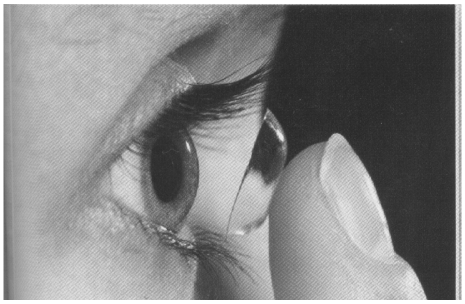
Name: ______________________________
Partners: ______________________________
____

PHYSICS 221 LAB #7: GEOMETRIC OPTICS

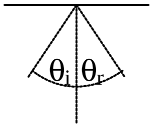


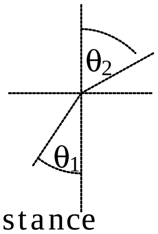
The equation describing the formation of images by lenses is based on Snell's Law which explains how the direction of rays change as they enter a different medium. Contact lenses correct the focus of the eye's lens. In this lab, you will study how two lenses that are close together focus light.

OBJECTIVES

1. Get practice drawing ray diagrams for mirrors, transparent materials, and lenses.
2. Understand and use Snell's Law for rays passing from one medium to another.
3. Apply the thin-lens equation for a lens or pair of lenses.

OVERVIEW





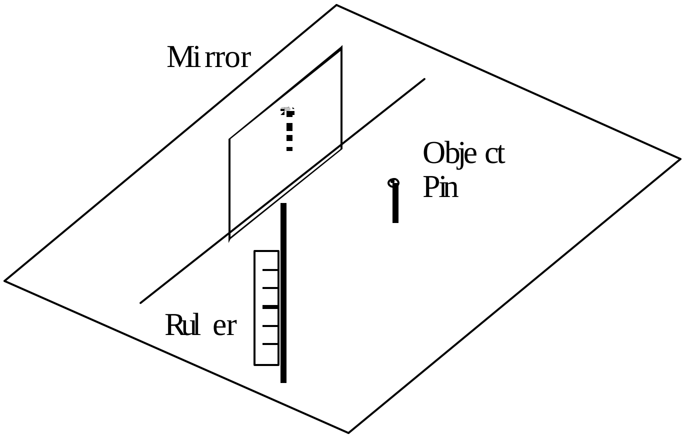
The Law of Reflection states that the angle of incidence equals the angle of reflection ($\theta_{\mathrm{i}} = \theta_{\mathrm{r}}$). Both angles are measured from the normal to the surface.

The speed of light in a material is $v = \frac{c}{n}$, where $c = 3\times10^{8}$ m/s (the speed of light in vacuum) and n is the index of refraction. When light passes from one material to another, the directions of the rays are related by Snell's Law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$. These angles are also measured from the normal to the surface.

The mirror equation and the thin-lens equation, $\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$, relate the object distance (d_o), the image distance (d_i), and the focal length of the lens (f). The focal length is positive for concave mirror or a converging lens and negative for a convex mirror or a diverging lens. For a circular or spherical mirror, the size of the focal length is half the radius. The image distance is positive if the image is real (on the same side of a *mirror* as the object or on the opposite side of a *lens* as the object) and negative if the image is virtual (on the opposite side of a *mirror* as the object or on the same side of a *lens* as the object). The magnification is $M = -d_i/d_o$. In terms of the object height (h_o) and the image height (h_i) ,which is negative if inverted, it is $M = h_i/h_o$. If the distance between two lenses is small, the effective focal length of the pair is $\frac{1}{f} \approx \frac{1}{f_1} + \frac{1}{f_2}$.

PART ONE: Reflection and the Mirror Equation

1. Pin a blank page to a bulletin board. Draw a straight line near the center of the page and place the back edge of the flat mirror along the line and put an "object pin" about 5 cm from its face. Mark the location of the pin.
2. Position the page near the edge of the table so that you can hunch down so it's at eye level, and look along it. Hunch down, and look along the page at the image of the pin from one vantage point. Lay a ruler on the page so, with one eye, you can 'site' along its edge to the look along it. From one side of the pin, carefully align the edge of a ruler with the reflection of the pin. Draw a line along the ruler to represent the ray reflected to your eye. Repeat this process from somewhere on the other side of the pin.



3. Remove the mirror and the pin. With solid lines, extend the reflected rays back to where the mirror was and with dashed lines, extend them ray behind where the mirror was. Mark and label the location where the two ray lines converge. This is the location of the image.
4. Complete the ray diagram by drawing lines from where the reflections occurred back to where the pin was.
5. Draw normal lines from each point of reflection, then label and measure the angles of incidence and reflection for both rays.

θ_{i1} = __________ θ_{r1} = _______

θ_{i2} = __________ θ_{r2} = _______

Question: Do your measurements confirm the Law of Reflection? Explain.

Question: Does the location of the image change as you view it from different angles? (Your can test this by placing another pin at the point where the two rays converge and seeing if the image lines up with the pin behind the mirror when viewed from different angles.)

6. Pin another blank page to the bulletin board. Place the circular mirror near center of the page and trace around it. Put on “object pin” about 5 cm on the “outside of the circle” so that the convex side of the mirror is used. Measure and record the object distance from the mirror surface.

   d_o = ___________

7. Repeat the process of drawing two rays. Extend the reflected rays until they cross to locate the image. Measure and record the image distance including its sign.

   d_i = ___________

8. Measure and record the radius of the outer surface of the mirror.

   R = ___________

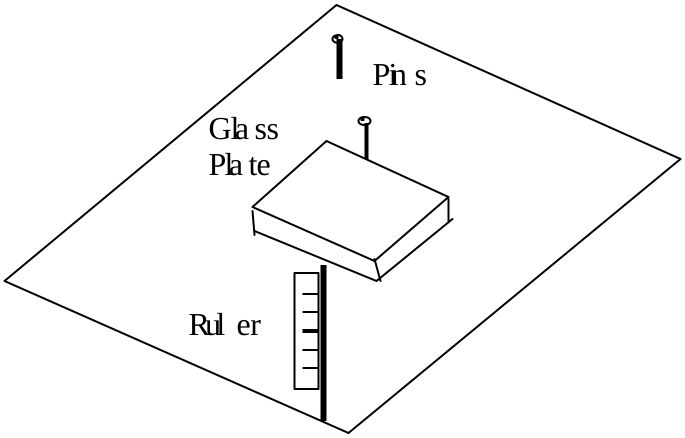
9. Calculate the focal length of the mirror from the image and object distances.

   f = ______

Question: How does the focal length compare to its expected value?

PART TWO: Refraction

1. Pin a blank page to a bulletin board. Place a rectangular glass plate in the middle of the top half of the page and trace around its edges.
2. Put one pin right next to the glass plate and another a few centimeters away so that they are along a line about 30° from a normal to the edge of the glass. From the opposite side, carefully align the edge of a ruler so that you can sight along it through the glass and make the pins line up. Draw a line along the ruler to represent a ray.



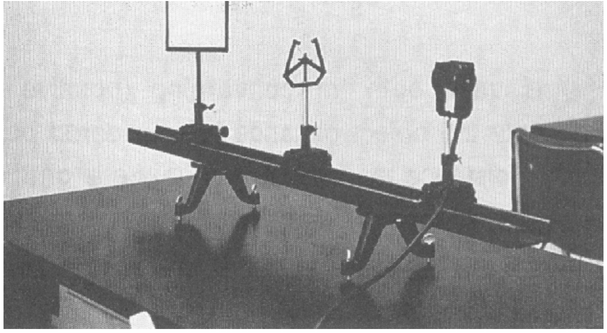
3. Remove the glass plate and extend the line that you have drawn to where the edge of the glass was. Remove the pins and draw a line that passes through the holes they were in and ends where the edge of the glass plate was.
4. Complete the ray diagram by drawing a straight line inside the trace of the glass plate that connects the lines on the outside. Now you have the complete path for one ray as it enters and leave the glass.
5. For one of the edges, draw a normal line where the ray crosses, label and measure the angles from the normal on each side.

θ_1 = ___________ θ_2 = ________

Question: The index of refraction of air is very close to 1. What is the index of refraction for the rectangular glass plate?

PART THREE: Lenses

1. The optical rail pictured below will be used to determine the focal lengths of lenses. It consists of a light (which will be the object), a lens holder, and a screen on which to view images.



2. Move the lens holder to the 50-cm mark and carefully place the converging lens marked “1” in it. Move the object light to the 0-cm mark, then adjust the position of the screen so that the image is as sharp as possible.
3. Measure the image and object distances to the nearest 0.1 cm and record them along with appropriate signs and units.

d_o = ___________ d_i = ________

Questions: What is the focal length of lens 1? What does its sign mean?

f_1 = ___________

4. Measure and record the heights of the object and the image (including the appropriate sign).

h_o = ___________ h_i = ________

Questions: The magnification can be calculated using either the object and image distances or using the heights of the object and the image. Calculate the magnification in both of these ways. How do the calculated magnifications compare?

Question: How does the image you observe change when the lower half of the lens is covered? Explain why.

5. Place an adjustable aperture just in front of the lens. Vary the size of the opening and measure the range of focus, which is how far the screen can be moved and a reasonable focus maintained. Record your observations below.

Diameter of Aperture (cm)	Range of Focus (cm)

Question: What affect does the aperture have on the range of focus?

Question: Does squinting improve your vision? Explain

6. Carefully place the diverging lens marked “6” in the holder.

Question: Can you position the screen so that there is an image on it? Explain.

7. Remove lens “6” from the holder and attach it to lens “1” with two small pieces of tape. Try not to block much of the lenses. Carefully place the pair of lenses in the holder.
8. Adjust the position of the screen so that the image is as sharp as possible. Measure the image and object distances to the nearest 0.1 cm and record them along with signs and units.

d_o = ___________ d_i = ________

Questions: What is the focal length of the pair of lenses?

$f_{1\&6}$ = ______________________

Questions: What is the focal length of lens 6? What does its sign mean?

f_6 = ______________________