Your Name: ______________________________

4 problems, 10 pages. No separate solution sheets necessary. Good luck!

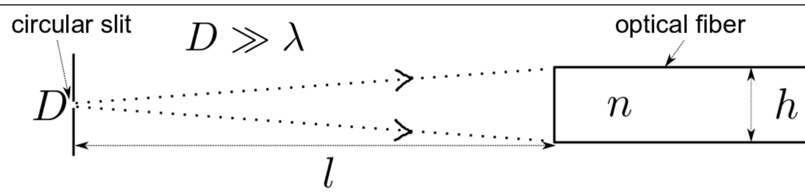
Please indicate clearly where your work can be found, if your work for any given problem goes beyond one page. If you do not, then you may not get full credit.

For all problems, you must show short but sufficient derivations. **Answer alone will not get you much credit**, even if it is correct. Correct steps will get you credit, sometimes much credit, even when the final answer is missing. **Your solution must be presented symbolically throughout**, and any numerical answer, if required, should appear only at the end. Each of the following four problems is worth 50 points.

Please take time to read each problem carefully. Incorrect solutions tend to make assumptions that contradict simple definitions or conditions given in the problem.

Problem 1 A plane wave of light of wavelength λ passes through a *circular* slit of diameter D ($\gg \lambda$) from the left and diffracts. At an adjustable distance l from the slit ($l \gg D$), a straight optical fiber cable is placed at the center as shown below and the diffracted light goes into one end of the optical fiber. We like to choose l so that just the entire central peak of the diffracted light goes into the optical fiber. That is, the two dotted lines hitting the top and bottom edges of the optical fiber cable (see below) correspond to the first minimum in the intensity pattern. We also require that any light that goes into the optical fiber does not escape through the sides (top and bottom lines in the diagram below) of the cable at all. (a) What should be the value of l as a function of D, λ, and h? (b) What is the requirement for n, the refractive index of the optical fiber, in terms of D and λ? [Note: when appropriate you may use the following approximations: $\sin x \approx x$ and $\tan x \approx x$, if $|x| \ll 1$.]

Your solution:



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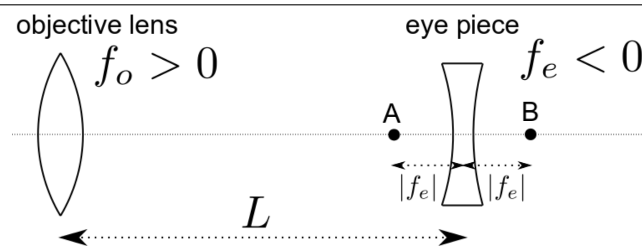
Problem 2 A refracting telescope is built with a convergent objective lens and a *divergent* eye piece, arranged as shown below. (a) Where should the image of a distant object be formed by the objective lens and why? Find your answer assuming relaxed eye. Note that, then, the answer should be one of the following four choices: a point infinitesimally to the left or right side of point A or B (see below). Justify your choice. (b) Find L in terms of f_o and f_e, the focal length parameters for the objective and the eye piece respectively (note: $f_e < 0$ while $f_o > 0$). (c) Is the final image formed by the eye piece inverted or upright, with respect to the original object, i.e., the object of the objective lens? (d) Find the angular magnification M of this telescope in terms of f_o and f_e. [Hint: for the last two parts, start by representing a distant object as a small arrow at a large, but finite, distance from the objective lens.]

Your solution:



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Problem 3 Consider Young's double slit experiment with slit spacing d, carried out using coherent but unpolarized light as light source. The width of each slit, D, is very small ($D \ll \lambda$). In this problem, you are to provide sketches of the intensity pattern. **In each sketch, the maximum, minimum, and average values of the intensity should be marked clearly, as should be the locations (in terms of δ) of the intensity maxima and minima. The zero intensity value must be marked clearly on the intensity axis as well.** (a) Sketch the intensity measured on the screen as a function of the phase difference variable $\delta = kd\sin\theta$. The intensity is given by $I = 4I_R\cos^2\frac{\delta}{2}$ or $I = I_0\cos^2\frac{\delta}{2}$, where $I_0 = 4I_R$ can be treated as independent of δ (and thus θ). (b) Suppose that you now reduce the width of *one* of the two slits to $D/2$ so that the intensity from *that* slit is reduced by half. Find the new maximum and minimum values of the intensity, I_{max} and I_{min}, in terms of I_R in part (a). Make a sketch of the new intensity pattern, $I = I_{min} + (I_{max} - I_{min})\cos^2\frac{\delta}{2}$. Explain why the new average intensity makes a physical sense (considering the energy flow). (c) Suppose that the widths of the two slits are the same as the original (D), but a linear polarizer now covers *each* slit so that light entering each slit is 100 % linearly polarized in the *same* direction. Sketch the new intensity pattern, making sure to indicate the new maximum, minimum, and average intensity values in precise relation to those of part (a). (d) (Bonus) Same as (c), but what if only one slit is covered with a linear polarizer?

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your solution:

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Problem 4 A diffraction grating is used to monochromatize ultra-violet light. Specifically, it needs to resolve 150.00 nm and 150.20 nm wavelength lights **in the second order**. The ruling (= groove) density is given by 3000 per cm. The initial beam is incident on the grating at normal angle. (a) At what angle would the second order light for 150.00 nm appear? (b) What is the minimum number of rulings that the grating must have to meet the required resolution? (c) What is the minimum number of rulings that the grating must have, if the requirement changes to resolving 150.00 nm light from 150.05 nm light? (d) What is the relative intensity of the principal maximum peak of case (c) in comparison to that of case (b), assuming the minimum number of rulings in each case? (e) And, what is the relative width of the principal maximum peak of case (c) in comparison to that of case (b)? For parts (d) and (e), note that the ruling density is held constant. Assume the initial beam illuminating a large area of the grating, shining all rulings, no matter how many rulings there are.

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your solution:

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