

Concepts of this week's Module

- Ray Tracing.
- Refraction and Total Internal Reflection.
- Reflection and Image Formation in Plane Mirrors.

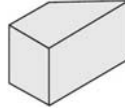


Expt Ray Optics Module - Activity 3

This activity uses the “Ray Box” feature of the PASCO Basic Optics Light Source. Place the light source flat on the table or on your notebook so it is sitting on its four little legs and plug it in. There is a wheel to select one, three or five parallel rays projected onto the table. If you place it on your open notebook the rays will be easier to see and you can trace them with a pen or pencil.

You also should have a transparent glass trapezoidal prism, a small protractor and a ruler.

Trapezoidal prism:



- Select the 1-ray and shine it on an open page of your notebook. Place the trapezoidal prism in the beam. You should see that part of the ray is refracted through the trapezoidal prism, but there also is a reflected ray. Adjust the angle of incidence. How does the brightness of the reflected ray vary with the angle of incidence? [Note, the angle of incidence is defined as the angle between the incident ray and the normal from the surface which emerges at the point where the ray touches the surface.]
- Choose an angle of incidence, and carefully sketch and label the incident ray, the reflecting surface of the trapezoidal prism, and the reflected ray. Use the ruler and protractor to sketch and label the normal to the surface at the point where the ray reflects. Measure the angle of incidence and angle of reflection. Is the Law of Reflection obeyed to within your errors? Repeat for twice for a total of three different incident angles. What is the largest source of error in measuring these angles?
- Select the 1-ray and shine it on an open page of your notebook. Place the trapezoidal prism in the path of the ray so that:
 - the angle of incidence is at least 45° , and

- the ray emerges from the other side of the trapezoidal prism. The side from which the ray emerges should be parallel to the side into which the beam enters. You should note that the emerging ray is parallel to the incident ray.

Sketch and label the incident ray and the surface of the trapezoidal prism through which you are refracting, the emerging ray, and the surface of the trapezoidal prism from which the ray emerges. Remove the trapezoidal prism, use the ruler to clearly mark all three parts of the ray, including the ray when it is inside the trapezoidal prism. Note that if you sketched the sides of the trapezoidal prism by running a pen along the surface, the line you drew will be about 1 mm in front of the actual glass surface; you should correct for this. Use the ruler and protractor to sketch and label the normals to the surface where the ray enters and exits the trapezoidal prism. Measure the angle of incidence and the angle of refraction for the ray when it first enters the trapezoidal prism. Use Snell's Law to determine the index of refraction of the glass.



**Course
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Ray Optics Module - Activity 4

Here is the URL of a Flash animation of a ray of light traveling between air and glass.

<http://www.upscale.utoronto.ca/PVB/Harrison/Flash/Optics/Refraction/Refraction.html>

[NOTE as of 1/27/09 there is a small bug in the animation: after entering an angle using the keyboard, you must click on the slider to show the refracted ray.]

Open the animation. There are two scenes you can toggle through: the first is of a ray traveling from air into glass, and the second is of a ray traveling from within some glass out into air. You may set the index of refraction of the glass within the range $n = 1.25$ to $n = 1.75$.

- In the Air to Glass scene, set $n_{\text{glass}} = 1.5$, and explore various angles of incidence. Record what happens for angles of incidence $\theta = 0^\circ, 5^\circ, 40^\circ, 50^\circ, 85^\circ$ and 90° . Note the strengths of the reflected and refracted rays, if they exist, and the angle of refraction.
- In the Air to Glass scene, set the angle of incidence to $\theta = 45^\circ$, and explore various indices of refraction of the glass. Record what happens at the minimum n_{glass} , and what happens as you increase n_{glass} .
- In the Glass to Air scene, set $n_{\text{glass}} = 1.5$, and explore various angles of incidence. Record what happens for angles of incidence $\theta = 0^\circ, 5^\circ, 40^\circ, 50^\circ, 85^\circ$ and 90° . Note the strengths of the reflected and refracted rays, if they exist, and the angle of refraction.
- In the Glass to Air scene, set the angle of incidence to $\theta = 45^\circ$, and explore various indices of refraction of the glass. Record what happens at the minimum n_{glass} , and what happens as you increase n_{glass} .

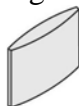


Expt Ray Optics Module - Activity 6

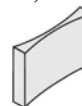
This activity uses the “Ray Box” feature of the PASCO Basic Optics Light Source. Place the light source flat on the table or on your notebook so it is sitting on its four little legs and plug it in. There is a wheel to select one, three or five parallel rays projected onto the table. If you place it on your open notebook the rays will be easier to see and you can trace them with a pen or pencil.

You also should have a flat glass convex lens, a flat glass concave lens, and a ruler.

Convex Lens:



Concave Lens:



- A. Select the 5-rays and shine them on an open page of your notebook. Take the convex lens and focus the rays, so that the focal point is on your page. Sketch the five rays and the exterior shape and position of the lens. Label the focal point. Measure the focal length of the lens, which is the distance between the centre of the lense and the focal point for initially parallel rays.
- B. Select the 5-rays and shine them on an open page of your notebook. Take the concave lens and de-focus the rays. Leave enough room on the page so that you will be able to sketch the rays backwards to the virtual focal point from which they appear to be emerging. Sketch the five rays and the exterior shape and position of the lens. Remove the lens and use a ruler to trace the rays backward to the spot from where they all seem to be emerging. Label the virtual focal point. Measure the focal length of the lens, which is related to the distance between the centre of the lens and the virtual focal point for initially parallel rays. Is the focal length for this lens negative or positive?
- C. [*If you have time.*] Switch the wheel to the red, green and blue thick beams. Using the lenses and these coloured beams, can you create white light?


**Course
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Ray Optics Module - Activity 2 [If you have time]

Here is a picture of Jason Harlow in front of a chalk-board, reversed several times to produce 4 possibilities. One image is the original, one is reversed left and right, one is reversed up and down, and the other is reversed both left and right and up and down.



1



2



3



4

- A. Can you tell which image of Harlow is the original (1, 2, 3 or 4)? Explain your reasoning. [Note: this question is meant for fun and may end up being more about fashion trends than physics – but it is meant to get you thinking about image reversal.]
- B. *"Why do mirrors reverse left and right and not up and down?"* Alice and Bob stand in front of a large mirror in a dance studio, looking at themselves. Alice wonders

- if their images are reversed “left and right” or “up and down”. She looks at Bob’s image in the mirror and memorizes what he looks like. Then she asks Bob to turn and face her, so she can compare the image to what Bob looks like in real life. Bob takes a couple of steps forward, turns around and faces Alice. Alice notes that, compared his the mirror image, Bob appears reversed left and right! Alice concludes: Mirrors reverse left and right, not up and down. Is this true? Can you see any flaws in Alice’s reasoning?
- C. You are supplied with a small sign on which is printed “**Charles Dodgson**”, which was Lewis Carroll’s real name. Hold the sign up to the supplied mirror with the writing facing the mirror: you will see the text in a mirror image. Now hold the sign up to a light and look at the writing on it from behind. Is there any difference between the appearance of the writing as seen in the mirror and the writing as seen from behind? Now curve the sign so the edges are closest to you and centre, about where the **D** is, is furthest away from you. Look at the sign in the mirror. In the mirror image are the edges curving towards you or away from you? In Part B, you may have concluded that mirrors reverse left and right. Do you want to change that conclusion? What do mirrors really reverse?

NOTE: When you are finished the activities, as a courtesy to the next group, please replace all the equipment into the bin provided, erase the white-boards and log off of the computer.

This Student Guide was written by Jason B. Harlow, Dept. of Physics, Univ. of Toronto, in the Fall of 2008. Part C of Activity 2 is by David M. Harrison, Dept. of Physics, Univ. of Toronto.

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