Physics 7C Midterm 1

September 23, 2010

Please write your discussion SECTION NUMBER on your blue books. If you do not know your section number, please write down the meeting day and hour of your section. Please show all work and record your answers in blue books.

Problem 1 Lenny and George have finished their optics lab early and decide to have some fun while the GSI is busy elsewhere. George remembers from lecture that light can exert a force on objects and decides to dazzle Lenny with a levitation trick. He directs a laser with a power output of P vertically upward and places a thin, reflective light-weight disk on the beam. The disk has mass m and has the same cross-sectional area A as the beam. Lenny is delighted to see the disk hover in mid-air.

a. George cleverly aligns his coordinate system so that the disk's axis runs parallel to the z-axis. The electric field of the laser light can be written in the form

$$\vec{E} = E_0 \sin(kz - \omega t)\hat{y}.$$

What is the corresponding magnetic field component that Lenny measures?

b. Lenny wants to write the electric field as $\vec{E} = E_0 \cos(kz^2 - \omega t)\hat{y}$? Can he do so? Could he instead write the electric field as $\vec{E} = E_0 \sin(kz - \omega t)\hat{z}$? Explain.

c. George challenges Lenny to calculate the power P (energy emitted per unit time) necessary to keep the object levitated. He reminds Lenny that the object is perfectly reflective and that the momentum carried by the wave is equal to $\frac{1}{c}$ times the energy it carries. What is the answer?

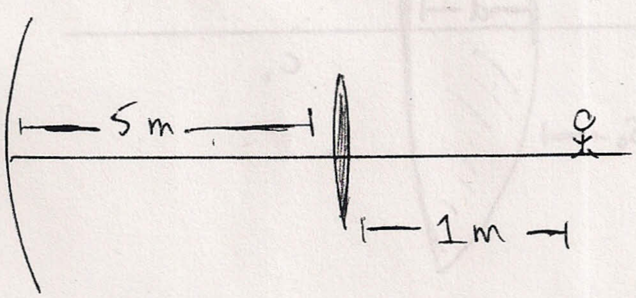
d. In terms of P, A and physical constants, what is the amplitude of the electric field E_0 coming from the laser?

Problem 2 A new optics exhibit has opened at the Exploratorium in which a $50cm$ focal length converging lens is placed $5m$ in front of a spherical concave mirror. The mirror has focal length $50cm$. Suppose you stand $1m$ in front of the lens. Refer to Figure 1 for this problem.

a. Where will your image appear relative to the lens? In your answer, carefully draw the ray diagram associated with this problem. You may find it easier to draw multiple ray diagrams instead of one.

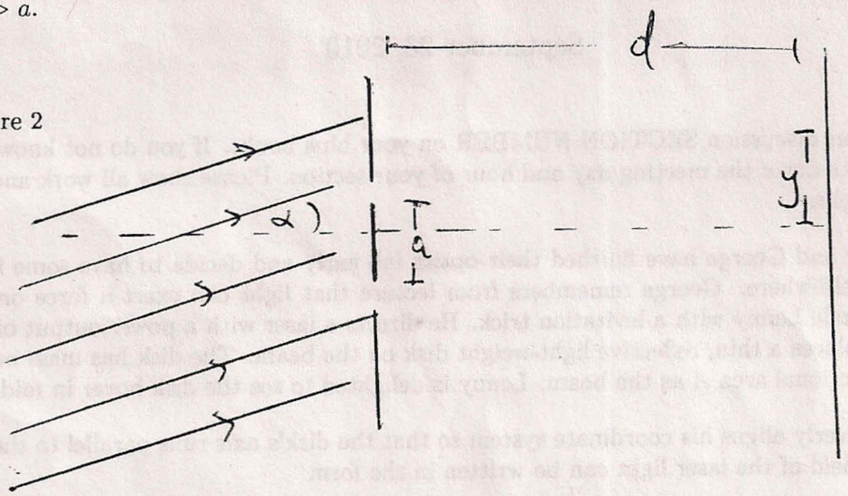
b. Will your image be upright or inverted? Calculate the magnification of your image.

Figure 1



Problem 3 Consider the double slit experiment where a coherent source of plane waves is incident upon a partition with two very thin slits cut into it. The size of the slits is small enough to ignore diffraction effects. Suppose the slit separation is given by a and let the incident plane waves make an angle α with respect to the line perpendicular to the partition screen (see Figure 2). Determine the amplitude of the electric field a height y above the axis on the screen as a function of wavelength λ, angle α,slit separation a and distance d. What does increasing α do to the pattern on the screen? Assume that $d >> a$.

Figure 2



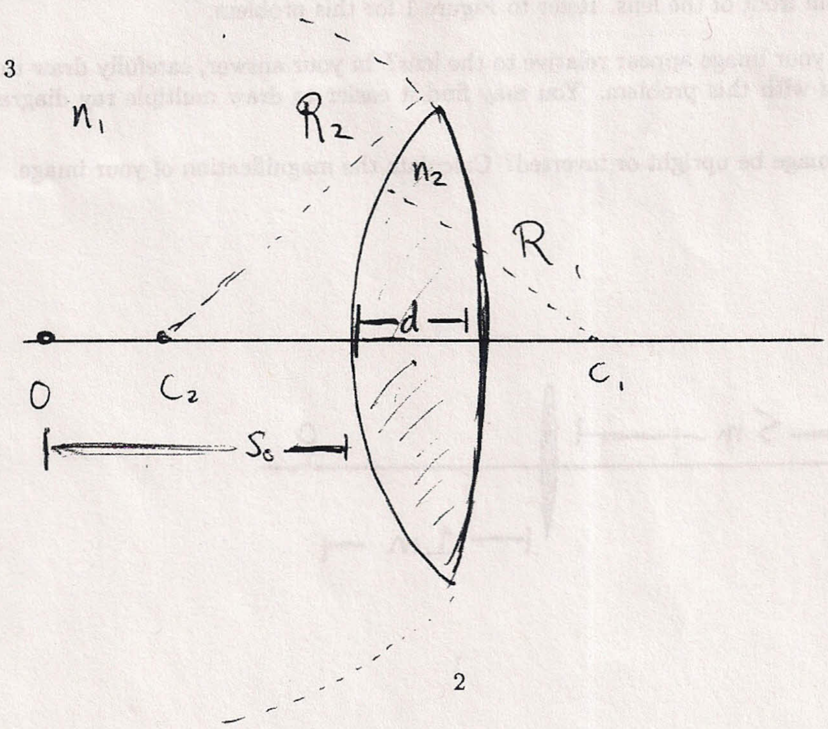
Problem 4 Refer to Figure 3.

Consider a lens made up of two spherical refracting surfaces as pictured in Figure 3. The spheres have radii R_1 and R_2 respectively. Suppose an object of negligible height is located on the optical axis a distance s_0 in medium 1. The light will refract at the spherical interfaces to produce an image a distance s_i from the second spherical surface. Given the relation

$$\frac{n_1}{d_0} + \frac{n_2}{d_i} = \frac{n_2 - n_1}{R}$$

describing refraction on a SINGLE spherical interface, compute the focal length of the lens. Here R is the radius of curvature of the sphere. You must assume that the thickness d in Figure 3 is very small in comparison to s_i and s_0. In the figure, the sign of R is positive since it bends towards the incident light from the object.

Figure 3



Problem 5 Refer to Figure 4 for this problem. Steve takes a day off to visit the local aquarium. Being an inquisitive person, he puts his face directly against the glass which is thin enough that its effect can be ignored entirely. Denote the index of refraction of water as n_w.

a. If there is a fish located d meters away from the surface of the glass , where does the fish appear to Steve?

b. The outside world appears as a compressed disk to the fish. What is the radius of this disk?

c. Above, we assumed that the glass did not affect where Steve sees the fish. If the glass thickness is t and the index of refraction of the glass is n_g, show that the above assumption is justified. Refer to Figure 5.

Figure 4

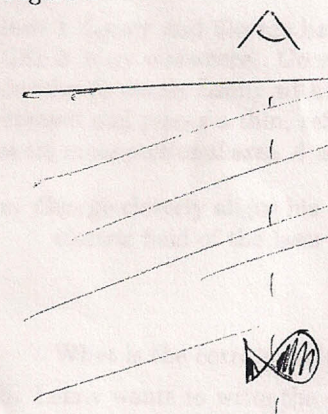


Figure 5