Your name: ___________________ TA name: ____________________

Written HW 6: Sun and laser light
(due Thurs, Nov 11, 2010 at 5 PM)

Turn in this written homework in the appropriate slot in the brown Homework Cabinet at the entrance of the HelpRoom, Duane G2B90. Please STAPLE pages together, and **put your name and TA name at the top of every page!**

In all written homework, you will be graded on the clarity and completeness of your answer. ***No credit*** *will be given for an answer in a calculation without a derivation, even if the answer is correct. A calculation without units is also incorrect.*

IN THIS HW, YOU MAY CHOOSE TO DO EITHER PART 1 OR PART 2. YOU DO NOT NEED TO DO BOTH. If you hand in both without specifying which one you wish to be graded, the TA will choose one at random to grade.

1. Sun light

At noon on a nice summer day in Boulder, each 1 cm^2 of surface is exposed to perhaps 150 mW (milliWatts) of visible radiation.

a) You are considering adding solar panels to your house and want to see whether they will provide enough energy for your household needs. If your solar panels covered an area of 2 meter by 8 meters (that's about a dozen typical solar panels) how much solar power would be hitting the surface of the panels at noon on a clear day? (And, does 2 m x 8 m seem like a reasonable size, by which we mean, would it fit on a typical household roof?)

b) If the solar panels were 10% efficient at converting the solar energy into electrical energy, how much electrical energy would have been harnessed in 1 hour? (Assume that the exposure is pretty steady for that hour at 150 mW/ cm^2). For how many hours could this amount of energy power a 60 W bulb?

c) The above problems considered peak solar intensity at noon on a nice summer day. Of course, that doesn't last all day, nor all year. Make some reasonable "guesstimates" to predict how much electrical energy these panels would likely produce over the course of a (Boulder) year. An average American home uses about 500-1000 kW hrs of electrical energy each month. Will these panels be sufficient for "average Americans"? Given your numbers, (and considering how Boulder sunshine compares to other US cities) what can you conclude about the role of solar energy in the US' future energy balance?

2. Laser light

A laser is a device that is not only used in many technological applications but also for scientific experiments.

a) At CU Boulder, high intensity laser light pulses of extremely short duration are generated for experiments with atoms and molecules. The energy in such laser pulses is relatively small, just about 2 mJ, but the pulse duration is very short, about 10 fs (= 10^{-14} s). How large is the power output of such a laser?

b) In the experiments the laser pulses are focused on a circular spot with a radius of about 10 μm. How large is the intensity of the laser pulse at the focus? (Intensity is measured in W/m^2). How does this intensity compare with the intensity of sunshine in part 1? (You don't need to have done part 1 to answer this question.) How large is the electric force exerted by the electric field of the *focused* laser pulse on an electron? (Hint: For this, you will need to use a formula we didn't cover in class, it's Eq. 22-8 of your text, which relates intensity to E-field.) Is it feasible to liberate (ionize) the electron from the proton in a hydrogen atom with such a laser pulse? (Hint: The electric force between the electron and the proton in the hydrogen atom is calculated in section 16-5 of your textbook.)

c) In another scientific application laser light is used to measure the distance of the earth to the moon. To this end, the Apollo 11 astronauts have installed a mirror on the moon. A laser pulse is sent from the earth, is reflected from the mirror on the moon, and is detected at its starting point. In the experiment the time elapsed for the round trip is measured. Calculate this time and explain why this measurement determines the earth-moon distance. (Something for you to think about as we study optics, but you don't need to write up - how can you build a mirror so that the laser light always reflects *straight back*? A good hint can be found in the hallway display outside G1B30 as you leave the physics building!)

d) The measurement pinpoints the distance between moon and earth with a staggering precision of almost 1 mm. What does this tell you about the precision of the time measurement?