Physics 108 Final Exam (Spring of 2018)

1. **Thin lens**

You have two thin lenses, one with focal length of + 10 cm, and the other with focal length of - 10 cm. You may use them to form an image of an object on a screen.

1) (**10 points**) With the lens of f = + 10 cm, where would you place the lens from t a real object y_0 to form an real image with a linear magnification of 10.
2) (**5 points**) If instead you use the lens of f = + 10 cm as a magnifying glass, what is the achievable angular magnification?
3) (**5 points**) With the lens of f = - 10 cm, where would you place the lens relative to a virtual object y_0 to form a 10-fold enlarged image on the screen?

2. **Geometric optics and diffraction**

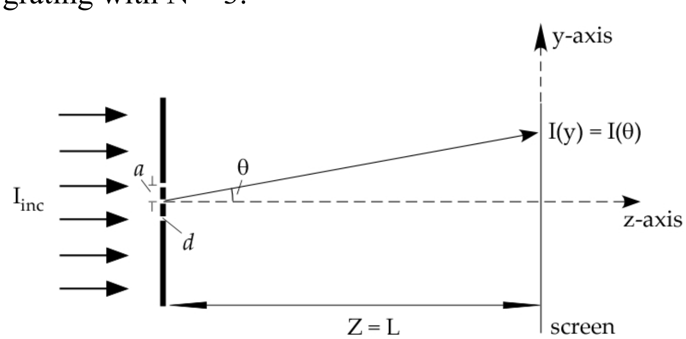
You have a simple telescope consisting of a large objective lens with f_0 = 150 cm and an eye piece with f_e = 2.5 cm. The objective lens has a diameter of D = 9 cm. The mean wavelength in the visible range is taken to be $\lambda = 0.5$ µm (1 µm = 10^{-6} m).

1) (**10 points**) Find the angular magnification of the telescope.
2) (**5 points**) Find the smallest angle that this telescope can resolve due to diffraction.
3) (**Extra 5 points**) Let the distance to the Moon be L = 4×10^8 m. What is the smallest separation between two point sources on the Moon you can resolve using this telescope?

3. Interference:

Instead of Young's double slits, you have now three identical slits that are equally separated by a distance of a. The widths of three slits d are smaller than a. Let a collimated (plane-wave) beam with wavelength λ and intensity I_{inc} normally incident on the slits. A screen is placed at a distance $L >> a$ behind the slits and parallel to the plane that contains the slits. Assume that $d^2/\lambda L << 1$ (the Fraunhofer diffraction limit).

1) (**10 points**) Find the intensity of the light on the screen as a function of out-going angle θ away from the incident direction when only the middle slit is open.
2) (**10 points**) Find the intensity of the light on the screen as a function of the angle θ when all three slits are open.
3) (**5 points**) Confirm your result in Part (2) by treating the problem as a transmission grating with N = 3.



4. **Fresnel equations (reflection and transmission coefficients)**

1) (**5 points**) Vegetable oil with $n_{oil} = 1.47$ floats on top of water with $n_{water} = 1.33$. Viewing from the side of a clear glass cup half filled with water and quarter filled with the vegetable oil. Explain why you can visually tell you have oil on top of water in the cup even though both are colorless.
2) (**5 points**) Following Part (1), when you look into the cup, again explain why you can tell you have vegetable oil on top of the water.
3) (**10 points**) Find the Brewster (external polarizing) angle from the air into the vegetable oil.
4) (**5 points**) Find the incidence angle in the air at which the angle inside oil is the Brewster angle from the oil into the water. You can assume that the two surfaces of the oil are parallel.
5) (**10 points**) Show that there is no incidence angle in the air at which the transmitted light inside the oil becomes totally reflected at the oil-water interface.

5. **State of polarization and Jones vectors**

Determine the state of polarization for each of the following by first finding the respective normalized Jones vector.

1) (**15 points**) (a) $\begin{bmatrix} -3 \\ 1 \end{bmatrix}$; (b) $\begin{bmatrix} 2\,i \\ -i \end{bmatrix}$; (c) $\begin{bmatrix} 1-i \\ i-1 \end{bmatrix}$.
2) (**10 points**) $\vec{E}(t) = 3\cos(\pi/4 - \omega t)\,\hat{x} - 4\cos(\omega t)\,\hat{y}$
3) (**Extra 10 points**) $\vec{E}(t) = 2\cos(\pi/4 + \omega t)\,\hat{x} + 2\sin(\omega t - \pi/4)\,\hat{y}$

6. **Polarizing devices**

You have at your disposal a collection of half-wave plates, quarter-wave plates, linear polarizers, and rotators that yield rotation of any magnitude. Start with a *linearly polarized* light beam,

$$\tilde{E}_{in} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \end{pmatrix}$$

1) (**10 points**) If you can have some loss, what device will you use to produce a *linearly polarized light along **x**-axis*, and how you will orient this device?
2) (**10 points**) Without losing any power, what device will you use to produce a *linearly polarized light along **y**-axis* and how will you orient the device?
3) (**10 points**) Without losing any power, what devices will you use to produce a *right-circularly polarized* light?
4) (**Extra 5 points**) For Part (2), what is your alternative choice?
5) (**Extra 5 points**) For Part (3), what is your alternative choice?