1. Turn in your lab report, including the data plots, as problem 1 of this problem set.

2. The optical activity of quartz, defined as the difference in the refractive indices for the two circular polarizations, is equal to $7 \times 10^{-5}$, at the wavelength of a sodium lamp.
   (a) I have a slab of quartz which is 2.6 mm thick. I illuminate it using a sodium lamp, with x-polarized radiation, and then put the output through an x-polarizer. What fraction of the power incident on the quartz slab is transmitted through the polarizer?
   (b) Now, I do the same experiment, except instead of x-polarized incident radiation, I use right-hand circular polarized radiation for the input. Now, what fraction is transmitted?

3. A bundle of parallel rays is incident on a thin lens of focal length $f = 50$ cm. We showed in lecture that, if the rays are all parallel to the optic axis (i.e., they all have $\theta \mathbf{n} = 0$), then they all cross at a focal point on the optic axis, a distance $f$ beyond the lens. However, in this case, the bundle of input rays approaches the lens at an angle of $2^\circ$ with respect to the optic axis. Use ray matrices to answer these two questions:
   (a) What is the distance from the lens to the focal point?
   (b) What is the displacement of this focal point from the axis?

4. In lecture 18 (slide 7) we discussed the generation of sidebands – new frequency components generated by modulating the phase of a light wave. An analogous process to the generation of frequency sidebands can occur if we modulate the wave spatially, rather than temporally. We can show that this leads to the generation of new spatial frequency components.

Consider a plane wave propagating in the $z$ direction: $E(\vec{r}) = E_0 e^{jkz}$. (Note: the time dependence is still there, we’re just not writing it.) At any plane of constant $z$, this wave has an amplitude that doesn’t vary with $x$ (or $y$). But now, let’s imagine that we can modulate the intensity in the $x$ direction, so that it oscillates as a function of $x$, with a very small amplitude $\eta$. The modulated wave $E_{mod}$ could be written: $E_{mod}(\vec{r}) = E_0 \left[ 1 + \eta \cos(\beta x) \right] e^{jkz}$. Here, $\eta$ is the amplitude of the variation of the electric field along the $x$ direction (around its average value), and $\beta$ is the frequency of variation along $x$. In this problem, we assume that $\eta << E_0$ and that $\beta << k_0$. Show that this spatial variation of the amplitude of the wave is equivalent to the addition of two new plane waves to the original plane wave. You will find that these two new plane waves are not propagating parallel to the $z$ axis. These are the new spatial frequency components (i.e., waves with different $k$ vectors, although the same wavelength). Determine their angles of propagation relative to the $z$ direction. This result will resurface in lecture 31, when we discuss diffraction gratings.

5. Suppose I have a thin plano-convex lens with a focal length of 60 cm. What is the focal length of this lens under water? The lens is made of BK7 glass with a refractive index of 1.52, and $n_{water} = 1.33$. 