Online laboratory assignment 11 – Geometric optics

Purpose: to understand the projection and magnification using converging lenses.

Introduction

The design of high quality optical instruments can be complicated, involving compound lenses and intricate lens coatings. But many of the complications arise from the need to reduce the effects of spherical and chromatic aberration. Understanding the basic principles of standard optical instruments is not complicated. It requires a simple understanding of the fundamental lens equation,

$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$$

and the magnification of an image, which is given by the equation

$$m=-\frac{s'}{s}=\frac{y'}{y}$$

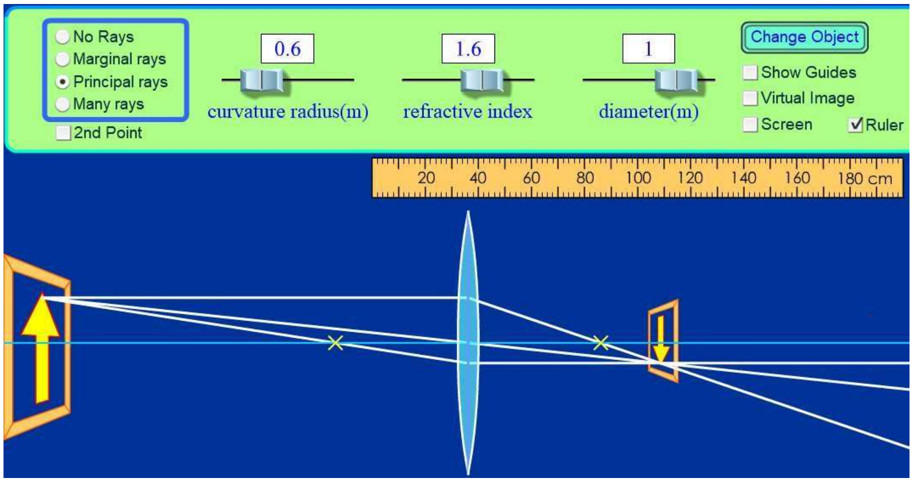
When an object is located between the focal point and twice the focal point, 2*f*, of a converging lens, a real, inverted, magnified image is formed. If a viewing screen is placed at the location of the image, the image will be in focus on the screen. Thus, the lens functions as a projector. Note that an object located a distance greater than 2*f* from the lens will produce an image that is smaller than the object.

Laboratory assignment

1. Run the "Geometric optics" PhET simulation.
2. Maximize your screen. WARNING: the ruler in the PhET program will only measure horizontally so all magnification measurements must be done using the equation $m=-\frac{s\prime}{s}$ and NOT the equation $m=\frac{y\prime}{y}$.
3. Take some time to play with the simulation familiarize yourself with how it works.

Part I: Imaging

4. In this lab, you will be moving the object to analyze how images are formed. When you are ready to get started be sure that your settings and values are exactly as shown below. Hit the change object button until it cycles through to the yellow arrow.



○ No Rays
○ Marginal rays
● Principal rays
○ Many rays
☐ 2nd Point
curvature radius(m): 0.6
refractive index: 1.6
diameter(m): 1
☐ Show Guides
☐ Virtual Image
☐ Screen
☑ Ruler

5. Using the ruler, measure the distance from the “×” marks to the center line of lens. Record the value in Table 1 as the focal length f.
6. Double the value of the focal length written in step 5 and record as $2f$ in Table 1. Table I: focal length data

f (cm)	$2f$ (cm)

7. Place the yellow arrow to the left of the lens at a distance greater than $2f$ (for example, around $4f$ or so, but at a distance in which the ruler can still be used to take the measurement).
8. Measure and record the values for the object distance d and the image distance d in Table II.
9. Calculate the magnification and also fill in the remaining boxes in that column for Table II.
10. Now place the yellow arrow to the left of the lens at a distance somewhere between f and $2f$ (for example, around $1.5f$).
11. Measure and record the values for the object distance d and the image distance d in Table II.
12. Calculate the magnification and also fill in the remaining boxes in that column for Table II.
13. Place the yellow arrow to the left of the lens at a distance somewhere between the lens and the focal point f (for example, around $0.75f$). Explain what is happening with the principle rays (are they converging to a point or diverging away on the right-hand-side of the lens)?

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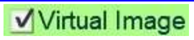
14. Without moving the object, check the “virtual image” box. 

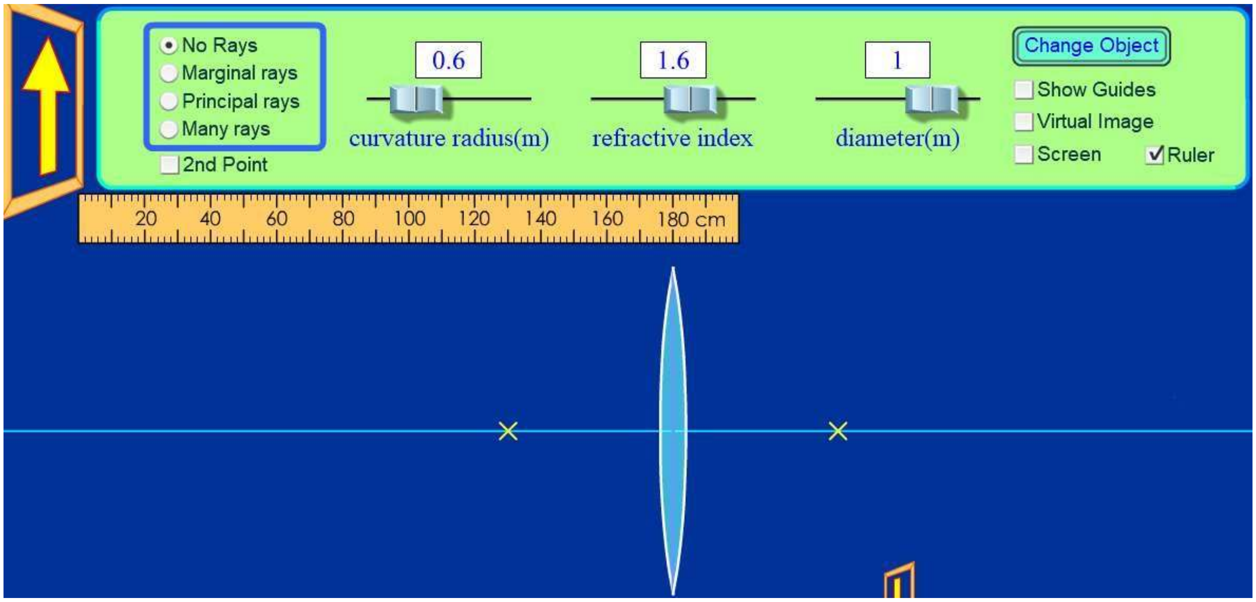
15. Measure and record the values for the object distance s and the image distance s' in Table II. Remember that if the object is on the left, then any image also on the left is virtual with a negative image distance.
16. Calculate the magnification and fill in the remaining boxes in that column for Table II.

Table II: experimental data from simulation.

	Greater than $2f$	Between f and $2f$	Less than f
s (cm)			
s' (cm)			
m (including negative or positive)			
Image type (real or virtual)			
Image direction (upright or inverted)			

Part II: Lens design

17. Select “no rays” and deselect the virtual image box. Also move the object away from the horizontal path of the lens (to the upper right corner works well). You should have the settings as shown below



● No Rays
○ Marginal rays
○ Principal rays
○ Many rays
☐ 2nd Point

0.6 curvature radius(m)

1.6 refractive index

1 diameter(m)

Change Object

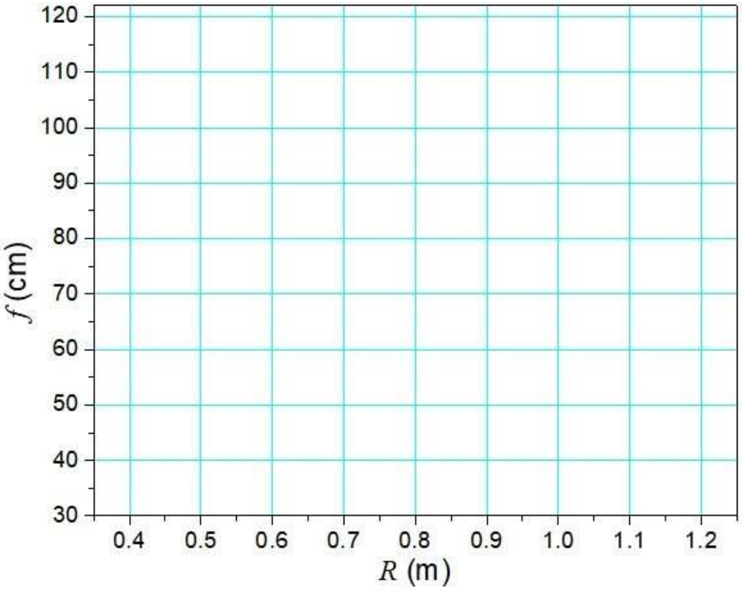
☐ Show Guides
☐ Virtual Image
☐ Screen ☑ Ruler

18. Keeping a constant value for the refractive index, $n = 1.53$, we want to see how the focal length depends on the curvature radius.
19. Adjust the curvature radius to the values given in Table III, and record the focal length of the lens for each value of the curvature radius at a constant value of $n = 1.53$.

Table III: focal length as a function of the curvature radius for constant $n = 1.53$.

R (m)	0.4	0.6	0.8	1.0	1.2
f (cm)					

20. Plot the data on the below graph and draw a best fit line or curve.



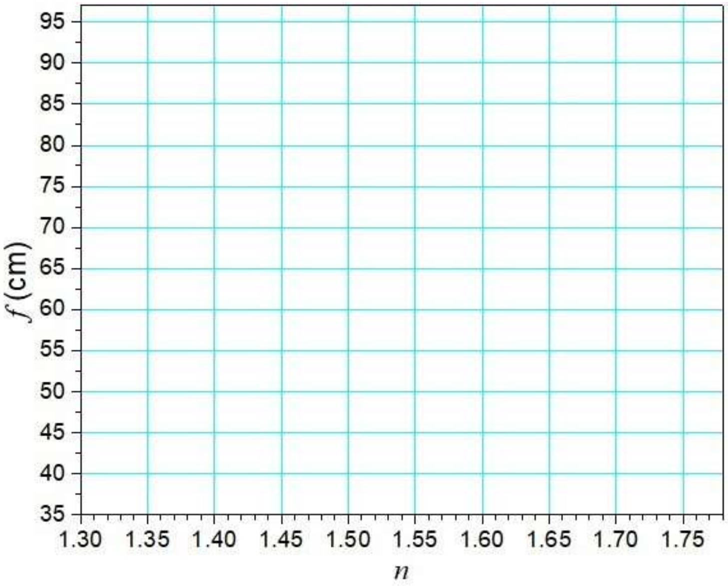
21. Keeping a constant value for the curvature radius by setting it to $R = 0.6$ m, we want to see how the focal length depends on the refractive index.

22. Adjust the refractive index to the values given in Table IV, and record the focal length of the lens for each value of the refractive index at a constant value of $R = 0.6$ m.

Table IV: focal length as a function of the refractive index for constant $R = 0.6$ m.

n	1.33	1.43	1.53	1.63	1.73
f (cm)					

23. Plot the data on the below graph and draw a best fit line or curve.



24. Write a brief conclusion to the laboratory.

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