EE119 Homework 1

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Due Friday, January 30, 2009

1. The Electromagnetic Spectrum and Units

   There are many different units used to describe light. Wavelengths, energies, and frequencies are all related to each other through the speed of light and Planck's constant. These relationships are given in the first set of lecture notes. In the table below, one unit describing light is given for each type of light. Fill out the table for the rest of the units:

	wavelength(nm)	energy (eV)	frequency (Hz)
Silicon bandgap		1.1 eV	
infrared light	1200 nm		
red ligth	630 nm		
yellow light	575 nm		
green light	530 nm		
blue light	450 nm		
ultraviolet light	100 nm		
x-rays light	5 nm		
Power Transmission			60 Hz
KDFC Radio Station			102.1 MHz

2. Unpolarized sunlight is reflected off the surface of a lake (n_{water}=1.33) at an angle of 70° to normal. What fraction of the total incident sunlight is reflected? What fraction of the reflected light is s-polarized? What fraction is p-polarized?

3. (a) Unpolarized light passes through two linear polarizers. The second polarizer is aligned so that its transmission axis is 80° from that of the first polarizers. What fraction of the incident is transmitted through the two polarizers? How is this light polarized?

   (b) You position a third linear polarizer between the first two. At what angle should the transmission axis of this polarizer be aligned to maximize the total intensity of transmitted light?

4. (a) Superman has been told that he is faster than a speeding bullet, but he has never checked whether this is actually true. He does an experiment and finds he is indeed faster than a speeding bullet! In fact, his friend Spiderman found that it only took him 2 seconds to fly around the earth (40,000km). Superman decides to try and impress Lois Lane by showing her that he is faster than light! He is looking for a material to build a 100m tube in which he can pipe light into, and race it for 100m. What is the index of refraction he needs the tube to be made out of if he is to tie the 100m race?

   (b) Superman is happy with his win at the race and decides to make a cup of tea. He uses his heat vision to send infrared radiation (λ= 1000nm) at an angle of 75° from

the normal towards a cup of water to heat it up. The index of refraction of water is 1.33. Assuming his eyes are unpolarized (equal s-polarization and p- polarization), what is the ratio of the energies of p-polarized to s-polarized light transmitted into the water? If his eyes were only p-polarized, what is the optimal angle to heat the water at, such that the infrared radiation is fully transmitted? What about if his eyes were only s-polarized?

5. (a) On a sunny day in Berkeley at noon, the sun shines from directly overhead with an intensity of approximately 10^{21} photons per square meter per second. You want to boil a liter (1000 grams) of water in a pot that has a diameter of 10 cm. Since water only absorbs infrared light (at approximately 1000 nm), each photon will deliver the same amount of energy to the water (This is, of course, a simplification, but it will give you an upper limit on how fast direct sunlight can boil water). Remember that it takes 1 calorie of energy to raise 1 gram of water 1 degree C, and that there are 4.18 Joules in a calorie. Water has an index of refraction of 1.33. What fraction of the incident sunlight will enter the water? (Hint: reflected and transmitted light intensity added together equal the incident light intensity). Assume for simplicity that all the light that enters the water is absorbed. How long will it take to bring the water to a boil from room temperature (25° C)?

   (b) Now assume that instead of‘ “thermalizing” each photon and only getting 1000 nm worth of energy from it, the water is a black body that can absorb all the energy contained in a photon. Assume that the energies of incoming photons are uniformly distributed between infraredred (1000nm) and violet (400 nm) (remember that energy is proportional to frequency, not wavelength!). Now how long will it take to boil a liter of water in the container?

6. A narrow beam of white light passes through a prism at an angle of 70° from normal. The apex angle of the prism is 50°. The index of refraction of the prism is 1.51 for red light and 1.56 for violet light.

   (a) At what angle does the light emerge? What is the angular spread of the emerging light?

   (b) If you place a screen 10 cm away from the prism, by what distance will the red light be separated from the violet light?

   (c) You want to disperse the white light without using a prism, so you decide to use a piece of glass. How thick a piece of glass would you need to place in the beam of white light to separate the red and violet light by the same distance that you calculated in part 6b, using the same incident angle?

7. **Hecht 4.58** A glass block having an index of 1.55 is covered with a layer of water of refractive index 1.33. For light traveling in the glass, what is the critical angle at the interface?

8. The critical angle of a prism is the angle of incidence at which no light exits the opposite side of the prism from the apex angle A right angle prism (see notes) has two critical angles that correspond to the two different apex angles. What are these critical angles?

9. Green light has a wavelength of 530 nm in air. What wavelength will it have in glass that has an index of refraction of 1.52?