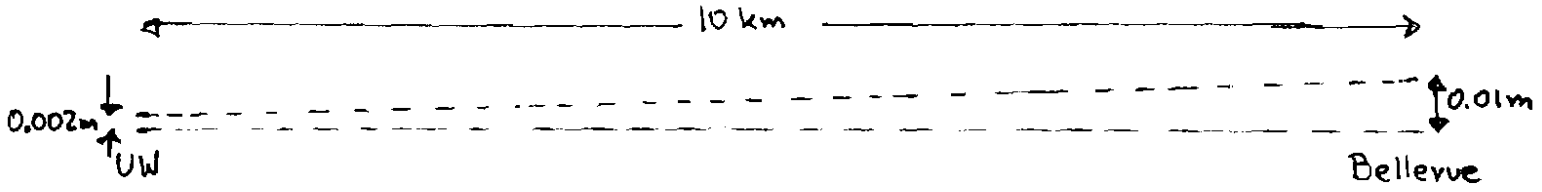
PROBLEM 4 (30 points)



A 10 mW laser at the University is pointed towards Bellevue, 10 km away. When the beam of light ($\lambda \approx 7.3 \times 10^{-7}$ m) starts at UW, its diameter is 0.002 m. When it reaches Bellevue, its diameter has increased to 0.01m. Assume no energy losses.

(4) (a) Calculate the frequency of the radiation

(4) (b) Calculate the time it takes for the beam to travel from UW to Bellevue

(4) (c) Make a qualitative picture of the e-m wave traveling from UW to Bellevue. Make sure to include the $\vec{E}$ and $\vec{B}$ fields and the direction of propagation

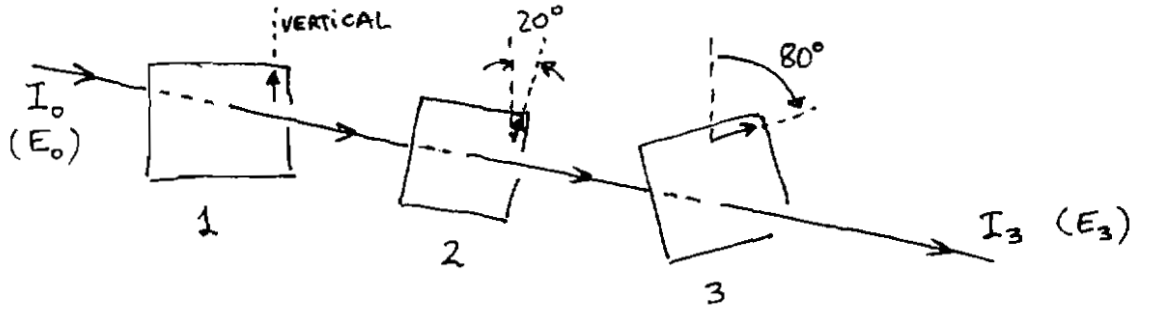
(4) (d) What fraction of the 10mW of power is carried by the $\vec{B}$ field portion of the wave.

(8) (e) Calculate the amplitude of the $\vec{E}$ field at UW and at Bellevue

(6) (f) Using your result for (e) [or 1500 Volts/m for the amplitude of the $\vec{E}$ field], calculate the rms values of $\vec{E}$ and $\vec{B}$ [Calculate E_{rms} and B_{rms}]

PROBLEM 2 (20 points)

(2)



The graph above shows a beam of incident unpolarized light of intensity I_0 going through three ideal polarizers. The first polarizer has its easy axis in the vertical direction, for the second one the easy axis is at 20 degrees clockwise with respect to the vertical, and the third one 80 degrees clockwise with respect to the vertical.

(15) a) Calculate the intensity of the light beam emerging from the third polarizer.

Incident light is unpolarized. Thus light through first polarizer will have $\frac{1}{2}$ the intensity of the incident light.

$$I_1 = \frac{1}{2} I_0$$

For the other polarizers, "Malus law" works

$$I_2 = I_1 \cos^2 20^\circ$$

$$I_3 = I_2 \cos^2 60^\circ = I_1 \cos^2 20^\circ \cos^2 60^\circ = \frac{1}{2} I_0 \cos^2 20^\circ \cos^2 60^\circ.$$

$$I_3 = 0.11\, I_0$$

(5) b) If the amplitude of the electric field in the unpolarized incident waves was E_0, using your result from part (a) calculate the amplitude of the electric field wave emerging from polarizer number 3 (E_3).

The intensity is proportional to the square of the amplitude of the electromagnetic wave.

Thus $I = \varepsilon_0 c E^2$, or "average" $\overline{I_0} = \frac{1}{2} \varepsilon_0 c E_0^2$

and $\overline{I_3} = \frac{1}{2} \varepsilon_0 c E_3^2$

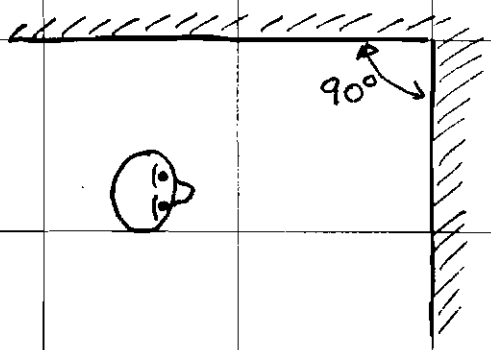
Thus $\frac{\overline{I_0}}{\overline{I_3}} = \frac{E_0^2}{E_3^2} \Rightarrow E_3 = \sqrt{\frac{\overline{I_3}}{\overline{I_0}}}\, E_0 = \sqrt{.11}\, E_0$

$$\boxed{E_3 = 0.33\, E_0}$$

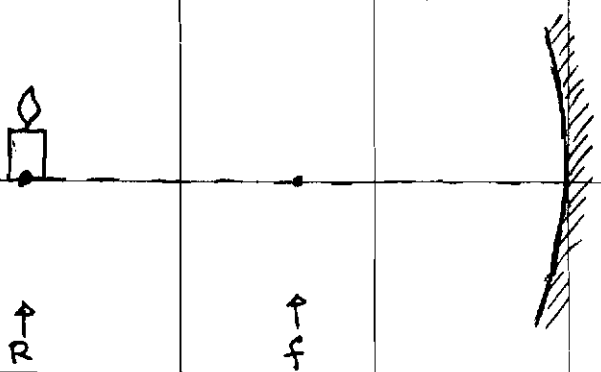
PROBLEM 1 (20 Points) NAME: _____

Find, by RAY TRACING, the images of the objects below placed in front of mirrors

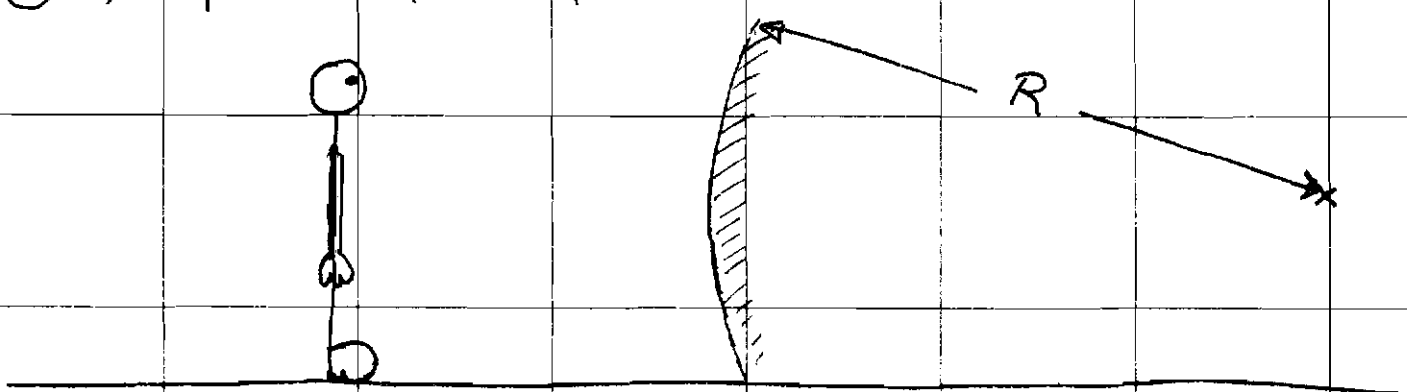
(10) a) A person in front of a 90° mirror (find all images)



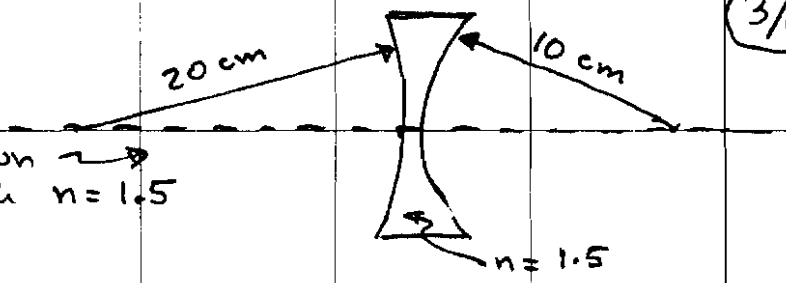
(5) b) A candle in front of a concave mirror



(5) c) A person in front of a convex mirror



PROBLEM 2 (20 Points)



A lens of the shape shown → is made out of glass with $n = 1.5$

(5) a) Calculate the focal length of this lens (Answer should be -13.3cm)

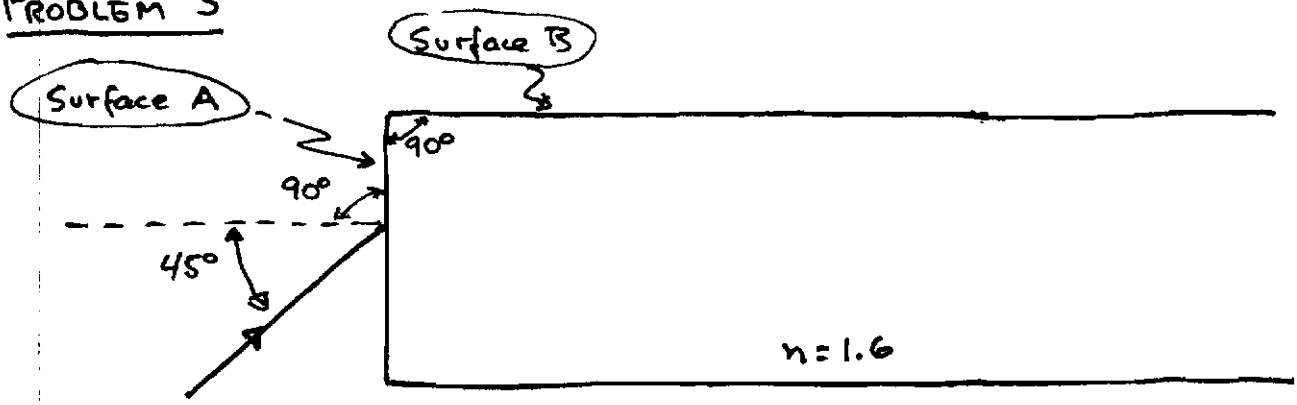
b) An object of height 1 cm is placed 20 cm in front of the lens above and on the optical axis (say on the "left side" of picture above)

(6) b_1) Make a picture of the lens and object, and find the image formed by the lens by ray tracing.

(3) b_2) Which side of the lens should a person be to see the image?

(6) b_3) Calculate the location and height of the image

PROBLEM 3 (17 Points)



Light from a red laser ($\lambda = 7.3 \times 10^{-7}$ m) strikes the surface (A) of a lucite block at 45° to the normal - $n_{lucite} = 1.6$

(10) a) Calculate the angle to the normal at which the light beam strikes surface B

(7) b) Draw a ray showing what the laser beam does after striking surface B, and write one short (3 lines maximum!) sentence to justify your picture

PHYSICS 116A
WINTER 1993
O.E.VILCHES

I don't have a "blank" of this on next page - O.V.

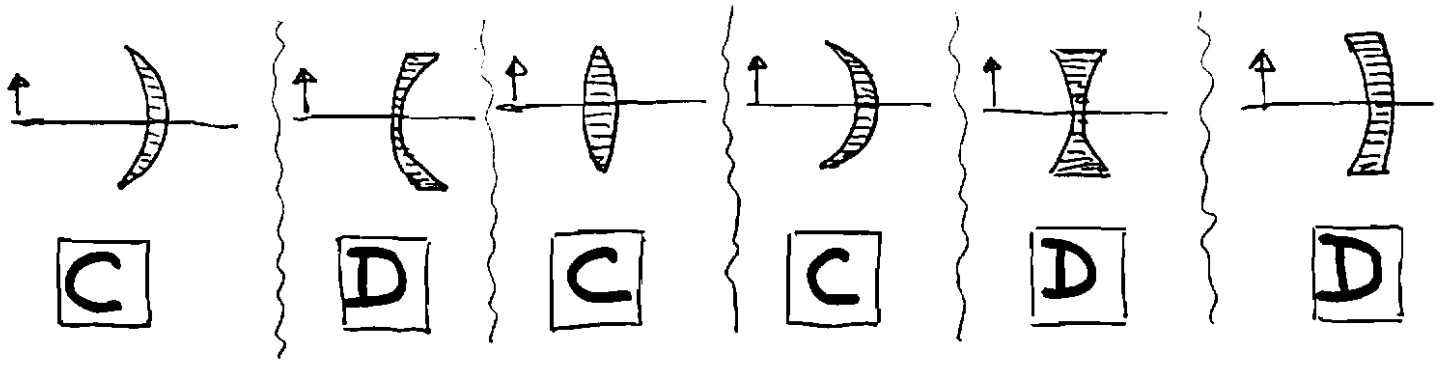
THIRD MIDTERM

YOUR NAME... ANSWERS .....

Please don't forget to write your name!!!! This test has one "name the picture" question, 9 multiple choice questions, and 2 relatively short problems. *There is no penalty for choosing the wrong answer in the multiple* choice questions. You should not spend more than 15 minutes in the picture and questions part, so you have adequate time to work the problems. In the problems, show your work. Partial credit will be given for right method or portions. You can work this test in any order you like. The scoring for the test is on the last page, 2nd problem.

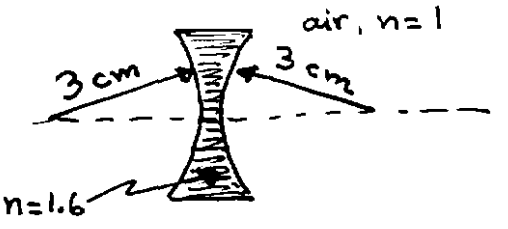
QUESTION 1

The pictures below show 6 different lenses, made out of glass with index of refraction of 1.5 . In the box below each picture, write C for a converging lens, and D for a diverging lens. In the 6 cases the object is to the left of the lens at a distance $d_o > f$ (the focal length of the lens).



QUESTION 2

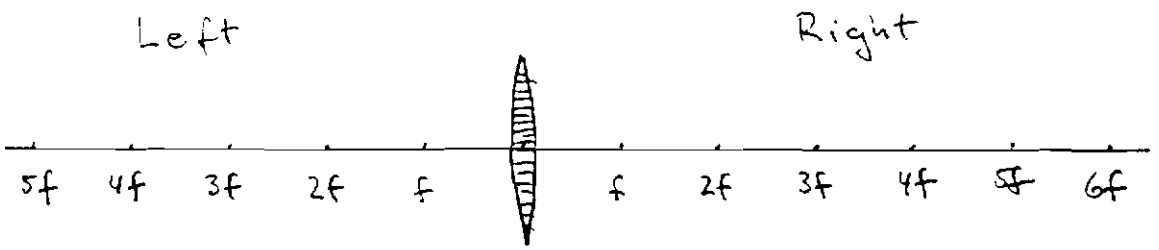
The picture on the right shows a lens made out of glass of index of refraction 1.6 . The dimensions in the figure are in centimeters (cm)



The focal length for this lens is (choose one):

a) +3 cm b) - 3 cm c) -1.5 cm d) + 2.5 cm e) - 2.5 cm

$\frac{1}{f} = (1.6-1)\left[-\frac{1}{3} - \frac{1}{3}\right] = -.6 \times \frac{2}{3} = -.4 \Rightarrow f = -2.5$

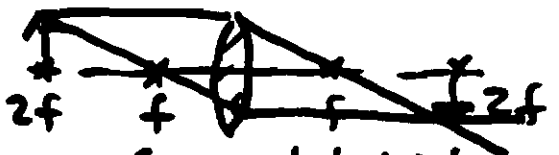


The following 3 questions refer to the general picture above. The lens is a converging lens of focal length f.

QUESTION 3

If an object is placed at a distance 2f from the lens on the left side of the lens, then the image is formed at a distance from the lens of (circle one)

a) 2f on the right side of the lens
b) Larger than 4f on the right side of the lens
c) Infinity on the right side of the lens
d) 2f on the left side of the lens
e) 3f on the left side of the lens



Symmetric picture
Also same as homework assignment

QUESTION 4

If an object is placed at a distance of 0.5f from the lens and on the left side of the lens, then the image is formed at a distance from the lens (circle one)

a) Larger than 4f on the right side of the lens
b) 2f on the right side of the lens
c) Less than f on the right side of the lens
d) Less than 0.5f on the left side of the lens
e) f on the left side of the lens.

Image will be virtual if $d_o < f$

QUESTION 5

If the object (for example, a candle) is placed at a distance of 0.5f from the lens and on the left side of the lens, just as in question 4, an observer searching for the image with a screen will find (choose one)

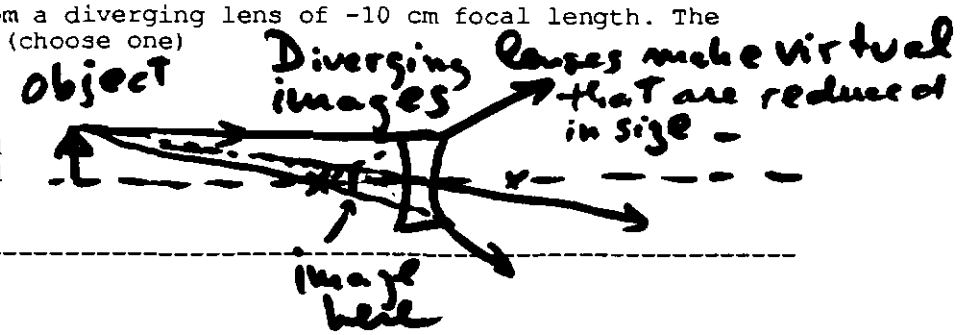
a) No sharp image anywhere
b) A sharp image at a distance f from the lens, to the right of the lens.
c) A sharp image at a distance f from the lens, to the left of the lens.
d) A sharp image at a distance larger than 4f to the right of the object.
e) A sharp image at a distance larger than 4f to the left of the object.

Image is virtual, rays diverge on right side of lens. Image is on extension of rays.

QUESTION 6

An object is placed 40 cm from a diverging lens of -10 cm focal length. The image that is formed will be (choose one)

a) real, inverted, reduced
b) real, inverted, enlarged
c) virtual, inverted, reduced
d) virtual, upright, enlarged
e) virtual, upright, reduced

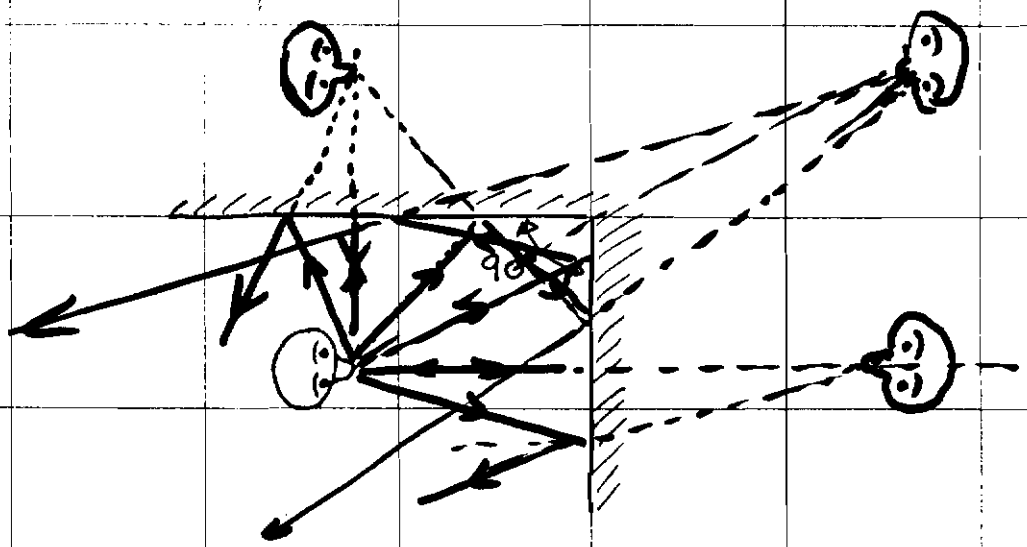


PROBLEM 1 (20 Points) NAME: Answers

Find, by RAY TRACING, the images of the objects below placed in front of mirrors

(10) a) A person in front of a 90° mirror (find all images)

There are 3 images



(5) b) A candle in front of a concave mirror

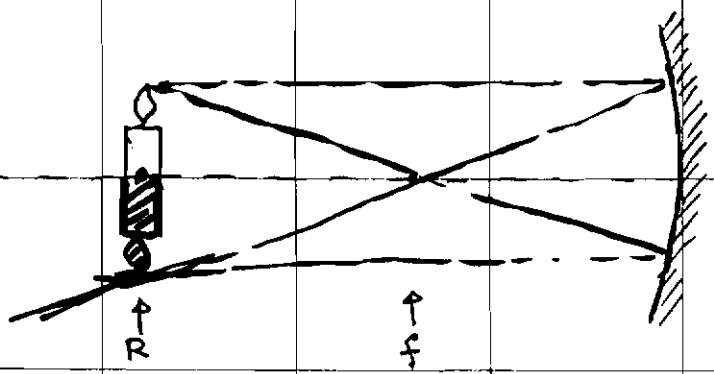


Image at R upside down.

(5) c) A person in front of a convex mirror

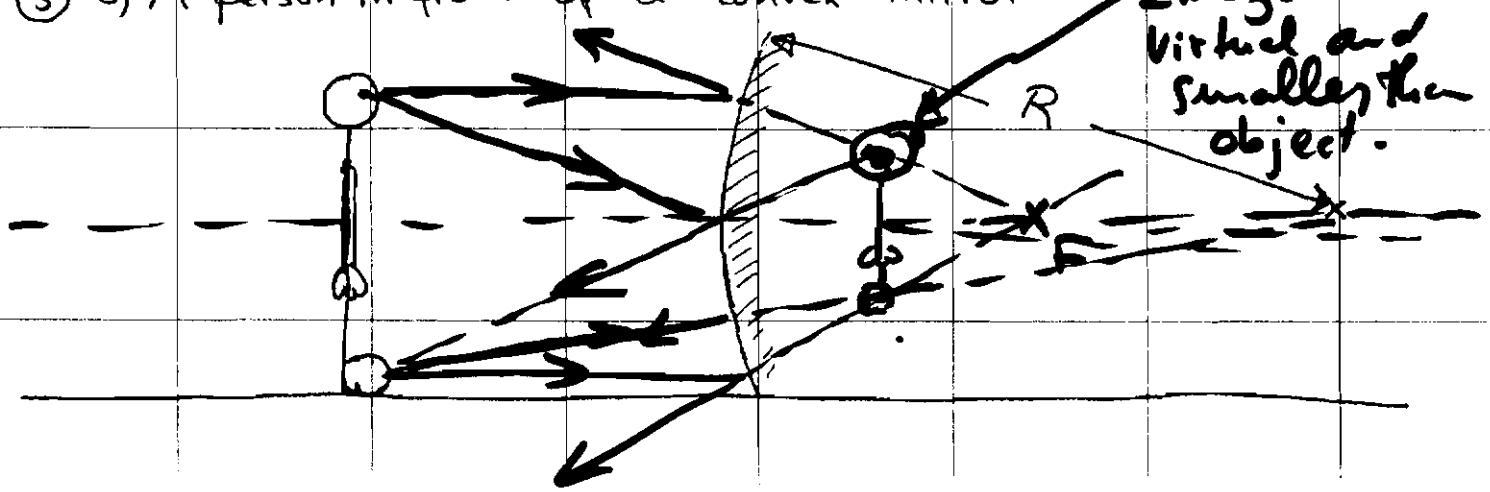
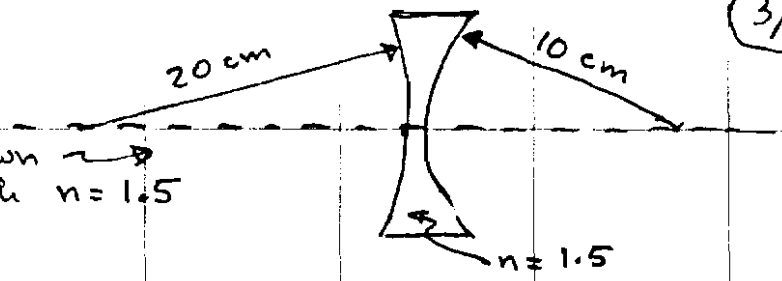


Image is virtual and smaller than object.

PROBLEM 2 (20 Points)



A lens of the shape shown → is made out of glass with $n = 1.5$

(5) a) Calculate the focal length of this lens (Answer should be -13.3cm)

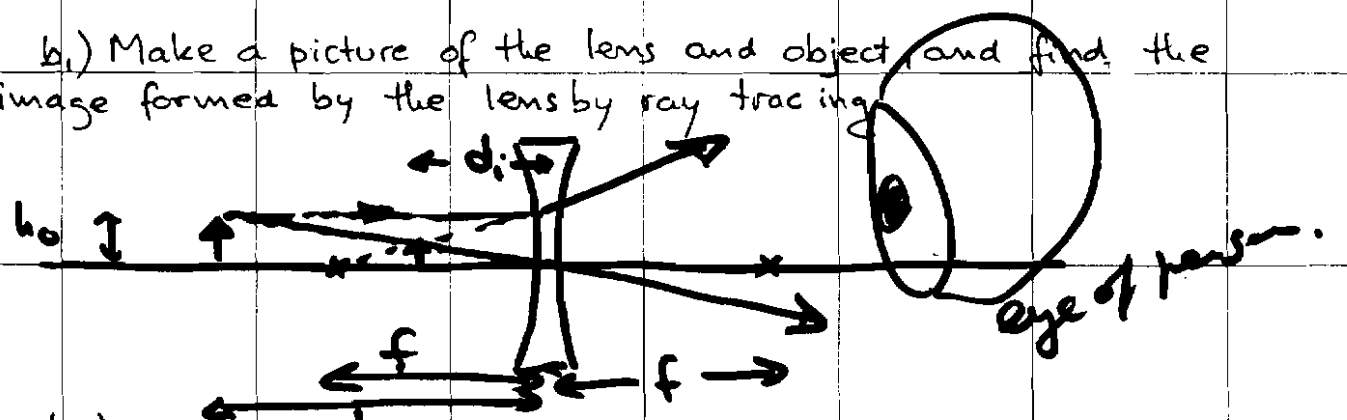
Use lensmaker's equation.

$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \quad \text{with } R_1 \text{ and } R_2 \text{ negative}$$

$$= (1.5-1)\left(-\frac{1}{20} - \frac{1}{10}\right) = -7.5\times10^{-2} \Rightarrow f = 13.3 \text{ cm}$$

b) An object of height 1 cm is placed 20 cm in front of the lens above and on the optical axis (say on the "left side" of picture above)

(6) b_1) Make a picture of the lens and object, and find the image formed by the lens by ray tracing.



(3) b_2) Which side of the lens should a person be to see the image? To see image person has to be on the right side (or other side of object), Image is seen through lens.

(6) b_3) Calculate the location and height of the image

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow \frac{1}{-13.3\text{cm}} = \frac{1}{20\text{cm}} + \frac{1}{d_i}$$

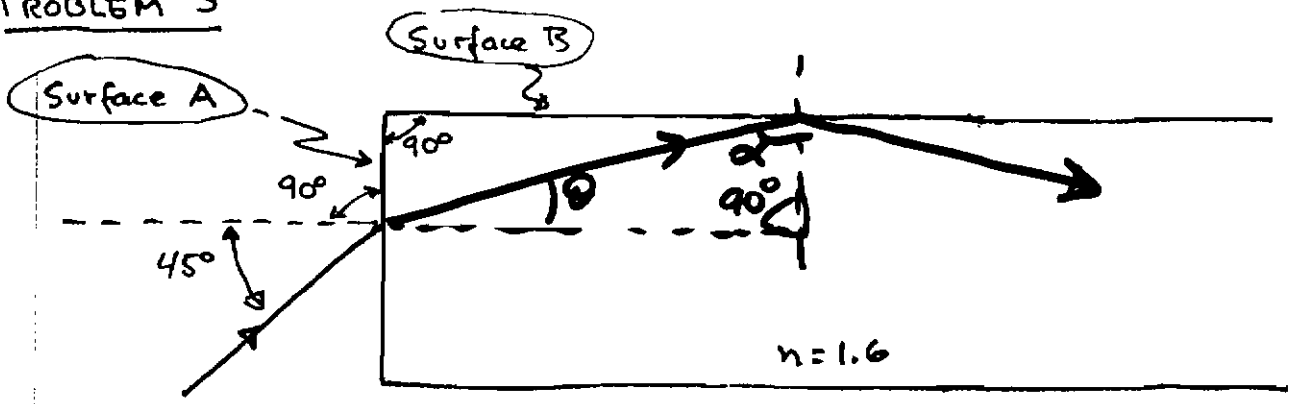
$$\frac{1}{d_i} = -\frac{1}{13.3} - \frac{1}{20} = -0.125 \Rightarrow d_i = -8 \text{ cm}$$

(or -7.99 cm)

$$m = -\frac{d_i}{d_o} = -\left(\frac{-8\text{cm}}{20\text{cm}}\right) = +0.4$$

$$h_i = m\, h_o = 0.4 \times 1\text{cm} = 0.4\text{cm}.$$

PROBLEM 3 (17 Points)



Light from a red laser ($\lambda = 7.3 \times 10^{-7}$ m) strikes the surface (A) of a lucite block at 45° to the normal - $n_{lucite} = 1.6$

(10) a) Calculate the angle to the normal at which the light beam strikes surface B

First calculate θ.

$$n_1 \sin 45^\circ = n_2 \sin\theta$$

$$\sin\theta = \frac{\sin 45^\circ}{n_2} = \frac{\sin 45^\circ}{1.6} = 0.442$$

$$\theta = 26.2^\circ$$

$$\boxed{\alpha = 90^\circ - \theta = 63.8^\circ}$$

(7) b) Draw a ray showing what the laser beam does after striking surface B, and write one short (3 lines maximum!) sentence to justify your picture

The ray is totally reflected since the critical angle of incidence is

$$\sin\alpha = \frac{1}{1.6} = 0.625 \Rightarrow \alpha = 38.7^\circ$$

Any angle α larger than 38.7° is totally reflected (like in lecture demonstration)