SI Physics - Full Discipline Demo

Focal Length of a Convex Lens

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Categorize each statement as relating to a converging lens, a diverging lens, or both.

Bends light away from optical axis
Bends light toward optical axis
Concave
Convex
Inverted image
Real image
Upright image
Virtual image

Converging lens	Diverging Lens	Both converging and diverging
1	2	3

Correct answers:

1 Bends light toward optical axis Inverted image Convex Real image

2 Bends light away from optical axis Concave

3 Upright image Virtual image

Match each term to the best description.

Concave	Center is thicker than edges	1
Convex	Center is thinner than edges	2
Focal point	Line through the center of a lens and perpendicular to the lens surfaces	3
Image point	Location of image on optical axis	4
Optical axis	Location where incoming parallel rays meet	5

Correct answers:

1 Convex 2 Concave 3 Optical axis 4 Image point

5 Focal point

Categorize each ray tracing statement as relating to ray 1, ray 2, or ray 3.

- Drawn from the top of the object so that it passes through the center of the lens at the optical axis.
- Drawn from the top of the object so that it passes through the focal point on the same side of the lens as the object
- Drawn parallel to the optical axis from the top of the object.
- Ray bends parallel to the optical axis
- Ray bends so that it passes through the focal point on the opposite side of the lens as the object
- Ray does not bend

Ray 1	**Ray 2**	**Ray 3**
1	2	3

Correct answers:

1 Drawn parallel to the optical axis from the top of the object.

Ray bends so that it passes through the focal point on the opposite side of the lens as the object

2

Drawn from the top of the object so that it passes through the focal point on the same side of the lens as the object

Ray bends parallel to the optical axis

3

Drawn from the top of the object so that it passes through the center of the lens at the optical axis.

Ray does not bend

Exploration

A _____ lens bends light toward the optical axis.

- concave
- converging ✔
- diverging
- None of the above

A lens is considered a _____ lens when its diameter is much greater than its thickness.

- converging
- diverging
- thin ✔
- None of the above

A larger lens collects more light so that the image it forms appears _____.

- larger
- brighter ✔
- more focused
- None of the above

The focal point is the point at which parallel rays converge after passing through a converging lens.

- True ✔
- False

A(n) _____ image is always formed when rays actually pass through the image point.

- real ✔
- virtual
- upright
- None of the above

A(n) _____ image always has a positive image distance.

- real ✔
- virtual
- upright
- All of the above

An inverted image will have a _____ magnification.

- positive
- negative ✔
- zero
- None of the above

Ray tracing requires _____ ray(s) in order to find the image distance of a lens.

- one
- two ✔
- three
- None of the above

The magnification depends on the lens alone.

- True
- False ✔

Exercise 1

Why is it beneficial to perform these exercises in a dimly-lit room?

The image is formed by light rays from the object converging at the screen. In a brightly-lit room, the light rays from the overhead lights can overpower the light rays that come through the lens to form the image. In a dimly-lit room, it is easier to see the image.

Is magnification a constant property of a lens? Reference Data Tables 2 and 3 and the definition of magnification to explain your answer.

No, the magnification is not a constant property of a lens – it varies based on the position of the object: $M=-d_i/d_o$. In **Data Tables 2** and **3** we find different magnification values for the same lenses based on the changing object and image distances.

What factors contribute to error in this exercise? Describe experimental factors that could be modified, and unalterable properties of materials used.

Factors contributing to error in the experiment may include: reading the measuring tape accurately, identifying the exact location where the image comes into focus, the thickness of the lens (unalterable), whether the screen is perfectly vertical, etc.

Did your prediction in Panel 1 match the results you described in Panel 2? Explain the physical phenomenon that produced what you described in Panel 2 and any discrepancies with your prediction.

The most common prediction is that half of the image will disappear. However, the image will only decrease in brightness. This is because the number of light rays passing through the lens is decreased. The entire image is still seen because light rays from every point on the object spread out in many different directions and are focused by the lens onto the screen. Some rays from the bottom of the candle, for example, will go through the part that is eventually covered, but others still pass through the uncovered half.

What is the focal length of a convex lens that produces an image on a screen 40 cm away with an object placed 10 cm from the lens? What is the magnification? Is the image inverted or upright? Show all calculations in your answer.

Using the thin-lens equation, we have: $1/f=1/d_o+1/d_i$
$1/f=1/10\text{ cm}+1/40\text{ cm}$
$1/f=(40\text{ cm}+10\text{ cm})/(10\text{ cm} * 40\text{ cm})$
$1/f=50\text{ cm}/400\text{ cm}^2$
$f=400\text{ cm}^2/50\text{ cm}$
$f= 8\text{ cm}$
The magnification is given by: $M=-d_i/d_o=-40\text{ cm}/10\text{ cm}=-4$
The image is inverted because the magnification is negative.

Data Table 1: Focal Length of Lenses Using a Distant Object
(SAMPLE ANSWER BELOW)

Lens	Measured Focal Length (cm)
A	5.6
B	20.3

Data Table 2: Focal Length of Lens A Using a Candle
(SAMPLE ANSWER BELOW)

Trial	1	2
Candle Position (cm)	0.0	0.0
Screen Position (cm)	30.0	30.0
Lens Position (cm)	6.8	23.4
d_o (cm)	6.8	23.4
d_i (cm)	23.2	6.6
Upright or Inverted	Inverted	Inverted
Larger or Smaller	Larger	Smaller
Calculated Magnification	-3.4	-0.3
Calculated Focal Length (cm)	5.3	5.1
Average Focal Length (cm)	5.2	

Data Table 3: Focal Length of Lens B Using a Candle
(SAMPLE ANSWER BELOW)

Trial	1	2
Candle Position (cm)	0.0	0.0
Screen Position (cm)	110.0	110.0
Lens Position (cm)	25.9	83.5
d_o (cm)	25.9	83.5
d_i (cm)	84.1	26.5
Upright or Inverted	Inverted	Inverted
Larger or Smaller	Larger	Smaller
Calculated Magnification	-3.2	-0.3
Calculated Focal Length (cm)	19.8	20.1
Average Focal Length (cm)	20.0	

Panel 1: Prediction for Image Appearance
(SAMPLE ANSWER BELOW)

Student answers will vary. Most may predict that half of the image will disappear. Some may predict the entire image remains but becomes dimmer.

Panel 2: Observation of Image
(SAMPLE ANSWER BELOW)

The entirety of the image remains but gets dimmer.

Exercise 2

How do your results from ray tracing compare to your results from using the thin-lens equation? Reference Photos 1 and 2 and Data Tables 4 and 5.

Student answers will vary – most will likely say yes. **Photos 1** and **2** shows their ray diagrams and **Data Tables 4** and **5** show their calculations and percent error. Percent error is likely low enough to show the two methods agree.

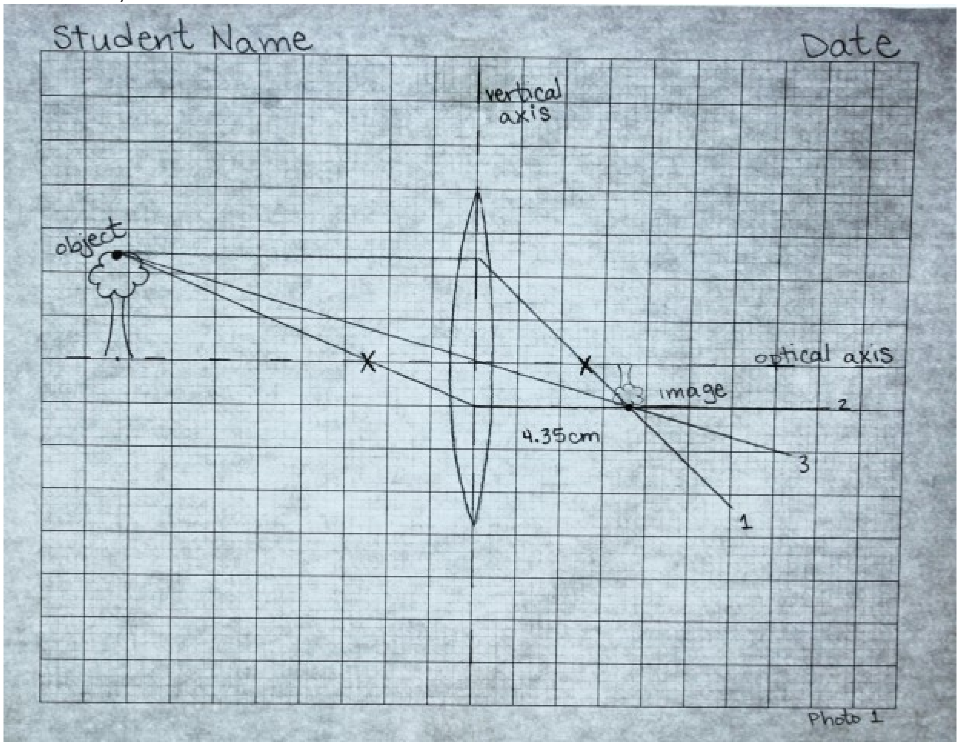
What is the focal length of a convex lens that produces an image 10 cm away with a magnification of -0.5? Show all calculations in your answer.
Hint: Use the definition of magnification and the thin-lens equation.

First, use the equation for magnification to find the object distance: $M=-d_i/d_o$. Rearranged, this is: $d_o =- d_i/M$. So, d_o = -10 cm/(-0.5)= 20 cm.
Using the thin-lens equation, we have: $1/f=1/d_o+1/d_i$
1/f=1/20 cm+1/10 cm = (10 cm+20 cm)/(10 cm * 20 cm)=(30 cm)/200 cm^2
So, f= 200 cm^2/30 cm = 6.67 cm.

Data Table 4: Image Distance Using Ray Tracing
(SAMPLE ANSWER BELOW)

Measured Image Location (cm)	4.35
Calculated Image Location (cm)	4.29
Percent Error (%)	1.40

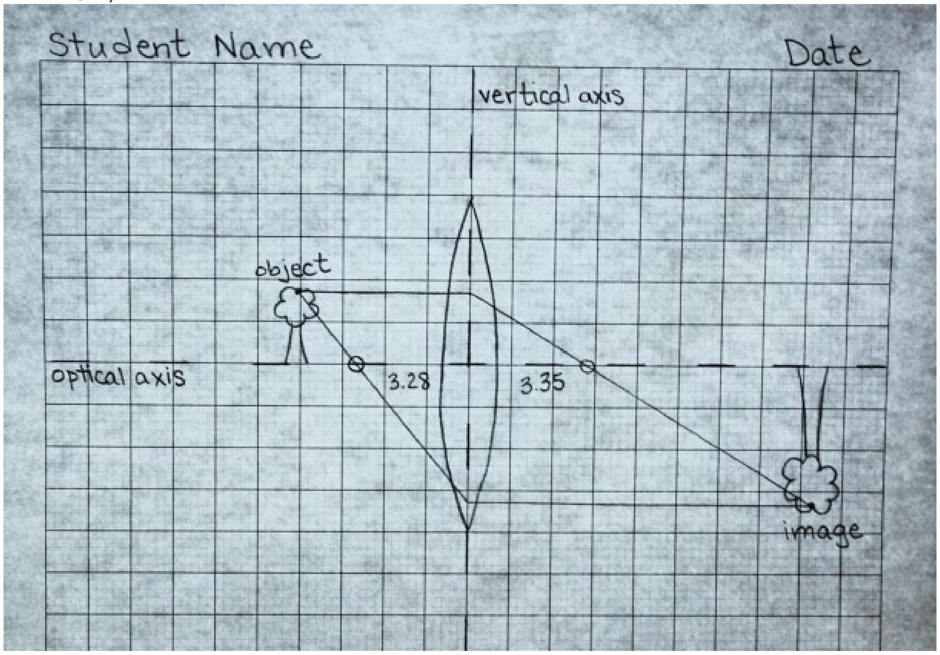
Photo 1: Ray Tracing of Image Distance
(SAMPLE ANSWER BELOW)

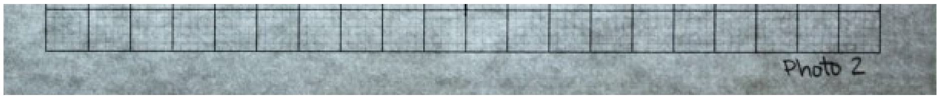


Data Table 5: Focal Length Using Ray Tracing
(SAMPLE ANSWER BELOW)

Measured Focal Length - Left (cm)	3.28
Measured Focal Length - Right (cm)	3.35
Average Focal Length (cm)	3.32
Calculated Focal Length (cm)	3.33
Percent Error (%)	0.55

Photo 2: Ray Tracing of Focal Length
(SAMPLE ANSWER BELOW)





Competency Review

The distance from the center of a lens to the location where parallel rays converge or appear to converge is called the _____ length.

- convergence
- meeting
- focal ✔
- None of the above

When incoming rays are _____, the focal point and the image point are the same.

- parallel ✔
- from a nearby object
- passing through the near side focal point
- None of the above

A(n) _____ image will not appear on a screen placed at the image plane.

- real
- virtual ✔
- inverted
- None of the above

A _____ lens is thicker in the center than at the edges.

- convex ✔
- concave
- thin
- None of the above

The image distance is measured from the nearest edge of the lens.

- True
- False ✔

A virtual image has a _____ image distance.

- positive
- negative ✔
- virtual
- None of the above

The magnification of a lens is _____ one when the image is smaller than the object.

- equal to
- greater than
- less than ✔
- None of the above

The ray that starts out parallel to the principle axis for a converging lens passes through the _____.

- lens without bending
- center of the lens
- focal point f ✔
- None of the above

The ray that starts out passing through the near focal point f' for a converging lens exits _____.

- without bending
- through the center of the lens
- parallel to the optical axis ✔
- None of the above

The ray that passes through the center of the lens exits _____.

- without bending ✔
- parallel to the optical axis
- through the focal point f
- None of the above

The image formed by a convex lens is _____ when the object is far away.

- virtual
- real ✔
- upright
- None of the above

The image point is always equal to the focal point of a convex lens.

- True
- False ✔

The magnification of a convex lens with a real image formed at an image distance of 18 cm when the object is at an object distance of 22 cm is _____.

- 0.8
- -0.8 ✔
- 1.2
- None of the above

A convex lens with a real image formed at an image distance of 18 cm when the object is at an object distance of 22 cm has a focal length of _____ cm.

- 9.9 ✔
- -9.9
- 0.1
- None of the above

When using ray tracing for a convex lens, the _____ is located where the rays meet.

- image ✔
- focus
- lens
- None of the above

The focal length on the left side a convex lens is _____ the focal length on the right side of the lens.

- greater than
- less than
- equal to ✔
- None of the above

Extension Questions

Consider a single point on an object near a lens. a. How many rays are necessary to find the image point of the object? b. For every point on the object, how many rays actually pass through the lens and reach the image point? (SAMPLE ANSWER BELOW)

a. Only two rays are necessary to find the image point of an object, although three rays are preferred to confirm. b. Many rays actually pass through the lens. All the rays that leave the object and travel toward any part of the lens will be refracted to the image point.