Homework #4
Due in Class on September 22, 2011

QUESTIONS ABOUT LIGHT

1. **Definitions.** In your own words, write a one-sentence definition for each of the following terms: Electromagnetic radiation, spectrum, wavelength, and frequency. For wavelength and frequency, you should also specify their units of measurement.

2. **Wavelength & Frequency.** Announcers at a certain radio station say they are broadcasting at "103.2 FM on your dial," meaning that they are transmitting light at a frequency of 103.2 MegaHertz (MHz). What is the wavelength in meters of the radio waves from this station? (You will need a calculator for this problem, and the speed of light, which is 300 million meters per second. You may also need to look up the metric system prefix "Mega")

3. **Light Carries Energy.** Write 3-4 sentences explaining why UV light can cause skin cancer but radio waves from cell phones cannot.

QUESTIONS ABOUT THE SUN

4. 620 million tons of Hydrogen are converted to Helium per second in sun (1 ton=2,000lb and 1kg=2.2lb). The reaction that produces one helium nucleus consumes four hydrogen nuclei, each of which has a mass of 1.67×10^{-27}kg.
    a. How many hydrogen atoms are consumed in the sun per second?
    b. How many helium atoms are created?
    c. What is 620 million tons as a percentage of the mass on the Sun if the Sun's total mass is 2×10^{30}kg?
    d. What is it as a percentage of the mass of the Earth, which has a total mass of 6×10^{24}kg?
5. In reality, only ~10% of the mass of the Sun's hydrogen will ever be consumed by fusion, because the Sun's core is the only place hot enough for fusion to occur.
    a. Assuming that the sun continues burning that fuel at the same rate for its whole lifetime, how long will the sun live in years? You may also assume that the sun began with 100% of its mass in the form of Hydrogen.
    b. If the sun has been burning for approximately 4.6 billion years, approximately what percentage of the sun's total lifetime has already passed?
6. The energy released by each reaction of four protons becoming one helium atom is 26.7MeV (Mega Electron volts, where the electron volt is a unit of energy that is important on atomic scales).
    a. How much total energy is released by the sun per second (in MeV)?
    b. Let's put this energy into context by comparing it to the energy released in a modern thermonuclear bomb explosion, which is the equivalent of 1.2 million tons of TNT. A ton of TNT is equivalent to 4.2 GJ (Giga Joules, where Joule is another unit of energy), and 1 Joule is equivalent to 6.2×10^{12} MeV. How many nuclear bombs worth of energy does the sun produce every second?
7. This energy propagates outward from the sun in three dimensions, so only a fairly small portion of it ends up reaching the earth.

   c. How much solar energy is intercepted by the earth every second? (hint: consider the total energy of the sun spread over the surface area of a sphere at the distance of earth from the sun (1 AU in radius). What percentage of that total sphere does the Earth take up/intercept? You will need to consider the "cross sectional area" of the Earth which is just the area that it takes up in two dimensions. The formula for the surface area of a sphere is $4/3*pi*radius^2$)
   d. If the earth were two times father away, but its size remained the same, how much solar energy would it receive relative to what it receives now?
8. 3% of the solar flux comes in the form of neutrinos, each of which has an energy of ~2eV.
   a. How many neutrinos flow through the Earth per second?
   b. How many neutrinos flow through your body per second? (Hint: you will have to estimate the "cross-sectional area" of your body, or the percentage of a sphere centered on the sun that is taken up by your body – explain your reasoning in coming to this number in your answer)
   c. In your entire lifetime only about one neutrino will interact with the atoms in your body. Use this fact (and an estimate of the average human lifetime) to calculate the probability of a neutrino interacting with a particle of matter.