Phys 531 Midterm Exam Due October 21

Instructions:

This is a take home, unlimited time exam. You may not discuss the exam with other people, but you are free to use the textbook, your notes, and any other reference materials you wish. You may use a computer for numerical calculations if you want, but you should not expect to need anything more than a calculator.

The exam consists of four short-answer conceptual questions and four longer problems requiring detailed solutions. Each short question is worth 5 points, and each problem is worth 10 points. Partial credit on the short questions, if awarded, will be based on how close to correct your answer is. Partial credit on the longer problems will be based on the work you show. Especially on the problems, be sure to explain your methods and copy your solutions out clearly.

The exam is due at the begining of class on Thursday, October 21. Off-campus students may turn it in to their administrator at this time, or may scan their solutions and email them to me before 5:00 PM that day. Late exams will not be accepted without prior approval.

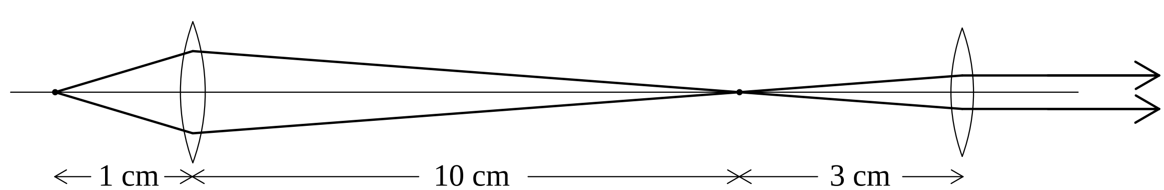
Questions

1. Consider a plane light wave propagating in the $+z$ direction in vacuum, with a wavelength $\lambda = 500$ nm. At time $t = 0$, the electric field is zero at $z = 0$ and is 10 V/m pointing in the $+x$ direction at $z = 125$ nm. Use this information to write down the complete complex exponential form of the electric field. (You can leave your answer in terms of k and ω.)

2. At the top of Mount Everest, the air pressure is about 1/3 of that at sea level. Estimate the index of refraction n of air at this height.

3. Consider an imaging system used to observe a flat radiant object. The aperture stop and field stop of the system are both known. If the diameters of both of these stops are reduced by a factor of two, what change will be observed in:
(a) the total power in the image and
(b) the irradiance of the image.
Assume that the object is large enough to always fill the field of view and that it radiates light uniformly in all directions.

4. Suppose you are designing a simple compound microscope as shown. You will use off-the-shelf components for the objective and eyepiece lenses, and you wish them to be as inexpensive as possible. If you require diffraction-limited performance at an objective numerical aperture of 0.05, which lenses (if any) need to be doublets, and which can be singlets?

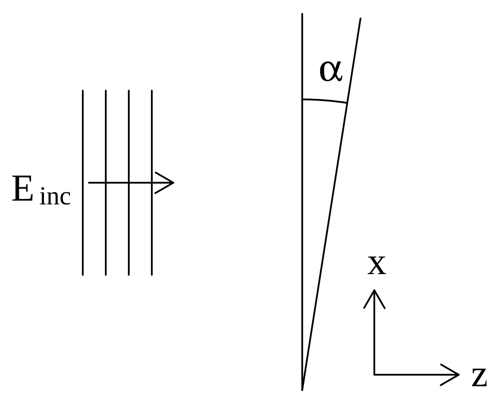


Problems

5. Consider a plane wave transmitted through a thin transparent wedge as shown. Assume that the angle α is small and that the index of refraction of the wedge material is close to one.
(a) For an incident wave $\mathbf{E}_{\text{inc}} = \mathbf{E}_0 e^{i(kz-\omega t)}$, use Snell's Law to determine the transmited wave.
(b) In class, we derived that light passing through a length L of a weakly scattering medium (with susceptability $\chi \ll 1$) produces a scattered field

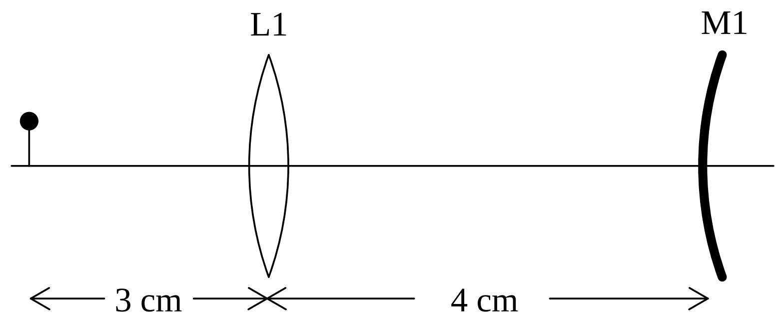
$$\mathbf{E}_{\text{scat}} = i\frac{kL}{2}\chi\mathbf{E}_{\text{inc}}.$$

For the wedged medium shown, the thickness $L = \alpha x$. Use the scattering approach to calculate the total transmitted field (assuming x is small enough that the scattered field remains weak.)
(c) Show that the results of (a) and (b) are consistent.



6. Consider a laser pulse with energy 3 mJ, duration 30 ns and area 3 mm^2, incident from vacuum onto a block of glass ($n = 1.5$) with TE polarization and an angle of incidence of 30°. Calculate the energy, irradiance, and electric field amplitude of the transmitted pulse (in the glass).

7. In the lens system shown below, L1 is a thin lens with focal length $f_1 = 2$ cm and M1 is a curved mirror with radius of curvature $R = 12$ cm. For an object located 3 cm in front of L1, find the location and magnification of the image produced by M1. Draw a sketch showing the location and orientation of the image relative to the lenses.



8. For a lens system composed of two thin lenses of focal length f separated by a distance $2f$:
(a) Calculate the vertex-to-vertex system matrix $\mathcal{M}_v$
(b) What is the system focal length, and where are the principle planes located?
(c) For an object located a distance s_o in front of the front vertex, find the image distance s_i from the back vertex.