Reflection and Refraction

Equipment List

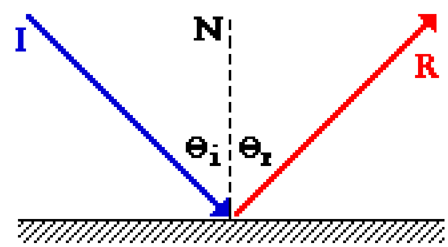
Qty	Items	Part Numbers
1	Light Source, Basic Optics	OS-8517
1	Ray Optics Set	OS-8516
2	White paper, sheet	
1	Metric ruler	
1	Protractor	

Introduction

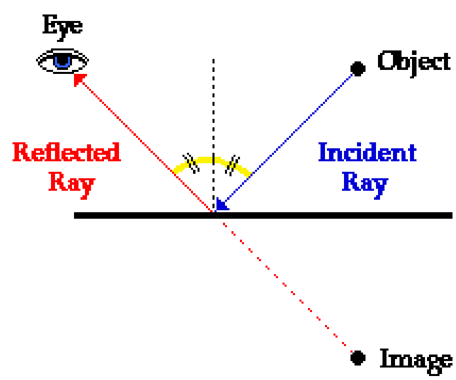
The purpose of the first part of this activity is to determine the relationship between the angle of incidence and the angle of reflection for a light ray reflecting from flat, concave, and convex mirrors. The purpose for the second part is to examine the relationshop of the angle of incidence and the angle of refraction for a light ray passing through a rhombus prism. Use a light source, three-way mirror, rhombus prism, and protractor to measure angles of a light ray.

Background:

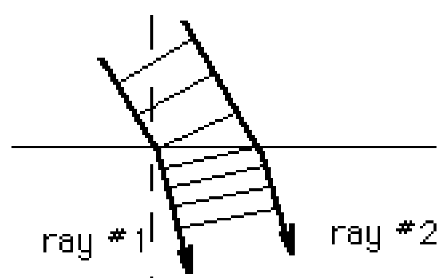
Reflection



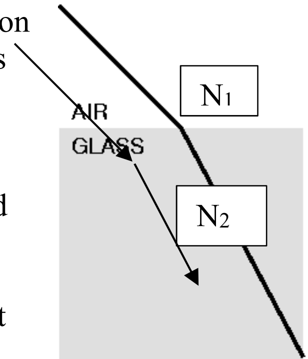
When a ray of light strikes a plane mirror, the light ray reflects off the mirror. Reflection involves a change in direction of the light ray. The convention used to express the direction of a light ray is to indicate the angle which the light ray makes with a normal drawn to the surface of the mirror (a line that is perpendicular to the surface). The angle of incidence is the angle between this normal and the incident ray; the angle of reflection is the angle between this normal and the reflected ray. According to the law of reflection, the angle of incidence equals the angle of reflection.
To view an image of an object in a mirror, you must sight along a line at the image location. As you sight at the image, light travels to your eye along the path shown in the diagram. The diagram shows that the light reflects off the mirror in such a manner that the angle of incidence is equal to the angle of reflection.



Refraction



The most common example of refraction is the bending of light on passing from air to a liquid, which causes submerged objects to appear displaced from their actual positions. Refraction is also the reason that prisms separate white light into its constituent colors. Refraction is commonly explained in terms of the wave theory of light and is based on the fact that light travels with greater velocity in some media than it does in others. When, for example, a ray of light traveling through air strikes the surface of a piece of glass at an angle, one side of the wave front enters the glass before the other and is retarded (since light travels more slowly in glass than in air), while the other side continues to move at its original speed until it too reaches the glass.



As a result, the ray bends inside the glass, i.e., the refracted ray lies in a direction closer to the normal (the perpendicular to the boundary of the media) than does the incident ray. A light ray entering a different medium is called the incident ray. After bending, the ray is called the refracted ray. The speed at which a given transparent medium transmits light waves is related to its optical density (not to be confused with mass or weight density). In general, a ray is refracted toward the normal when it passes into a denser medium, and away from the normal when it passes into a less dense medium.

The law of refraction relates the angle of incidence (angle between the incident ray and the normal) to the angle of refraction (angle between the refracted ray and the normal). This law, credited to Willebrord Snell, states that the ratio of the sine of the angle of incidence, θ_i, to the sine of the angle of refraction, θ_r, is equal to the ratio of the speed of light in the original medium, v_i, to the speed of light in the refracting medium, v_r. Snell's law is often stated in terms of the indexes of refraction of the two media rather than the speeds of light in the media. The index of refraction, *n*, of a transparent medium is the ratio of the speed of light in a vacuum, *c*, to the speed of light in the medium: $n = c/v$.

Using indexes of refraction, Snell's Law (also known as the Law of Refraction) takes the form $\sin\theta_i/\sin\theta_r = n_r/n_i$, or $n_i \sin\theta_i = n_r \sin\theta_r$.

Snell's law has two special cases: critical angle and total internal reflection. When the angle of incidence makes a 90° angle of refraction, total internal reflection occurs. When there is total internal reflection, then you can obtain the critical angle. The critical angle is measured with respect to the normal at the refractive boundary and is equivalent to

$$\theta_r = 90° \rightarrow \theta_i = \theta_c = \arcsin\left(\frac{n_i}{n_r}\right).$$

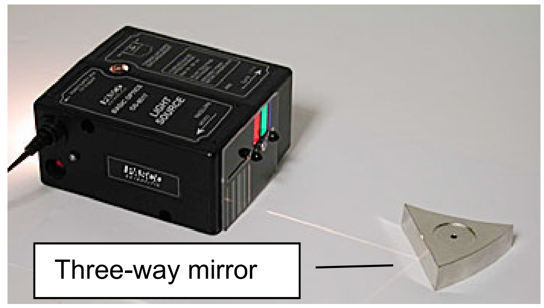
The critical angle only takes place when the light is traveling from a medium with a higher index of refraction to a medium with lower index of refraction. This is to say, we find the critical angle when the value of the incident theta is equal to 90° and thus $\sin(\theta_i)$ is equal to 1. The resulting value of the refracted theta will then be equal to the critical angle. For total internal reflection to occur, n_r must be greater than n_i.

Prediction

What kind of relationship will there be between the angle of incidence and the angle of reflection for a light ray and a convex mirror? What is the relationship for a concave mirror?

Setup: Reflection

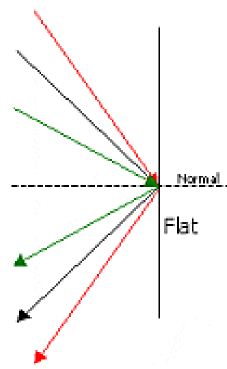
1. Place the Light Source, label side up, on a white sheet of paper on a table. Adjust the mask on the end of the light source so one white ray is showing.
2. Place the mirror on the paper and position the plane surface of the mirror at any angle to the ray so that both the incident and reflected rays are clearly seen on the paper.



Procedure: Reflection

Mirror, Mirror, Mirror

1. Start the experiment using the plane mirror side of the three-way mirror.
2. Trace the surface of the mirror with a thick line and label it "plane mirror".
3. Trace the incoming ray (incident ray) and outgoing ray (reflected ray). Indicate the incoming and outgoing rays with arrows in the appropriate directions.
4. Reposition the light source so that it strikes the mirror at an different angle, but at the same location as the previous trial.
5. Trace the incident and reflected rays. Indicate the incoming and outgoing outgoing rays with arrows in the appropriate directions. (Hint: use a different color pen or pencil for each trial as shown in the example diagram.)
6. Repeat steps 3-5 two more times for a total of three trials.
7. Repeat steps 2-6 twice more; the first time using the *concave* side of the three-way mirror and the second time using the *convex* side of the three-way mirror.



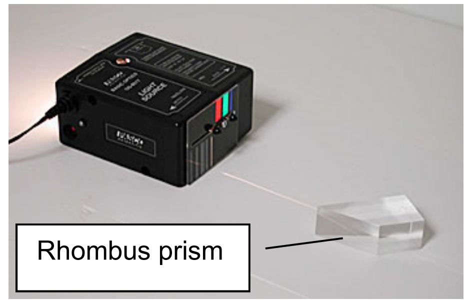
Analysis: Reflection

1. Remove the paper from under the light source and mirror.
2. Using your protractor and ruler, draw a dotted line perpendicular to the surface of the mirror at the point where all rays struck the surface of the mirror. This line is called the normal to the surface.
3. For each trial, measure the angle of incidence (angle of the incoming ray relative to the normal) and the angle of reflection (angle of the outgoing ray relative to the normal).
4. Record each angle (30°, 45° & 60°) in the Analysis section.

Setup: Refraction

1. Place the Light Source, label side up, on a new sheet of paper on a table. Adjust the mask on the end of the light source so one white ray is showing.
2. Place the rhombus on the paper so that the long side faces the light source and the textured side of the rhombus faces down. Also, position the rhombus so the ray passes through the parallel sides.



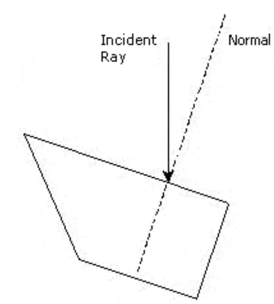


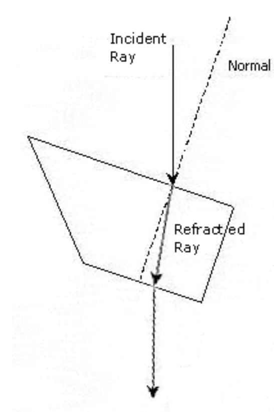
Procedure: Refraction

1. Trace the shape of the rhombus and then position the light ray entering the rhombus at 30 degrees such that the light enters and exits the rhombus through parallel sides. Then trace the incoming and outgoing rays with arrows in the appropriate directions.
2. Reposition the light source so the light strikes the rhombus at a 45 degree angle of incidence and trace the incoming and outgoing light rays.
3. Repeat step 2 but with a 60 degree angle of incidence.

Analysis: Refraction

1. Remove the paper from under the light and rhombus.
2. Using your protractor and ruler, draw a line perpendicular to and through the surface of the rhombus at the point where the ray of incidence strikes the rhombus. This line is the normal.
3. Trace the path of the light ray as it moves through the rhombus. This is the line that connects the point where the light ray enters the rhombus to the point the light ray exits the rhombus.
4. Measure the angle of incidence (angle of the incoming ray relative to the normal) and the angle of refraction (angle of the ray transmitted through the rhombus relative to the normal) and record the value in the chart.
5. Repeat steps 2-4 for each trial. Record the values in the Lab Report.



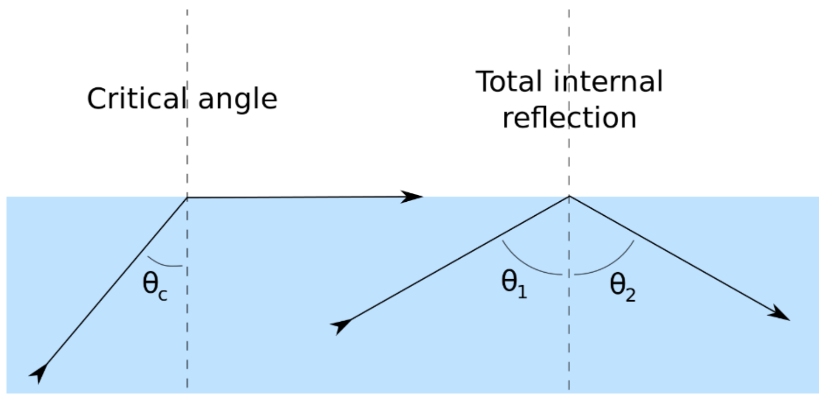


Setup: Critical Angle

1. Place the Light Source, label side up, on a new sheet of paper on a table. Adjust the mask on the end of the light source so one white ray is showing.
2. Place the rhombus on the paper so that the long side faces the light source and the textured side of the rhombus faces down. Also, position the rhombus so the ray passes through the parallel sides.

Procedure: Critical Angle

1. Trace the shape of the rhombus.
2. Shine a single slit light source into the rhombus, increasing the angle of incidence until total internal reflection occurs.
3. Trace the incoming light ray and mark the position on the opposite side of the rhombus where the internal light beam strikes the side of the rhombus.



Analysis: Critical Angle

1. Remove the rhombus, connect the incoming ray to the position just marked.
2. Trace a line in the internal normal direction where the internal light ray struck the rhombus.
3. The angle formed from this normal and the internal light ray formed is the critical angle for the rhombus.

Analysis of Reflection and Refraction Lab

Name____ Group#________
Course/Section_______________________________________
Instructor____

Reflection

Data Table (10 points)

Plane Mirror		Convex Mirror		Concave Mirror	
Angle of Incidence (degrees)	Angle of Reflection (degrees)	Angle of Incidence (degrees)	Angle of Reflection (degrees)	Angle of Incidence (degrees)	Angle of Reflection (degrees)
30		30		30	
45		45		45	
60		60		60	

1. What is the relationship between the angle of incidence and the angle of reflection? (5 points)

2. Does the relationship hold true for all mirrors? Cite evidence to support your position. (10 Points)

Refraction

Data Table (15 Points)

Rhombus Prism		
Angle of Incidence (degrees)	Angle of Refraction (degrees)	Critical Angle (degrees)

1. Use *Excel* to graph the sin of the angle of incidence vs the sin of the angle of refraction. From the graph, determine the Index of Refraction of the material the rhombus is made from. (10 points)

2. Describe what happens as the ray of light enters the rhombus. (10 points)

3. Describe the relationship between the angle of incidence and angle of refraction. (10 points)

4. Using the measured index of refraction, calculate the critical angle for the rhombus surrounded by air. Show work. (5 points)

5. What is the percent error between the measured and calculated values of the critical angle? Use the calculated as the theoretical value. Show work. (5 points)

6. Using Snell's Law, explain why the index of refraction is a dimensionless quantity. (5 points)

7. What are some reasons for our percent error in this experiment? (5 points)

8. Did our experiment confirm the Laws of Reflection and Refraction? Why or why not? (5 points)