

Lab 07 - Optics

NAME: _____

Time spent on Lab 07 = approximately 2 hours, does not need to be done at one sitting

Materials needed = Access to computer and high speed internet, Java installed on the computer, a browser with Flash built-in (likely Chrome is best)

Learning Objectives:

- Use geometry to manipulate light in different mediums
- Apply this manipulation to thin lenses

Virtual Lab:

To begin this week's lab, proceed to: https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html

Once you have the browser open you will see something like the screenshot below:

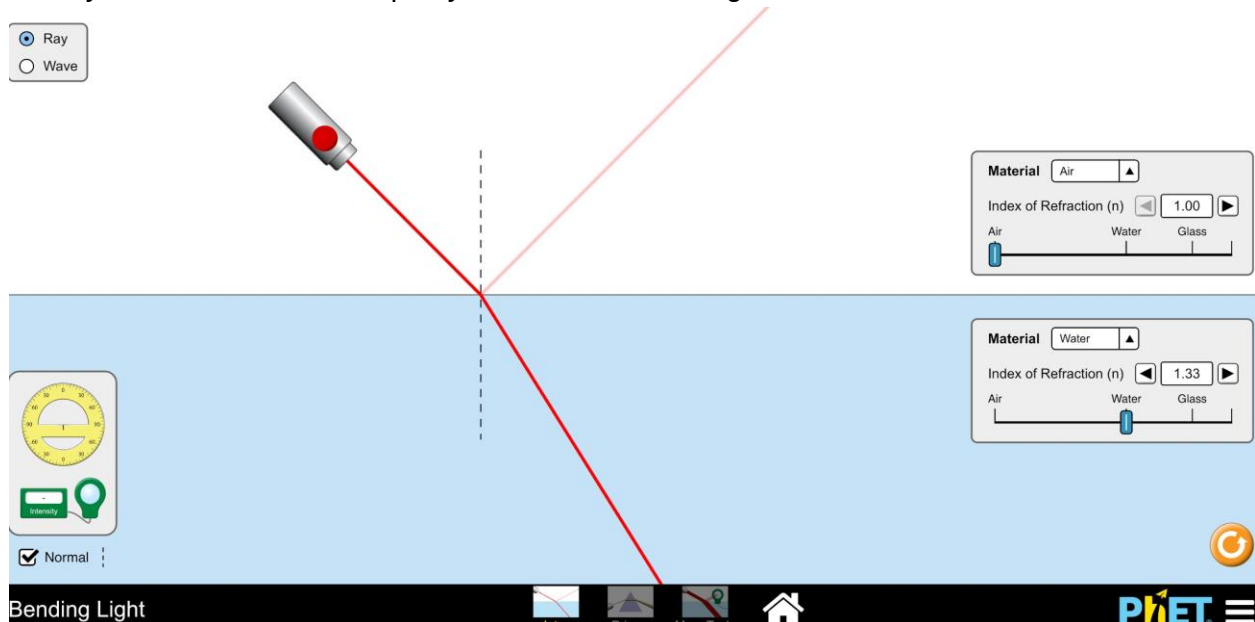


Figure #1

The screenshot shows a laser which is turned on, shining light from air to water. If you drag the protractor so that the central point is over the laser light when it hits the water, then you can measure the angles between the laser beam and the normal (dashed line) on both side of the water.

1. Please go ahead and measure the angle between the incoming light and the dashed line going up. Also, please measure the angle between the light in the water, and the dashed line going down. Write the answers below and comment on whether the angles SHOULD be the same, different, in what way.

Incident angle 45

Refracted angle 32

The angles should not be the same because the two mediums are of different refractive indexes. When a ray of light moves from one medium to another its velocity changes so that it either moves towards or away from the normal.

You may have already read in the textbook that Snell's Law states that light entering into a different substance, at some angle, will "refract" by some angle which is given by Snell's Law, $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$ (eq. 1)

2. Check that Snell's Law is correct for the default situation in the simulator. Develop a method to check this, write it out below, and then proceed to test the theory. Write the results of your test below as well.

METHOD:

1. measure the angle between the incident ray and the normal and record it as angle A (incident angle)
2. Measure the angle between the ray and the normal in the water and record it as angle B (refracted angle)
3. Repeat the procedures 1 and 2 above with different incident angles and record the refracted angle of each.
4. Verify that the ratio of the sine of the angle of incidence to the angle of refraction is a constant ($\sin A / \sin B = K$) where K is a constant.

RESULTS

A	$\sin A$	B	$\sin B$	$(\sin A / \sin B)$
30	0.5	22	0.3746	1.33
40	0.6428	30	0.4833	1.33
50	0.7660	35	0.5736	1.33
60	0.8660	41	0.6560	1.33

Snell's law is correct for the default situation in the simulator because $(\sin A / \sin B)$ is a constant.

Hopefully you found that Snell's Law does apply to the situation depicted in the simulator. Now let's use Snell's Law in a more practical way, to figure out what an unknown substance is made of!!

3. On the right side of the screen you are able to change the lower material to a different substance, Mystery A. Please do so and then develop a NEW method to test the index

of refraction of the substance Mystery A and write down your procedure below. **You must take at least 5 sets of data with the protractor in your method!**

1. Measure the angle between the normal and the incident ray. Let this be angle **C**.
2. Measure the angle between the ray and the normal after the ray has penetrated the surface of the substance. Let this angle be **D**.
3. Take five sets of the data as provided in procedures 1 and 2 above and record it.
4. Calculate the sine of angle(s) **C** and multiply the answer by the index of refraction of the medium above which is air (**refractive index of air is 1**)
5. Divide the answer from procedure 4 above and divide it by the sine of angle(s) **D**.

4. Write out your data and your conclusions of your tests below. Include a guess as to what the mystery substance is!

C	Sin C	D	Sin D	(1)Sin C/ Sin D
30	0.5000	22	0.3746	1.33
45	0.7071	32	0.5299	1.33
50	0.7660	35	0.5736	1.34
70	0.9397	45	0.7071	1.33
80	0.9848	48	0.7431	1.33

The mystery substance could be water.

So great, light hits a different substance at some angle with respect to the normal and it bends. Big deal. It becomes a rather big deal when discussing people with imperfect vision and their desire to see correctly! The light that comes into their eyes is not bending properly, because their eye has formed slightly differently than normal. The way to correct this slight deformity is with a pair of "prescription lenses"! In order to better understand eyeglasses, let's first do our best to understand thin lenses!

To begin, proceed to the webpage: https://phet.colorado.edu/sims/geometric-optics/geometric-optics_en.html

Here you will see a screen similar to the one below:

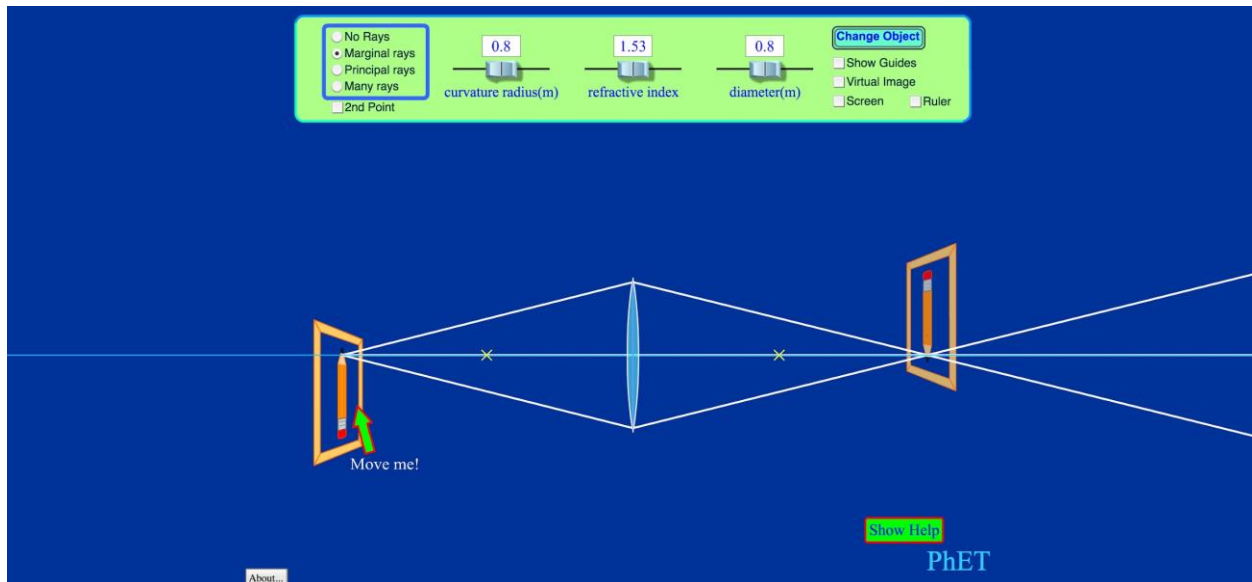


Figure #2

This is a simulation which has a picture of a pencil on the left that is an actual, physical object. The light from the picture of the pencil is sent out in all directions, but SOME of that light goes through a small lens in the middle of the screen. That lens will bend the light and then the light will form a crystal clear image on the right side, of what was shining light on the left side.

To view this effect more clearly, click on the “Many Rays” button at the top/left of the simulator. This will show you several rays coming from the left and only some of them are sent through the lens.

This bending of light by a lens, to form a clear image, is typically referred to as the physics of thin lenses. In order to manipulate thin lenses and perform experiments, please play around with what you can change and what you cannot in the simulator.

5. Write out what you find most interesting about the simulator. What you find least interesting about the simulator.

Most interesting: As the object moves toward the lens, the image becomes bigger and when it goes beyond the focal point the image is formed at infinity. Least interesting: rays passing through the center of the lens do not get refracted.

Now let's get into some quantification of lenses! Below are some important equations you may want to keep in mind!

Important Formulas: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ or $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$ $\frac{1}{f} = (n-1)\frac{2}{R}$ $m = \frac{h_i}{h_o} = \frac{-d_i}{d_o}$ or $m = \frac{h_i}{h_o} = \frac{-q}{p}$

Figure #3

In case you have not encountered it yet, this [Khan Academy video](#) will help illustrate the sign convention for lenses. Please watch the video all the way through and then proceed with the lab. To begin let's:

- Click to draw the rays using the 3-ray system
- Move the object towards the lens. What happens to the image formed on the other side of the lens?

The image becomes bigger and it is inverted. at the focal point the image forms at infinity

- As you move the object inside the lens' focal point something odd happens. Rays that don't meet **diverge**. Does this mean no image will be formed? Where is the image?

The image is formed at infinity.

- Click on "Virtual Image." How are a real image and a virtual image similar? How are they different?

Both images are the effect of light being reflected off or through a lens
A virtual image is always erect while a real image is always inverted.

- Click on the ruler. You will need to make several measurements during the lab. You may, if you wish, leave your measurements in **cm** when using the formulas given above.
- Set the lens's refractive index (n) to 1.8 and the radius of curvature (R) to 0.7m. Use the appropriate equation above to solve for the focal distance (f). (Measure the focal distance to confirm your answer.)

44cm

- Using the focal distance you just found, complete the table below and check your work in the simulation.

Object distance (d_o)	Image distance (d_i)	Magnification (m)
120 cm	69cm	-0.5750
90 cm	86cm	-0.9556
60 cm	165cm	-2.7500
30 cm	-94cm	3.1333
15 cm	-23cm	1.5333

- Repeat the previous exercise, but with a very different lens with the following characteristics: $R = 80\text{cm}$, $n = 1.25$. Calculate the focal length below

$$\begin{aligned} 1/f &= (1.25-1)/80 \\ 1/f &= 0.25(1/40) \\ 1/f &= 1/160 \\ F &= 160\text{cm} \end{aligned}$$

- Now fill in the data table below.

Object distance (d_o)	Image distance (d_i)	Magnification (m)
120cm	-480cm	4.0000
90 cm	-206cm	2.2889
60 cm	-96cm	1.6000
30 cm	-37cm	1.2333
15 cm	-17cm	1.1333

Summary statements:

6. Images formed behind the lens are....?

Inverted

7. As the radius of curvature of a thin lens increases, the focal point of the lens becomes.....?

The focal length becomes bigger

8. What advantage does a larger lens have over a smaller lens?

A larger lens produces brighter images than a smaller lens

9. An object 35 cm away from a lens projects a real image 0.55 m behind the lens. What is the lens' focal length?

21cm

10. An object 20 cm to the left of a convex lens is 1.0m in height. What is the height and location of its image, if the lens has a magnification of **2.0**!

The image is 200cm and it is on the left side of the lens

11. Imagine you are [nearsighted](#). At your last eye appointment, your optometrist tells you that she will need to increase your prescription because as it turns out, light is focusing “too soon” in front of your retina. What sort of lens will your optometrist prescribe and why?

A diverging lens. A diverging lens will serve to diverge the lens before it reaches the retina so that the rays of light will be converged by the cornea to produce an image at the retina.

We have dealt with light as if it were traveling in nice-clean straight lines. Recall that light is a wave! So why don't we depict light as a wave in geometrical optics? The answer is, there is

really no need to do so, with Huygen's principle, and we will see more on why in the next and final lab!

- Portions of this lab were taken from a write up by Chris Bires - Phet

Once you have completed all lab questions, please download this document as a PDF only! Then upload this PDF to Blackboard under the assignment "Lab 07", for grading.