Spherical Mirrors & Index of Refraction
Spring 2025

Introduction

In this lab, you will be using ray tracing to locate the image created by an object near a spherical mirror, and to calculate the index of refraction for a glass prism. *You **must** use a very sharp pencil or pen to pass this lab!* Where appropriate, label the object and the image, and indicate their direction (before and after they reflect or refract). Draw a solid line for real rays, and a dashed line for virtual rays. *Each person will turn in their own journal, but you only need one set of ray tracings per group.*

Spherical Mirrors:

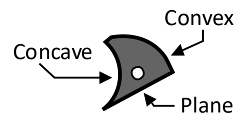

Figure 1a

Figure 1a shows the small three-faced mirror that you will use. The mirror has magnets that will hold the mirror and paper to the metal board so that they don't move while you are tracing the rays. Each side represents a different type of mirror surface: *concave* (the inner curved portion); *convex* (outer-curved portion); and a flat plane mirror (not used in today's experiment). Note that the cross-section of each curved face is that of a sphere (or a circle, in the plane of the paper)

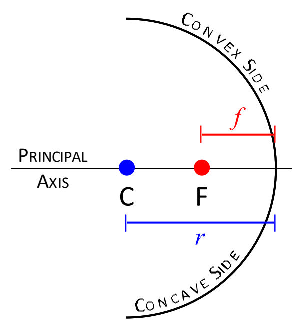

Figure 1b

Figure 1b shows the spherical mirror reference points. The principal axis is the line that intersects the mirror at the center. Point *C* marks the center of curvature, and its distance from the mirror is the radius of curvature, *r*. The focal point, *F* is located midway between the mirror and the center of curvature, and its distance from the mirror is the focal length, *f*. If a mirror is spherical, then $r = 2f$.

Ray Tracing:

Figure 2 shows that the center of curvature, *C* is located by noting the intersection of at least two axial rays (a ray that reflects upon itself). The focal point, *F* is located by noting where a ray that was parallel to the principal axis reflects and crosses the principal axis.

Three additional rays can be drawn to locate images created by spherical mirrors (see the color-coded rays in **Figures 3** and **4**):

a) The incident ray is parallel to the axis, and reflects through the focal point, *F* (Red).

b) The incident ray goes through *F* and reflects parallel to the axis (Green).

c) The incident ray goes through the center of curvature, *C*, and reflects upon itself (Blue).

You need only draw *two* of the above rays to minimize clutter in your ray diagrams. If you find one ray to be difficult (or impossible) to use, draw the other two rays.

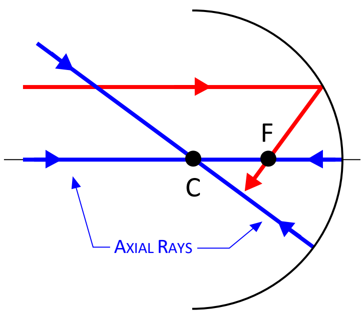

Figure 2: Locating *C* and *F*

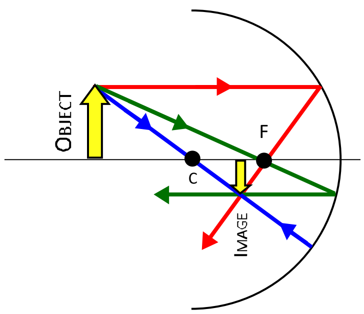

Figure 3: Concave mirror image

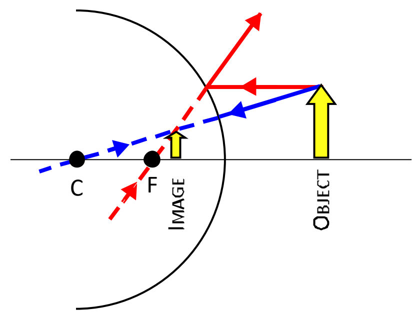

Figure 4: Convex mirror image

Experiment

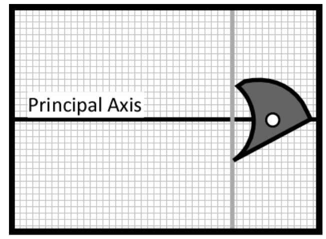

Figure 5: Location of concave mirror on page

1. ***Concave Mirror I*** *(Is the focal length ½ the radius?):*

   a. Place a piece of white paper on the metal board, and then the graph paper (*grid side **down***) on top. You will be able to see the gridlines of the graph paper. Draw two perpendicular lines on the **blank** side of a piece of graph paper, being sure to follow the gridlines: a dark line along the long axis of the page, and a lighter line along the short axis, about 5 centimeters from the right edge (**Figure 5**).

   b. Place the mirror centered along the long dark line (the *principal axis*) with the two edges of the mirror on the shorter light line (**Figure 5**). Plug in the light-ray box.

   c. Rotate the aperture on the light-ray box so that it emits three light rays. Align the center ray along the principal axis with the two other rays parallel to and on either side of the principal axis. Rotate the mirror as needed so that the three reflected rays intersect on the principal axis, and then trace along the front edge of the mirror to mark its location.

   d. Draw the two incident rays parallel to the axis and trace their reflections. Mark and label the *focal point,* **F** with a small dot (**Figure 2**).
      - *Drawing rays*: Mark the path of incident and reflected rays using small dots. Remove the mirror and light box, then use a ruler to connect the dots. **Draw an arrow** to indicate the direction of *each ray*.

   e. Remove the mirror, then measure and record the focal length, f.

   f. Replace the mirror, and check that it is aligned correctly. Set the light-ray box so that it emits a single ray and then aim it at the mirror at an angle so that it reflects upon itself (**Figure 2**). Draw this *axial ray* and label the radius of curvature, **C**. Remove the mirror and then measure the radius of curvature, r.

   g. If a mirror is spherical, then $r = 2f$. Do your measurements show this for your mirror?

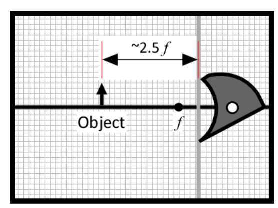

Figure 6: Image of distant object

2. ***Concave Mirror II****:* Finding an Image

   a. Create a new picture with the axes marked the same as before. Set the light-ray box to emit three rays and locate the focal point, marking it with a small dot (don't bother drawing rays here). Also, trace along the front edge of the mirror.

   b. Draw an arrow that is **4 grid-boxes tall**, starting on the axis about **2.5** focal lengths from the mirror; this arrow will represent the object (**Figure 6**, *not to scale*). Set the light box to emit a single ray and find the *image* of this *object* using two rays that originate at the arrowhead. The image is located where the reflected rays intersect; draw another arrow to represent the image of the object arrow (**Figure 3**).

   c. Label the object and image arrows. Is the image in this case real or virtual? Upright or upside down? Larger or smaller than the object?

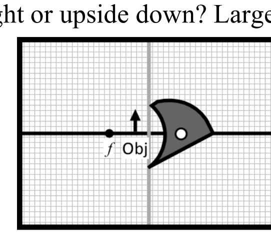

Figure 7: Image of close object

3. ***Concave Mirror III*** *("The makeup mirror"):*

   a. Create a new picture using the same mirror placed ***in the middle*** of your paper (**Figure 7**) and mark the focal point like you did in step *2a*. Draw an arrow **3 grid-boxes** tall, starting on the axis ½ the focal length from the mirror to represent an object.

   b. Find the image of this object using two rays that originate from the object arrowhead. The image is located where the reflected rays intersect. If the reflected rays diverge, you need to trace them backwards until they meet.

   c. Is this image real or virtual? Upright or Upside down? Bigger or smaller than the object? Again, be sure to label the object and image.
      - *Thought question: If the object is placed on the focal point, where will the image be located?*

4. ***Index of Refraction*** *(What is the value of* ***n*** *for acrylic?):*

In this section you will use *Snell's Law* to calculate the index of refraction, **n** for a trapezoidal prism made from acrylic. Snell's law is stated as:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

Note that $n = \frac{c}{v} = \frac{\text{speed of light in vacuum}}{\text{speed of light in material}}$, and the subscripts represent the angles and indices of refraction for the two materials the light ray passes through. Note that angles are measured **from** a normal to the surface **to** the ray.

a. Place the prism near the center of the page and trace around its edges. *Use the magnetic mirror to hold the paper in place!*

b. With the light box emitting a single ray, trace a ray entering the prism approximately 45° from a normal to the surface of the prism (**Figure 8**).

c. Use several dots to mark the direction of the ray as it enters and exits the acrylic, especially at the points where the ray enters or exits from the air-acrylic boundary. Remove the prism, and use a ruler to draw the rays, including the one that passes inside of the acrylic (**Figure 8**).

d. Measure the angles with a protractor. Make sure that you position the protractor correctly (**Figure 9**).

e. Calculate the index of refraction for the trapezoid by applying Snell's law to θ_1 and θ_2, then applying again to θ_3 and θ_4 (use $n_{air} = 1.00$).

f. Calculate the *%Difference* between your average measured value and the actual index of refraction for acrylic: $n_{acrylic} = 1.50$.

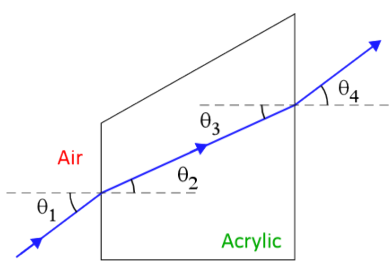

Figure 8:
Tracing a ray through the prism

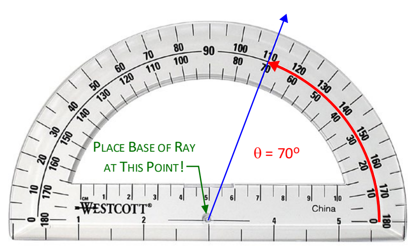

Figure 9:
Correct placement of protractor

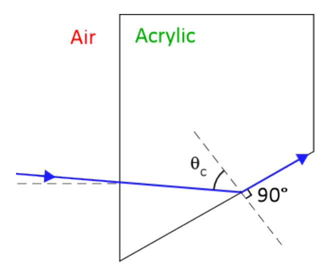

Figure 10:
Calculating the critical angle

5. ***Critical Angle****:*

a. Draw a *new* picture and aim a single ray at the prism so the angle of the final refracted ray is 90° (**Figure 10**), meaning it runs directly along the air-acrylic boundary.

b. Measure and record the angle **inside** the acrylic: this is the *critical angle*, θ_c, beyond which all the light will be reflected internally. *Note that you will probably see this internally reflected ray during your experiment.*

c. Calculate the expected value for θ_c for a ray traveling *from* acrylic *to* air (use the actual value for the index of refraction of acrylic).

d. Calculate the *%Difference* between your measured and expected values of the critical angle.

Discussion

- **No discussion is required**. Assemble ray tracings *in the order they were created*, staple together and hand them in along with your journal. Be sure that the name of all group partners appears on the first page.