Phys 531 Midterm Exam Due October 11

Instructions:

This is a take home, unlimited time exam. You are free to use the textbook or the class notes but you may not discuss the exam with other people or use other references. 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 questions and four longer problems requiring detailed solutions. Each short question is worth 5 points, and each problem is worth 10 points. For the short questions, you should briefly explain your reasoning, and for the longer problems you should show your work in detail.

The exam is due at the begining of class on Tuesday, October 11. Late exams will not be accepted without prior approval. Turn in your final solutions stapled to these exam sheets.

Name: ______________________________

Signature: ______________________________

Questions

1. Suppose an electric field is expressed as the sum of two plane waves

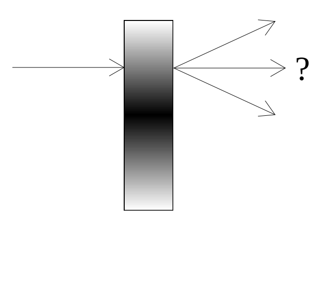
$$\mathbf{E} = E_1\hat{\mathbf{z}}\cos(kx - \omega t) + E_2\hat{\mathbf{z}}\cos(kx - \omega t + \pi/3)$$

for $E_1 = 4$ V/m and $E_2 = 3$ V/m. What is the total irradiance of the combined waves?
(a) 0.033 W/m^2
(b) 0.049 W/m^2
(c) 0.066 W/m^2
(d) 0.098 W/m^2
(e) None of the above, because the irradiance depends on the position x

2. The complex index of refraction of silver at 532 nm is $\tilde{n} = 0.13 + 3.19i$. What is the transmission for this light through a layer of silver that is one wavelength (in the medium) thick? Don't worry about reflections from the boundaries, just the consider the absorption loss in the silver itself.

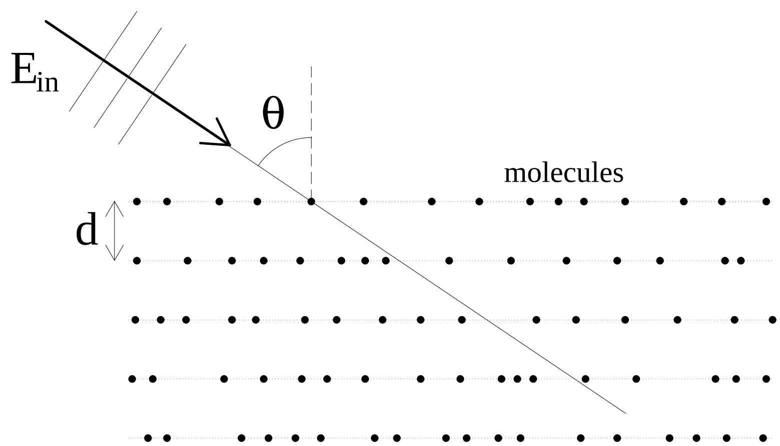
3. A large diameter, collimated laser beam can be well approximated by a plane wave. If you looked into such a laser beam with your relaxed eye, what would you see? (Assume here that the power in the beam is low enough to be safe – an assumption you should never make in real life.)

4. A flat plate of glass is doped so as to have a higher index of refraction in the middle and a lower index at the edge. Would a ray entering the glass at normal incidence as shown be deflected (a) upwards, (b) downwards, or (c) not at all?



Problems

5. Consider an inhomogeneous medium where the molecules all lie on layers separated by a distance d. (This could be considered a simple model for a crystal.) Assume that the molecules are randomly distributed within each layer. A plane wave of wavelength λ is incident on the medium at an angle θ to the layers. Use our scattering approach method to show that there is another direction besides forward where the scattered fields from all the molecules add up in phase. Determine the propagation direction of the strongly scattered light, and also find what values d must have for this to occur.



6. Suppose a linearly-polarized plane wave is normally incident on the curved surface of a plano-convex lens. The lens has radius of curvature $R = 20$ cm and index of refraction $n = 1.5$. The diameter of the lens is $D = 2.5$ cm. Since the light at the edge of the lens is incident on the glass at an angle, a different amount will be reflected than from the light at the center. Calculate the fractional difference between the mimimum and maximum reflectances across the entire lens. (Don't forget the lens is really three dimensional!)

7. Suppose a thick lens has a focal length of -10 cm, a front focal length of -12 cm, and a back focal length of -14 cm. The vertex-to-vertex length of the lens is 3 cm. If an object is located 5 cm in front of the lens, draw a ray diagram showing the location of the image. The diagram should show the locations of the two focal points, the two principle points, and should include all three simple rays.

8. You are using a film camera to take a picture of a disk-shaped object that has a brightness of 1 W/(cm^2 sr). The camera lens has a focal length of 5 cm, a front focal length of 4 cm, and a back focal length of 3 cm. The vertex-to-vertex width is 5 cm. The object is located 30 cm in front of the front vertex. The system aperture stop is located a distance 0.5 cm behind the rear vertex, and consists of a material aperture 1 cm in diameter. The film requires an exposure energy of 50 μJ/cm^2 in order to develop properly. How long an exposure time is required to achieve this?