Phys 375 – Homework #4

1) *Birefringent* crystals have a special axis, known as the optical axis. Light waves which are polarized parallel the optical axis experience a different index of refraction than light waves polarized perpendicular to the optical axis. For calcite, ($n_{||}$ = 1.486), while ($n_{\perp}$ = 1.658), at the sodium wavelength of 589.3 nm.

a) (3 points) Show that the difference in time it takes the two polarizations to cross a calcite crystal of thickness d is $\Delta t = \frac{d}{c}\left|n_{||} - n_{\perp}\right|$.

b) (3 points) Show that the phase difference between the two polarization after crossing the crystal is $\Delta\phi = 2\pi\frac{d}{\lambda}\left|n_{||} - n_{\perp}\right|$.

c) (3 points) What thickness is needed to create a phase difference of π/2? (A crystal of this thickness is known as a *quarter-wave plate*.)

2) (3 points) At what angles will light be completely linearly polarized when reflecting from a diamond-air interface? Consider both the air-into-diamond and diamond-into-air cases. The index of refraction of diamond is 2.42.

3) (3 points each) An unpolarized light source shines upon an ideal linear polarizer (*polarizer A*) whose polarization axis is vertical and is fixed. Next the light beam passes through a rotating linear polarizer (*polarizer B*). The total output intensity is measured by a photodiode.

a) Sketch the intensity observed by the photodiode as a function of the angle of the rotating *polarizer B*, with the zero angle referring to vertical. Sketch at least one full rotation. (The y-axis of your sketch can be in arbitrary units).
b) We now place an additional fixed linear polarizer (*polarizer C*) *after* the rotating *polarizer B*. *Polarizer C* has its polarization axis fixed in the horizontal direction. Make a new sketch to represent the intensity as a function of rotation angle for this arrangement. Sketch at least one full rotation, and describe briefly in words what has changed compared to part (a). (Again, we are not concerned with the overall magnitude, just the shape as a function of rotation angle.)
c) We now remove *polarizer C*, and we place a sugar solution between *polarizer A* and *rotating polarizer B*. The sugar causes the polarization direction of the light to rotate by small angle, roughly 10 or 20 degrees. Make a new sketch to represent the intensity as a function of rotation angle for this arrangement. Sketch at least one full rotation, and describe briefly in words what has changed compared to part (a). (You may consider the sugar to rotate the light in either the clockwise or counter-clockwise direction. Again, we are not concerned with the overall magnitude of the intensity, just the shape.)