

1. (7 pts) To improve the efficiency of a solar cell, you can put a thin-film anti-reflective coating on it to reduce the amount of light which reflects off the the solar cell's surface and thereby increase the amount which enters the cell. To figure out what type of coating is needed, you need to know the index of refraction of your solar cell. But you can't measure it using Snell's law or by putting it into a Michelson interferometer because the material that solar cells are made of is absorptive — they have to absorb light in order to generate electricity! In fact most of the visible light hitting a silicon solar cell is absorbed in the first $4\mu\text{m}$ of the silicon. So how can you measure the index of refraction of a solar cell?
2. (8 pts) In a sodium chloride crystal (NaCl — the kind of salt we put on food) the sodium ions form a cubic lattice. The lattice constant a (the distance by which each sodium ion is separated from its nearest neighbors) is 0.565nm at room temperature. I send a beam of x-rays at a crystal of NaCl . I find that the $m = 1$ diffraction order off of the Bragg planes which are spaced by a is traveling in a direction which is 20° from the direction of the incident beam of x-rays. I then shoot the same beam of x-rays at a crystal of KCl (which has a similar structure as NaCl) and I find that this particular diffraction order now makes an angle of 17.9° with respect to the incident beam. (a) What is the wavelength of the x-rays? (b) What is the lattice constant for the KCl crystal?
3. (8 pts) Light from an incandescent light bulb is unpolarized. I shine light from a light bulb with an intensity of $1\text{W}/\text{m}^2$ onto an "ideal" linear polarizer. (a) What is the intensity of the light which passes through the polarizer? (b) If a second polarizer is placed after the first one, with its transmission axis rotated 35° from the transmission axis of the first polarizer, what will the intensity of the light be after passing through the second polarizer? (c) If I add a third polarizer after the second one, with its transmission axis rotated 90° from the transmission axis of the first polarizer, what will the intensity of the light be after passing through the third polarizer? (d) If I remove the second polarizer, what will the intensity of the light exiting the third polarizer be?
4. (7 pts) You are looking across the surface of a very large, very calm lake. You are wearing polarized sunglasses, and you notice that your sunglasses nearly completely cut out the glare from the sun reflecting off of the lake. What is the angle from the horizon to the position of the sun in the sky? The density of water is $1000\text{kg}/\text{m}^3$, and the index of refraction for water is 1.333.

Extra problems I recommend you work (not to be turned in)

- In my lab we use a device called an acousto-optic modulator or AOM. In this device a tiny piezo-electric transducer generates traveling sound waves in a clear solid. The sound waves generate small changes in the index of refraction in the solid, such that light can scatter off of the sound waves. The waves simply act as Bragg planes. Imagine that I use a cube of glass as my solid. The speed of sound in my glass is $3800\text{m}/\text{s}$. My transducer is attached to one of the surfaces of the cube. I generate sound waves at a frequency of 40MHz and send a laser beam with a wavelength of 633nm into the glass. If I want to generate the first order Bragg diffraction peak, at what angle should I send a laser beam relative to the surface that the transducer is attached to?
- Another device we use is called a wave plate. These devices are thin disks made of a birefringent material such that as light passes through the disk the index of refraction is different for vertically an horizontally polarized light. Imagine that I want to make a wave plate out of quartz (who's two indices of refraction are 1.55328 and 1.54418) which will take a beam of light which is polarized at an angle of 30° from vertical and convert it into a beam which is polarized at an angle of -30° from vertical. How thick should the plate be?
- Some of the windows on our vacuum chambers in our lab have thin-film coatings to allow lasers to enter the vacuum chambers with little loss due to reflection. We also have some windows which have no coatings, but which are placed at an angle. How does putting the windows at an angle help reduce losses due to reflection?