UNIVERSITY OF CALIFORNIA AT BERKELEY

Physics 7C – (Stahler)

Spring 2018

FIRST MIDTERM

Please do all your work **in this printed exam** (not in a blue/green book). Below, write your name, SID, discussion section number, and GSI's name.

You must attempt all four problems. If you become stuck on one, go on to another and return to the first one later. Be sure to show all your reasoning clearly; *i.e.*, do not simply write down equations. **Remember to circle your final answer!**

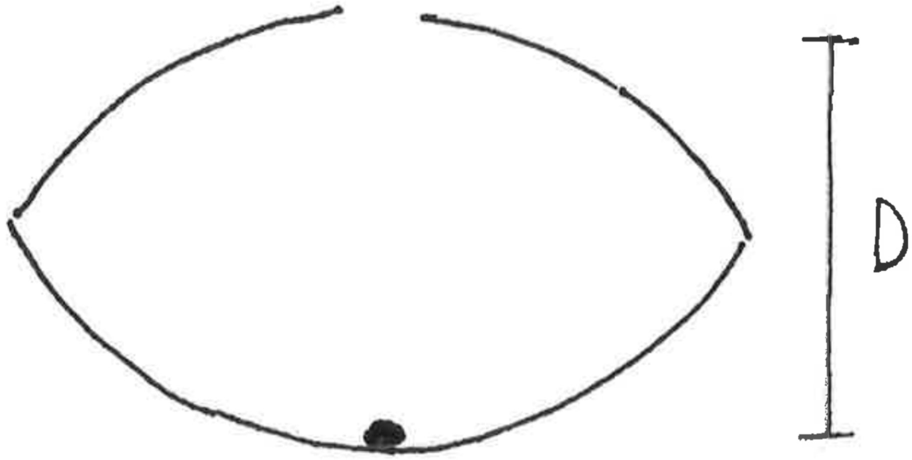
Name: ______________________________

SID: ______________________________

Discussion #: ______________________

GSI: ______________________________

Problem 1 (20 points)



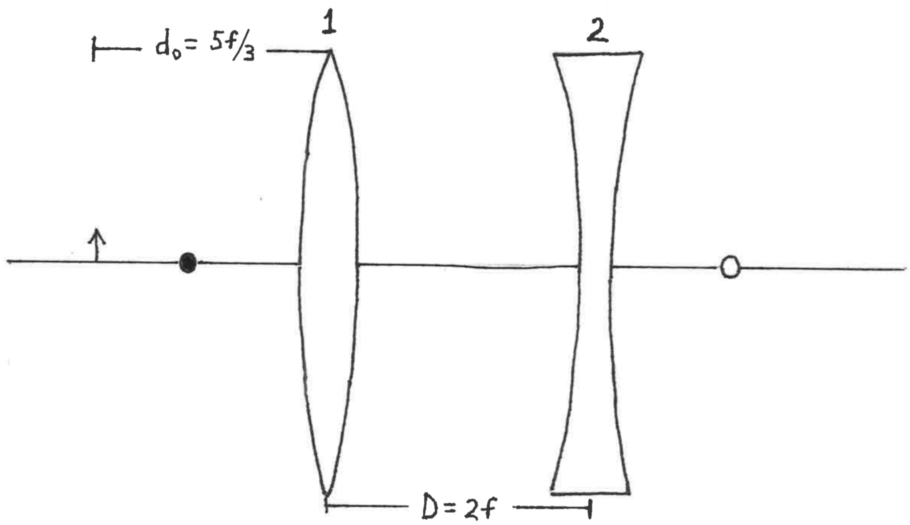
A "clamshell mirror" consists of two spherical, concave mirrors glued together. The top mirror has a hole cut out, as shown. The centers of the mirrors are separated by a distance $D = R/2$, where R is the radius of curvature of both mirrors. A small pebble rests on the center of the bottom mirror.

(a) Consider first the image that the *top* mirror makes of the pebble. You make take the object distance to be $D - \varepsilon$, where $\varepsilon \ll D$. What do you find for the image distance? Is the image virtual or real?

(b) Now consider this image to be the object for the *bottom* mirror. The mirror forms an image of this "object." Where is this final image located, in the limit $\varepsilon \to 0$? is this image virtual or real?

(c) Sketch two rays emanating from the pebble to show how they form the final image. Don't worry about the finite size of the pebble; it can be shown as a point in your drawing.

Problem 2 (30 points)



Two thin lenses, one converging and one diverging, are aligned horizontally. The two foci of the converging lens (number 1) are a distance f from its center; one such focus is shown by the filled circle. Similarly, the two foci of the diverging lens (number 2) are also a distance f from its center; the open circle shows one of these foci. The lens centers are a distance $D = 2f$ apart.

A small, upright object (arrow in the sketch) is placed a distance $d_o^1 = 5f/3$ in front of lens 1. If lens 2 were absent, lens 1 would form an image of this object.

(a) Find d_i^1, the distance of the image from lens 1.

(b) Is this image virtual or real?

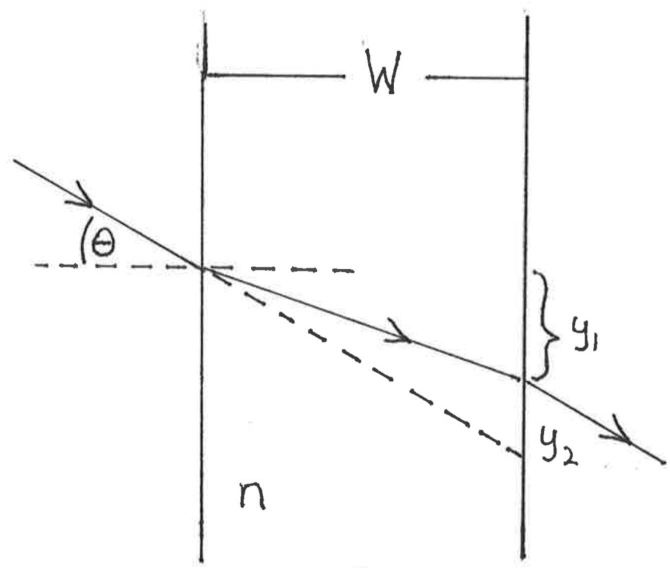
With lens 2 in place, the image you found in (a) does not actually form. However, the combined lenses do form an image.

(c) Find d_i^2, the distance of this image from lens 2.

(d) Is this image virtual or real?

(e) Carefully draw a ray diagram showing how the image you found in (c) is formed. You need not show in detail the formation of the *first* image; just place it in your drawing, using the location and orientation you found in (a).

Problem 3 (20 points)



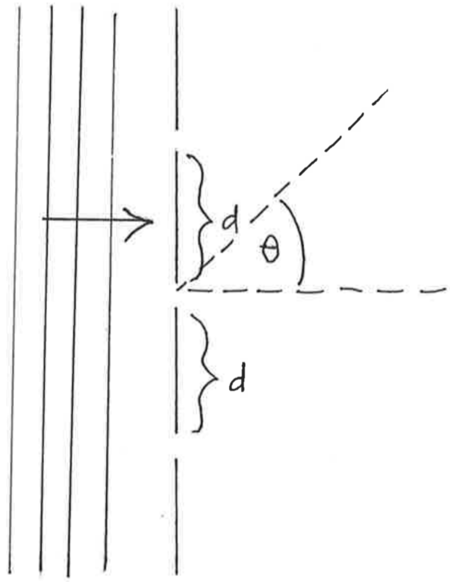
A laser beam is incident on a plane-parallel slab of width W. The slab is made of material whose index of refraction is n. Assume that $n = 1$ in the air surrounding the slab.

(a) The beam exits the slab a distance y_1 below the entry point. Find y_1 in terms of W, θ, and n.

(b) The exiting beam, which is parallel to the incident one, is displaced from it by a distance y_2, measured along the face of the slab. Find y_2 in terms of W, θ, and n.

(c) As a check on your answer in (b), find y_2 in the limit $n \to 1$. (Hint: Recall from trigonometry that $\sin^2\theta + \cos^2\theta = 1$.)

Problem 4 (30 points)



A plane EM wave of wavelength λ (and therefore wavenumber $k = 2\pi/\lambda$) approaches an opaque screen at normal incidence. In the screen there are 3 narrow, parallel slits. The top and bottom slits are separated from the middle one by the common distance d.

(a) Consider $E(r, \theta, t)$, the magnitude of the electric field at a distance r ($\gg d$) from the middle slit, at an angle θ to the incident wave direction, and at time t. The quantity $E(r, \theta, t)$ can be written as $f E_0 \cos(kr - \omega t)$, where E_0 is a constant. The modulating factor f is a function of θ, but you will find it more convenient to write it as a function of $\alpha \equiv (1/2)kd \sin\theta$. Find $f(\alpha)$.

(b) Using the identities

$$\sin(\theta_1 + \theta_2) = \sin\theta_1 \cos\theta_2 + \cos\theta_1 \sin\theta_2$$

and

$$\cos(\theta_1 + \theta_2) = \cos\theta_1 \cos\theta_2 - \sin\theta_1 \sin\theta_2,$$

show that $f(\alpha) = 3 - 4\sin^2\alpha$.

(c) The intensity of the transmitted wave is proportional to $f^2(\alpha)$. Find the two smallest positive values of α for which the intensity has its maximum value. Similarly, find the two smallest positive values of α for which the intensity has its minimum value.

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