1. A small light rests on the bottom of a swimming pool 1.6 meters deep. Though the light radiates uniformly in all directions, from above the light emerging from the water (n=1.34) surface forms a circle. What is the diameter of the circle? (Hint- total internal reflection)

\[ \Theta_e = \sin^{-1} \left( \frac{1}{1.34} \right) = 48.3^\circ \]

\[ r = 1.6 \tan 48.3^\circ = 1.8 \text{ m} \]

\[ \text{Diameter} = 2(1.8) = 3.6 \text{ meter} \]

2. A prism used in a spectrometer separates wavelengths because the index of refraction is different for different wavelengths (called dispersion). If the index for a red light (λ=680nm) is 1.40 and for a blue light (λ=460nm) is n=1.43, what will be the angular separation of these two colors emerging from the second face of a 60° -60° -60° prism if the two colors enter together at 30° from the normal to the first face.

\[ \sin 30 = 1.4 \sin \Theta_r \]

\[ \Theta_{r1} = 20.9 \]

\[ \alpha = 90 - 20.9 = 69.1 \]

\[ \beta = 180 - 69.1 - 60 = 50.9 \]

\[ \Theta_{i2} = 90 - \beta = 39.1^\circ \]

\[ \frac{\sin \Theta_r}{\sin 60} = 1.4 \sin 39.1^\circ \]

\[ \Theta_{r2} = 65.45^\circ \]

\[ 65.45 - 62 = 3.45^\circ \]
3. If you are using a diffraction grating instead of a prism in your spectrometer to separate the 460 and 680nm lines in problem 2 spectra, what will be the angular separation in the first order spectra for these lines if your grating had 6000 lines/cm.

\[
\sin \theta_{460} = \frac{460 \times 10^{-9}}{1.6 \times 10^5} \Rightarrow \theta_{460} = \frac{1}{(6000 \times 10^5)} = \frac{1}{6 \times 10^5}
\]

\[
\sin \theta_{680} = \frac{(680 \times 10^{-9})(6 \times 10^5)}{1} \Rightarrow \theta_{680} = 24^\circ
\]

\[
\Delta \theta = 8^\circ
\]

4. An object 5 cm. high is located 25 cm. to the left of a converging lens f=12cm. A second lens f=10 cm is placed 12 cm to the right of the first lens. Find and describe the final image of this optical system.

\[
\frac{1}{d_{o1}} + \frac{1}{d_{i1}} = \frac{1}{F_1}
\]

\[
\frac{1}{25} + \frac{1}{23} = \frac{1}{12} \quad d_{i1} = 23 \text{ cm} \quad m_1 = \frac{-23}{25} = -0.92
\]

\[
\frac{1}{d_{o2}} + \frac{1}{d_{i2}} = \frac{1}{F_2} \quad \frac{1}{-11} + \frac{1}{10} = \frac{1}{10}
\]

\[
\frac{1}{d_{i2}} = \frac{1}{10} + \frac{1}{11} \quad d_{i2} = 5.24 \text{ cm} \quad m_2 = \frac{-5.24}{11} = -0.476
\]

\[
M = m_1m_2 = 0.476(-0.92) = -0.44
\]

Final image 5.24 cm r.t. of lens 2, inverted, 2.2cm to
5. A thin film \((n=1.35, t=500\text{nm})\) forms a bubble (air inside and out). When white light (400-700 nm) illuminates it at normal incidence, what will be the wavelength, or wavelengths that dominate the reflected light?

\[2t = (m + \frac{1}{2}) \lambda_{air} \quad \text{constructive} \]

\[
\frac{2 \times (500\text{nm})(1.35)}{m + \frac{1}{2}} = \lambda_{air}
\]

\[
\frac{1350}{m + \frac{1}{2}} = \lambda_{air}
\]

For \(m = 0\) and \(m = 1\), it is infrared.

For \(m = 2\), \(\lambda_{air} = 540\text{nm}\)

For \(m = 3\), \(\lambda = 386\text{nm}\) (U.V.)

B. If the same film rests on glass \((n=1.5)\), what will be the wavelength(s) most strongly reflected and what wavelength(s) will be most dominant in the transmitted light?

\[
\frac{\lambda_{air}}{m} = \frac{\lambda}{1.35}
\]

\[
\lambda_{air} = \frac{1350}{m}
\]

\[
\lambda_{air} = \frac{1350}{2} = 675\text{nm} \quad \text{both visible}
\]

\[
\lambda_{air} = \frac{1350}{3} = 450\text{nm}
\]

For transmitted max want reflective minimum

\[
2t = \frac{1350}{m + \frac{1}{2}} = 540\text{nm}
\]