, that is, you might discuss how long seasons last on Uranus.

[1] The ecliptic plane is the plane in which the planets of the Solar System orbit.

8) Massive stars are quite luminous and have very short lives. Knowing what you have learned about how stars work and how fusion works, explain why you think this is.

9) It was announced recently that, based on recent results, the value of the Hubble constant (H_0) is now known to be very close to 71 km/sec/Mpc. How fast are galaxies that are 200, 500, and 1000 Mpc away moving away from us? Draw a Hubble diagram using this new value that shows these three galaxies. Explain what this diagram shows and means.