Physics H7C, Fall 2013 Instructor: Professor Adrian Lee
Midterm Examination, Thursday, October 10, 2013

Please do work in your blue/greenbooks. Show your reasoning carefully so that we can be sure that you derived the answer rather than guessing it or relying on memory; in addition, this enables us to give partial credit. You may use one double-sided 3.5 x 5 index cards of notes. You can use a simple calculator (no smart phones or devices that can store notes). Test duration is 90 minutes.

1 Qualitative Questions [40 pts. total]

Only a few lines of explanation is needed for these. You don't have to use cartoons or equations, unless specified, but you can. No derivations are needed.

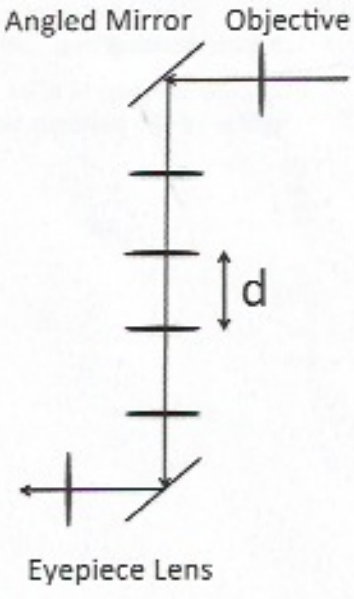
a) We have studied "thin-film" interference. Can you have "thick film" interference with white light? Consider a dielectric slab that is > 1000 wavelengths thick but the surfaces are perfectly parallel and the incidence of light is normal. The interference bands must have a finite width for your eyes to see them. [10 pts.]

b) Considering a model where a gas is filled with polarizable molecules, qualitatively explain why the sky is blue and why light has a slower speed in a medium than in vacuum. [10 pts.]

c) What are the conditions for total internal reflection? Does it occur at one angle or a range? When it does occur, is the energy density outside the volume where the reflection occurs completely zero? Why? A very simple answer is all that is required! [10 pts.]

d) Explain what circularly polarized light is with a few sketches. If you run such light through a polarizing grid what fraction of power makes it through? [10 pts.]

2 Periscope [40 pts. total]



This problem will analyze one way to build a periscope. First consider N identical converging lenses, each with focal length f. As shown in the drawing, they are all spaced the same distance d apart from one another.

a) For this part, ignore the objective and eyepiece lenses and just consider the series of identical lenses spaced apart by d. Place an object $d/2$ away from the first lens. Find the relationship between d and f such that there is a real image located a distance $d/2$ on the far side of each of the N lenses. [10 pts.]

b) With the geometry described above, including the results from part (a), the series of lenses "relays" the image with unity magnification. Is that property obtained regardless of the position of the object with respect to the first lens? If not, you can prove it by counterexample. If yes, you can show the property does hold for a general position of the object with respect to the first lens. [10 pts.]

c) Now, we will make a practical periscope with the parameters given at the beginning of the problem and part (a). As shown in the drawing, add 45 deg. angled flat mirrors at both ends, an objective lens at the entrance, and an eyepiece lens at the end. The focal length of the objective lens is f_{obj}. If the periscope is designed to act like a telescope with a magnification of 4, what is the focal length required of the eyepiece? Please derive and expression for the magnification even if you make an analogy to a simpler optical configuration. [10 pts.]

d) For the same setup as in part (c), should N be even or odd to have the image of the object be upright rather than inverted? [10 pts.]

3 Reimaging system [40 pts. total]

An upright object is placed a distance $2 \times f_1$ in front of a converging lens, where f_1 is the focal length of the lens. On the other side of the lens is a converging mirror of focal length f_2 separated from the lens by distance $2(f_1 + f_2)$.

a) Make a ray diagram showing where the final image is for a person looking from the source side of the lens. [10 pts.]

b) What is the distance from the lens to the image? [10 pts.]

c) What is the magnification (including orientation) of the image? Is the image real or virtual? [10 pts.]

d) Now assume $f_1 = f_2 = f$ and that the lens and mirror are separated by a distance equal to f. What is the magnification (including orientation) of the image? Is the final image real or virtual? Is the object for the mirror real or virtual? [10 pts.]

4 Newton's Rings [30 pts. total]

Consider thin-film interference between a curved glass surface sitting on a flat glass surface. The index of the glass is n, and interference is occurring in the gap between the convex glass surface and the flat glass surface which is filled with air with index equal to 1. The drawing shows the paths for the reflection case where paths A and B interfere.

a) Consider the two cases of transmission and reflection. The reflection case is shown in the drawing. In each case, is the center of the pattern light or dark? [10 pts.]

b) The radius of curvature of the top piece of glass is R, its diameter is D, and the wavelength of light is λ. In reflection, what is the radius of the mth dark and light rings, where the rings are numbered 1, 2, 3, ... , m? You can count the center region as one ring. [10 pts.]

c) Now the gap is filled with a liquid with index $n_{liq} > n$. What happens to the center of the patterns and radius of the mth rings in the reflection case? [10 pts.]