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OPTICAL BENCH

CAT NO. PH0649

Experiment Guide

GENERAL BACKGROUND:

This high quality, yet economical optical bench is specifically designed for optics demonstrations and basic experiments.

REQUIRED COMPONENTS (INCLUDED):

Name of Part	***Quantity***
Optical Bench	1
Adjustable Rider	8
Side Legs	2
Halogen Lamp	1
50 cm Double Convex Lens +10	1
50 cm Double Convex Lens +20	1
50 cm Double Convex Lens +50	1
50 cm Double Concave -20	1
Lens Holder	6
White Screen	1
Transparent Screen	1
Translucent Screen	1
Plain Mirror	1
Set of Diaphragms	1

RECOMMENDED COMPONENTS (NOT INCLUDED)

Name of Part	***Quantity***
PH0971ACDC Power Pack for Lamp	1
Connecting Leads	2

SAFE HANDLING OF APPARATUS:

The lamp casing gets extremely hot when in use. Do not touch the lamp until it has completely cooled. Use the plastic holder to adjust the lamp if need be and do not leave the lamp on for any longer than necessary to complete the experiment. Keep lamp turned off when not in use.

BREAKABLE WARNING:

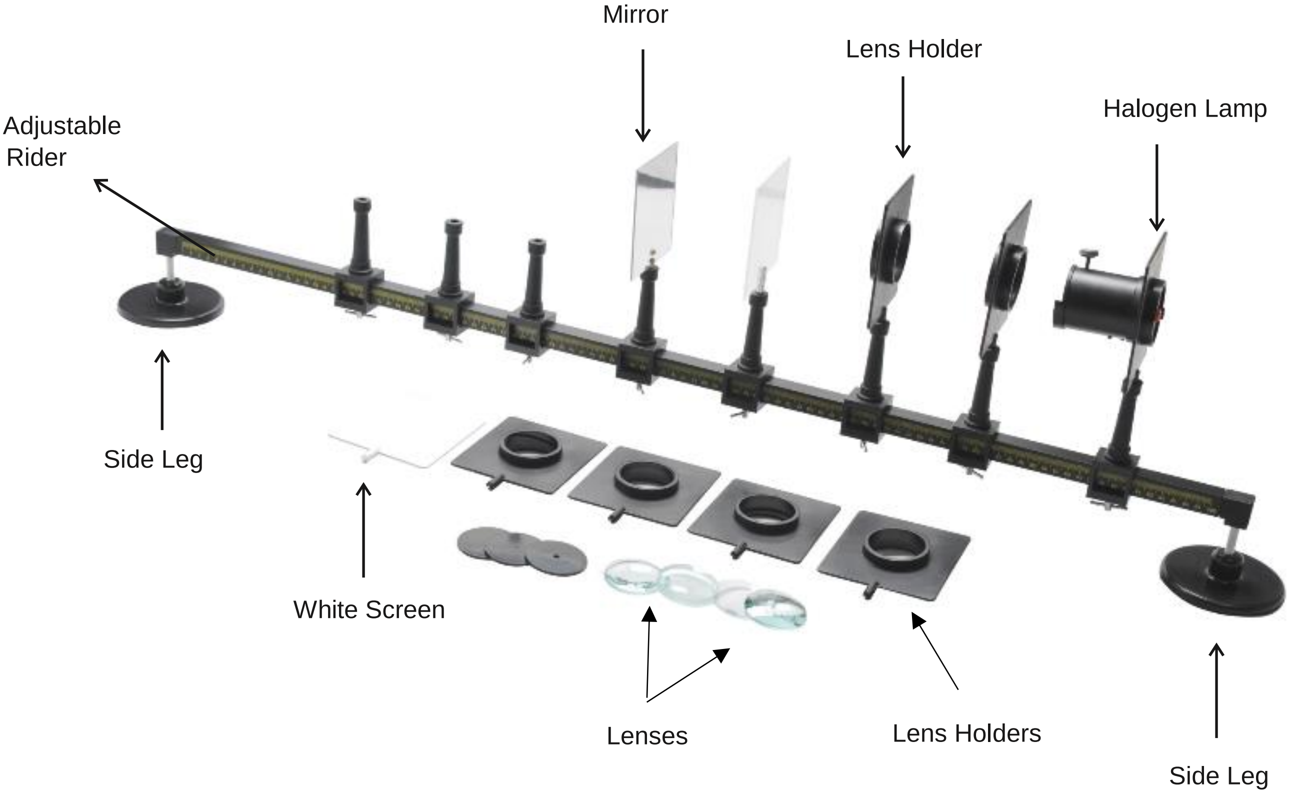
Many pieces of this optics bench are fragile, including the bench itself. Do not place this kit under heavy objects, expose to extreme heat or drop or strike the bench in any way.

The lenses in this kit should be handled with care. Do not unnecessarily touch or scratch the surface of these lenses. When not in use, place lenses in the appropriate holder or containers. Do not leave them on the lab table or place other objects on top of them.

MAINTENANCE REQUIRED:

Lenses may need to be cleaned from time to time to remove dust and fingerprints. Clean only with warm soapy water or lens cleaner. Rub dry in a single direction with a lint/dirt free cloth. A cloth used to clean glasses is ideal.

DIAGRAM LABELING PARTS:



OPERATING INSTRUCTIONS:

Connecting the Side Legs:

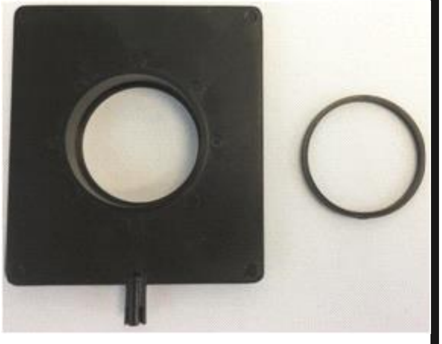
Two side legs are included to offer stability and support to the optical bench. Each side leg can be twisted into the end of the optical bench.

Adjustable Riders:

The adjustable riders allow for easy adjustment of the position of optical accessories during lab activities. Twist the knob of the rider to loosen it from the optical bench. The rider is than free to slide along the optical bench.
The post attached to the rider can be removed. Twist the post until it is removed.

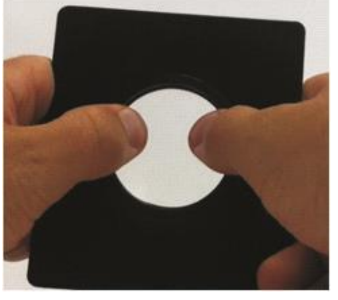
Accessories, such as the lens holder, can be attached to the posts of the riders. Gently twist the base of the accessory into the post. Similarly, twist the base of the accessory to remove it from the post.

Placing the Lens:



1. Remove the small ring inside the lens holder.
2. Place the lens inside the lens holder from the same side of the holder that the small ring was removed.
3. Place the small ring back inside the lens holder. Secure the lens by placing the ring tight against the lens.

Removing the Lens:



1. Gently press on the outside of the lens from the front side of the lens holder with your thumbs.
2. Remove the small ring inside the lens holder.
3. Remove the lens and properly store.
4. Replace the small ring inside the lens holder.

ACTIVITY 1: UNKNOWN FOCAL LENGTH

TEACHER INSTRUCTIONS

PURPOSE: To experimentally determine the focal length of a convex lens with an unknown focal length.

BASIC PRINCIPLES:

A convex lens is lens with a thick middle portion and thin edges. As light passes through a convex mirror, the rays of light change direction and focus to a point known as the focal point. This change in direction is caused by the light being refracted as it travels through the material of the lens. Unlike mirrors, lenses have two focal points, one on each side of the lens. The direction of travel for light rays in comparison to the lens will determine how the lens refracts each light ray. A light ray (1) that travels parallel to the principle axis will refract through the focal point on the other side of the lens. A light ray (2) that travels through the focal point on the same side of the object will refract parallel to the principle axis and a light ray (3) that travels through the vertex of a lens undergoes refraction, but does not change direction.

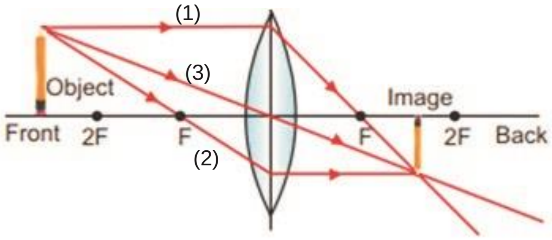


Figure 1: Ray diagram for convex lens

Each of the three light rays from figure 1 will intersect. Where these lines intersect is where the image forms. The position of intersection determines where the image forms, the size of the image, and whether or not the image is real. The location of the object from the lens (s_o), the location of the image from the lens (s_i), and the focal point (f) are related by the thin lens equation:

$$\frac{1}{s_0} + \frac{1}{s_i} = \frac{1}{f}$$

Equation 1: Thin lens equation

For a convex lens, both the focal length f and the object position s_o are positive. If s_i comes out positive, the image is real and on the opposite side of the lens from the object. If s_i comes out negative, the image is virtual and on the same side of the lens as the object. An image is said to be real if light rays actually focus at the image and virtual if they do not.

The relationship between the size of the object (h_o) and the size of the image (h_i) to the location of the object from the lens (s_o) and the location of the image from the lens (s_i) is given by magnification equation:

$$\frac{h_o}{h_i} = \frac{-s_i}{s_0} = M$$

Equation2: Magnification equation

where M is the magnification. If M is less than one, the image is smaller than the object. If M is greater than one, the image is larger than the object. If M is negative, than the image is virtual, and the image is real if M is positive.

TEACHER KEY

This lab is designed for the convex lens with a focal length of 20 cm. Do not use the convex lens with a focal length of 30 cm. A candle and candle holder can replace the LED lamp. **If using a candle, make sure to tie all hair back, remove all dangling or loose articles of clothing, and remove all flammable materials from the area. Take all safety precautions necessary when working with an open flame.**

The following is sample data taken from the student procedure.

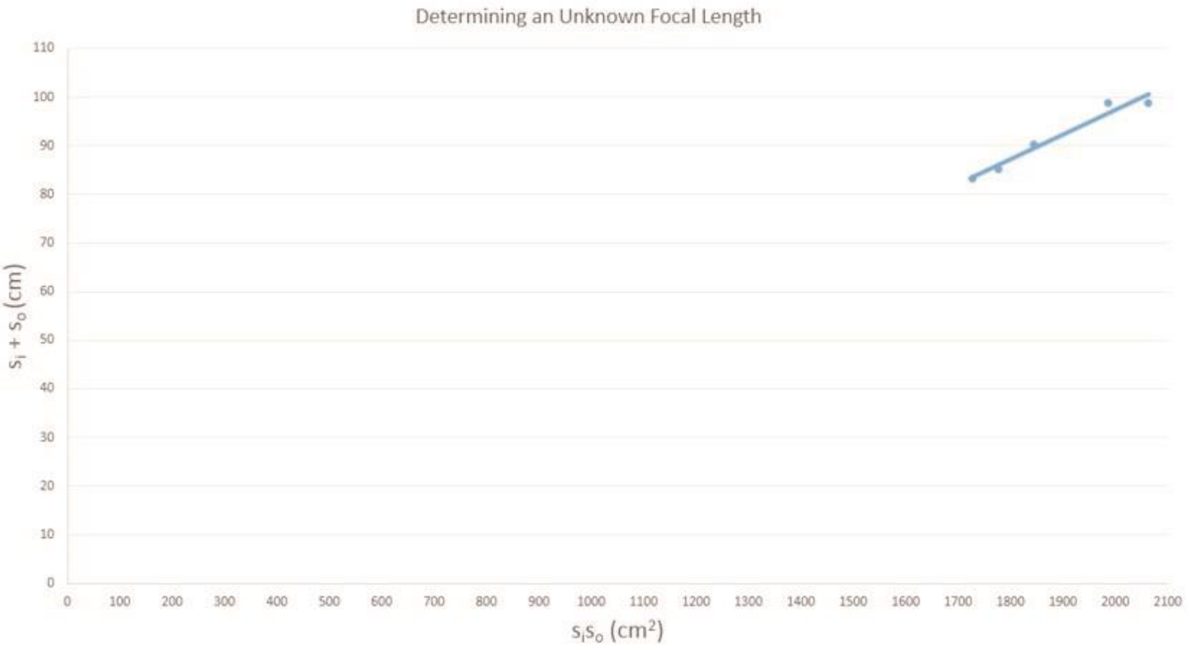
	Lamp Position (cm)	**Lens Position (cm)**	**s_o (cm)**	**Screen Position (cm)**	**s_i (cm)**
Trial 1	0.9	71.8	70.9	99.8	28.0
Trial 2	0.9	60.0	59.1	91.2	31.2
Trial 3	0.9	50.0	49.1	86.2	36.2
Trial 4	0.9	40.0	39.1	84.2	44.2
Trial 5	0.9	30.8	29.9	99.8	69.0

DATA ANALYSIS:

1. Calculate (s_o*s_i) and (s_o + s_i) and record these values in the chart below.

Trial	**s_o*s_i (cm^2)**	**s_o + s_i (cm)**
1	1985.2	98.9
2	1843.92	90.3
3	1777.42	85.3
4	1728.22	83.3
5	2063.1	98.9

2. Make a graph of (s_o*s_i) vs. (s_o + s_i).



3. Show mathematically how the graph will give you the focal length of the lens.

$$\frac{1}{s_0} + \frac{1}{s_i} = \frac{1}{f}$$

$$\frac{s_i}{s_0 s_i} + \frac{s_0}{s_i s_0} = \frac{1}{f}$$

$$\frac{s_i + s_0}{s_0 s_i} = \frac{1}{f}$$

The slope of a (s_o*s_i) vs. (s_i + s_o) will give the inverse of the focal length.

$$f = \frac{s_0 s_i}{s_i + s_0}$$

4. Determine the slope of your graph. *Slope = 0.0511 cm*$^{-1}$

5. From your slope, determine the unknown focal length.

$$\frac{1}{f} = 0.0511\ cm^{-1}$$

f = 19.6 cm

6. Determine a percent error for your experimental value.

$$\%\ error = \frac{|Accepted - Measured|}{Accepted} \times 100$$

$$\%\ error = \frac{|20\ cm - 19.6\ kg|}{20\ cm} \times 100$$

% error = 2 %

Name: ____ Date: _______________

ACTIVITY 1

<u>DETERMINING FOCAL LENGTH OF A LENS</u>

QUESTION: How can the focal length of a lens with an unknown focal length be found experimentally?

PROCEDURE:

1. With the measuring scale facing you, remove the post of the adjustable rider on the far left. Twist the post to remove it. Once removed, twist in the Halogen lamp.
2. Mount the lens in the lens holder and twist the lens holder in the third adjustable rider from the left.
3. Twist the white screen in the adjustable rider on the far right.

4. Position the Halogen lamp as far left as you can. Record the position in the chart.
5. Position the white screen as far right as you can. Record the position in the chart.
6. Connect the light source to the power supply. Slide the lens holder along the optical bench until the light is focused on the screen. The light is focused when a clear crisp image appears. Record the position in the chart.
7. Determine the object distance and the image distance from the lens. Record these values in the chart.
8. While leaving the lamp where it is, slide the lens holder 5 – 10 cm down the optical bench toward the lamp. Record the position of the lamp and the lens holder in the chart. Adjust the position of the white screen until the light is focused on the screen. Record the position of the white screen in the chart. Determine the object distance and the image distance from the lens. Record these values in the chart.

9. Repeat step 8 for three more times for a total of five trials.

	Lamp Position (cm)	**Lens Position (cm)**	**s_o (cm)**	**Screen Position (cm)**	**s_i (cm)**
Trial 1					
Trial 2					
Trial 3					
Trial 4					
Trial 5					

DATA ANALYSIS:

1. Calculate (s_o*s_i) and (s_o + s_i) and record these values in the chart below.

Trial	**s_o*s_i (cm^2)**	**s_o + s_i (cm)**
1		
2		
3		
4		
5		

2. Make a graph of (s_o*s_i) vs. (s_o + s_i).

3. Show mathematically how the graph will give you the focal length of the lens.

4. Determine the slope of your graph.

5. From your slope, determine the unknown focal length.

6. Determine a percent error for your experimental value.

ADDITIONAL SUGGESTED ACTIVITIES:

1. Use an outside light source and a convex lens to model how the eye forms an image on the retina.
2. Model how people with nearsighted and farsighted vision see.
3. Model how a movie projector makes an image on a screen.
4. Use an outside light source and the screen to model how an old film camera takes a picture.
5. Investigate the different images (real and virtual) produced by convex and concave lenses.

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