PHY385 Module 4
Student Guide

Concepts of this Module

- The Thin Lens Equation
- Focal Points in 2 Dimensions

Activity 1 – Thin Lens Solution When ($s_o + s_i$) is Fixed - Theortical

An object held a distance s_o in front of a thin lens with positive focal length f will form a focused image on a viewing screen a distance s_i beyond the lens if:

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

An object and a viewing screen are held at a fixed distance d, and a focusing lens with positive focal length f is placed part-way between them. In order to form a focused image, the sum of the object and image distances must be equal to d: $s_o + s_i = d$.

A. Combine the thin lens equation with the requirement that $s_o + s_i = d$ to eliminate so and solve for s_i in terms of f and d only.

B. Identify the discriminant of the quadratic equation for Part A. If the discriminant is negative, then the solution for s_i will have an imaginary component. Physically, this means that a focus is impossible and the image will always be blurry. For what condition on d will a focused image be impossible?

Magnification, M, is the ratio of the image size to the object size. By definition, $|M| = h_i/h_o$, where h_i is the height of the image measured perpendicular to the optical axis, and h_o is the height of the object measured perpendicular to the optical axis. If the image is inverted, M is negative. For an image formed by a thin lens:

$$M = -\frac{s_i}{s_o}$$

C. Consider a situation where $d = 1.0$ m, and $f = 0.2$ m. What are the two solutions of s_i ? What is the magnification, M, for the two solutions?

Activity 2 – Thin Lens Solution When (s_o + s_i) is Fixed - Experimental

This activity uses optical components clipped to the 2.2m aluminum track. It is easy to slide these components along the length of the track, and to measure their position using the ruler on the track. Set up the Viewing Screen at 20 cm. This means the front surface of the white screen should be above the 20 cm mark on the track, and facing down the length of the track where you will be placing other components. Place Lens "A" in the Dynamics Optics Carriage and set up the lens at about 80 cm and the light source with the illuminated crossed arrows pattern at 140 cm, so the pattern is facing toward the lens. In this case, the distance between the source and the screen, d, is 120 cm. But you can move the screen or the light source to reduce this.

A. Choose a value of d from the example table below, and set the illuminated pattern and the viewing screen to be at this separation. First slide the lens close to the screen, then slowly slide the lens away from the screen until a clear image of the crossed-arrow object is formed on the screen. Measure the image distance s_i and the object distance s_o. Also measure the object size h_o and the image size h_i. The object size is the distance between two pattern features on the crossed-arrow object, and the image size is the corresponding distance between these features in the image. From measurements of s_o and s_i you can predict the magnitude of the magnification, $|M_{pred}| = s_i / s_o$, and compare with the measured magnification $|M_{meas}| = h_i / h_o$. Note there may be *two* very different values of s_i that give a clear image. [As d decreases there may be only one or even no values of s_i that give a clear image – just fill in "NO FOCUS" under s_i in these cases.]

Lens "A"

d	s_i	$1/s_i$	s_o	$1/s_o$	h_i	h_o	$\lvert M_{meas}\rvert = h_i / h_o$	$\lvert M_{pred}\rvert = s_i / s_o$
120 cm								
120 cm								
110 cm								
110 cm								
100 cm								
100 cm								
90 cm								
90 cm								
80 cm								
80 cm								
70 cm								
70 cm								
60 cm								
60 cm								
50 cm								

50 cm								

B. Plot $1/s_o$ versus $1/s_i$ and find the best fit line (linear fit). This should give a straight line with the *y*-intercept equal to $1/f$. What is the value of *f* for this lens?

C. Repeat for Lens B.

Lens "B"

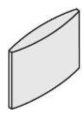
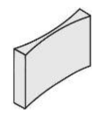
d	s_i	$1/s_i$	s_o	$1/s_o$	h_i	h_o	$\|M_{meas}\| = h_i / h_o$	$\|M_{pred}\| = s_i / s_o$
120 cm								
120 cm								
110 cm								
110 cm								
100 cm								
100 cm								
90 cm								
90 cm								
80 cm								
80 cm								
70 cm								
70 cm								
60 cm								
60 cm								
50 cm								
50 cm								

D. Plot $1/s_o$ versus $1/s_i$ and find the best fit line (linear fit). This should give a straight line with the *y*-intercept equal to $1/f$. What is the value of *f* for this lens?

Activity 3 – Focal Points in Two Dimensions

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.

Converging Lens:  Diverging Lens: 

A. Select the 5-rays and shine them on an open page of your notebook. Take the converging 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 lens 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 diverging 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.

C. Switch the wheel to the red, green and blue thick beams. Using the lenses and these coloured beams, can you create white light?

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