**HW O1. Elliptical Polarization.** Consider the electric wave traveling down the z-axis with the most general polarization state

$$\vec{E} = E_x \hat{i} + E_y \hat{j} = E_{ox} \hat{i} \cos(kz - \omega t) + E_{oy} \hat{j} \cos(kz - \omega t + \phi).$$

Choosing different values for $\phi$ leads to a rich variety of polarizations. Choosing $\phi = 0$ leads to linearly-polarized light and taking $E_{ox} = E_{oy}$ with $\phi = \frac{\pi}{2}$ leads to circularly polarized light. Here you will take $\phi = \frac{\pi}{2}$ and $E_{ox} > E_{oy}$. Set $z = 0$ and let $\theta = -\omega t$ like we did in class and show that the electric field vector traces out an ellipse. Give the equation for the ellipse in terms of the variables $E_x$, $E_y$, and constants $E_{ox}$, $E_{oy}$. Finally give the eccentricity in terms of the constants.

**HW O2. Quarter Wave Plate Design.** A birefringent material allows for double refraction affecting perpendicular polarization states differently. The different wave speeds for each polarization state can allow us to retard one polarization state by $\pi/2$ and produce elliptically polarized light. Consider normal incidence and quartz, where for 590 nm light the index of refraction $n_e = 1.553$ for the extraordinary wave and the index of refraction for the ordinary wave $n_o = 1.544$. By the way, calcite is too brittle for a wave plate.

(a) Show that the relative phase shift between the light for the 2 polarization directions is

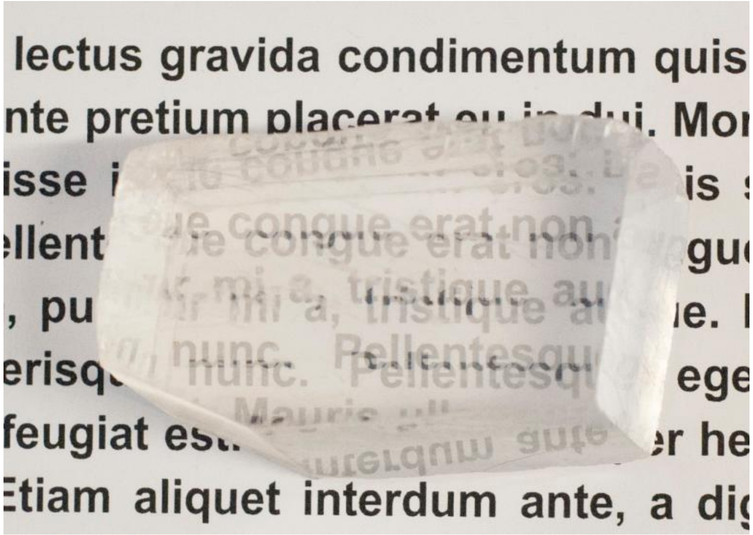
$$\Delta\phi = (2\pi / \lambda)\, d\, (n_e - n_o),$$

where $\lambda$ is the wavelength of the incoming light in vacuum or air, d is the thickness of the birefringent plate, and $n_o$, $n_e$ are the indexes of refraction for the ordinary and extraordinary rays. If $d\,(n_e - n_o) = \lambda / 4$, then $\Delta\phi = \pi / 2$. But $d\,(n_e - n_o) = (4m + 1)\, \lambda / 4$ also works where m = 1, 2, 3 …, i.e. an integral number of wavelengths plus $\lambda / 4$.

(b) Find the minimum thickness d, i.e. m = 0, tailored to 590 nm for quartz.

(c) Give the thickness for a quarter-wave quartz plate tailored to 590 nm where m = 200.

**HW O3. Birefringence in Rocks.**

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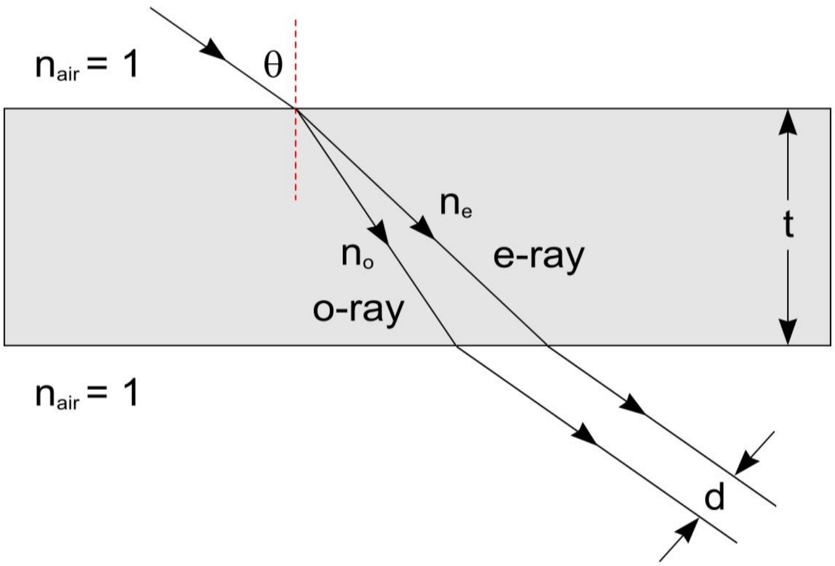
Near the wavelength of the sodium doublet, i.e., around 590 nm, the index of refraction for the ordinary ray and extraordinary wave are

$$n_o = 1.658$$

and

$$n_e = 1.486 .$$

Pick up the calcite so that there is a layer of air between the print and the calcite.




Find $d$ in terms of $n_o$, $n_e$, the incident angle $\theta$, and thickness $t$.

Find $d$ to 3 sig figs for calcite where $\theta = 30.0°$, and $t = 7.00$ cm.