Problem 1.1 (10 pts) A movie camera with a single lens of focal length 75 mm takes a picture of a 180-cm-high person standing 27 m away. What is the height of the image of the person on the film? You may assume that because 27 m is >> 75 mm, that the distance between the film and the lens is 75 mm.

\[
f = 7.5 \times 10^{-3} \text{ m} \\
\ell = 2.7 \text{ m} \\
\ell' = \frac{\ell f}{\ell - f} = \frac{(7.5 \times 10^{-3} \text{ m})(2.7 \text{ m})}{2.7 \text{ m} - 7.5 \times 10^{-3} \text{ m}} = 7.5 \text{ mm}
\]

Problem 1.2 (10 pts): A piece of plastic (n = 1.4) of thickness t = 0.3 \( \mu \text{m} \) is illuminated with light of wavelength 500 nm. What is the phase change attributable to the path length in the plastic?

\[
\Phi = \frac{\lambda}{\lambda_n} \times 2nt \\
= \frac{3.3 \times 10^{-6}}{500 \times 10^{-9}} \times 2 \times 0.3 \times 10^{-6} \text{ m} \\
= 2.0 \times 3.3 \times 10^{-8} \text{ rad} \\
= 1.0 \times 10^{-7} \text{ rad}
\]
Problem II.2 (25 pts): Consider the object and two lenses shown in the figure. If the object is 2 cm high and erect,

(a) Where is the image of the first lens relative to the location of the first lens?

\[
\frac{1}{P_1} + \frac{1}{i_1} = \frac{1}{f_1}
\]

\[
\frac{1}{i_1} = \frac{1}{f_1} - \frac{1}{P_1} = \frac{1}{-20} - \frac{1}{20} = -\frac{2}{20} = -\frac{1}{10} = -0.1
\]

So \( i = -10 \text{ cm} \)

(b) What is the location of the final image?

\[
\frac{1}{i_e} = \frac{1}{f_1} - \frac{1}{P_e} = \frac{1}{-10} - \frac{1}{20} = \frac{1}{20}
\]

So \( i_e = 20 \text{ cm} \)

(c) What is the size of the final image and is it erect or inverted?

\[
m_i = -\frac{i_1}{P_1} = +\frac{10}{-20} = \frac{1}{2}
\]

\[
M = m_1 m_2 = \left(\frac{1}{2}\right) (-1) = -\frac{1}{2}
\]

\[
m_e = -\frac{i_2}{P_e} = -\frac{20}{20} = -1
\]

\[h = M h_1 = \left(-\frac{1}{2}\right)(2) = -1 \text{ cm} \]

(d) Is the final image real or virtual?

\[\boxed{\text{Real}}\]
Midterm II
Problem 3
3:30pm Lecture
8:30pm Recitation

\[ \lambda = 480 \text{ nm} \]

\[ \frac{\lambda}{2} \text{ phase shift at } A \]

no phase shift at B

Bright fringe \( \Rightarrow \) path length difference \( \pm \) phase shift = integer \( \times \lambda \)

call thickness at \( i \)th fringe \( t_i \)

\[ (m_i - \frac{1}{2}) \lambda = 2t_i \Rightarrow m_i \lambda - \frac{1}{2} \lambda = 2t_i \]

\[ \Rightarrow m_i \lambda = 2t_i + \frac{1}{2} \lambda \Rightarrow m_i = \frac{2t_i}{\lambda} + \frac{1}{2} \]

\[ \Rightarrow \Delta m = m_{16} - m_6 = \left( \frac{2t_{16}}{\lambda} + \frac{1}{2} \right) - \left( \frac{2t_6}{\lambda} + \frac{1}{2} \right) \]

\[ = \frac{2}{\lambda} (t_{16} - t_6) \equiv \frac{2}{\lambda} \Delta t \]

\[ \Rightarrow \Delta t = \frac{\lambda}{2} \Delta m = \frac{480 \text{ nm}}{2} \times 10 = \boxed{2400 \text{ nm} = 2.4 \mu m} \]
Problem IV (25 pts):

In a double slit experiment the wavelength of the light $\lambda$ is 500 nm, the slit separation is $17 \, \mu m$, and the slit width is 4 $\mu m$. In this problem, you will need to consider both the diffraction of the light through each slit and the interference of the light from the two slits.

(a) At what angle (in radians) is the first minima in the diffraction pattern?

\[
\sin \theta = \frac{\lambda}{d} = \frac{500 \, \text{nm}}{17 \, \mu \text{m}} = 0.135 \, \text{rad}
\]

(b) How many interference maxima are located within the central maximum of the diffraction pattern?

\[
m = \frac{\theta_{\text{max}}}{\theta} = \frac{4.25}{0.135} \quad \text{so there are 4 bright fringes}
\]

(c) What is the angular location in radians of the 5th side maxima in the interference pattern?

\[
\sin \Theta = \frac{5 \lambda}{d} = \frac{5 \times 500 \, \text{nm}}{17 \, \mu \text{m}} = 0.147 \, \text{rad}
\]

(d) What is the intensity of this maximum relative to that of the central maximum?

\[
I = I_m \left(\frac{\sin \alpha}{\alpha}\right)^2 \left(\frac{\sin \beta}{\beta}\right)^2 = I_m \left(\frac{\sin \alpha}{\alpha}\right)^2 \left(\frac{\sin \beta}{\beta}\right)^2 = I_m \left(\frac{\sin 3.62 \, \text{rad}}{3.62 \, \text{rad}}\right)^2
\]

\[
\frac{I}{I_m} = \left(\frac{\sin \alpha}{\alpha}\right)^2 \left(\frac{\sin \beta}{\beta}\right)^2 = \left(\frac{0.147 \, \text{rad}}{0.147 \, \text{rad}}\right)^2 \left(\frac{0.135 \, \text{rad}}{0.135 \, \text{rad}}\right)^2
\]

\[
\frac{I}{I_m} = \left(\frac{0.147 \, \text{rad}}{0.135 \, \text{rad}}\right)^2
\]