“L E N S E S”

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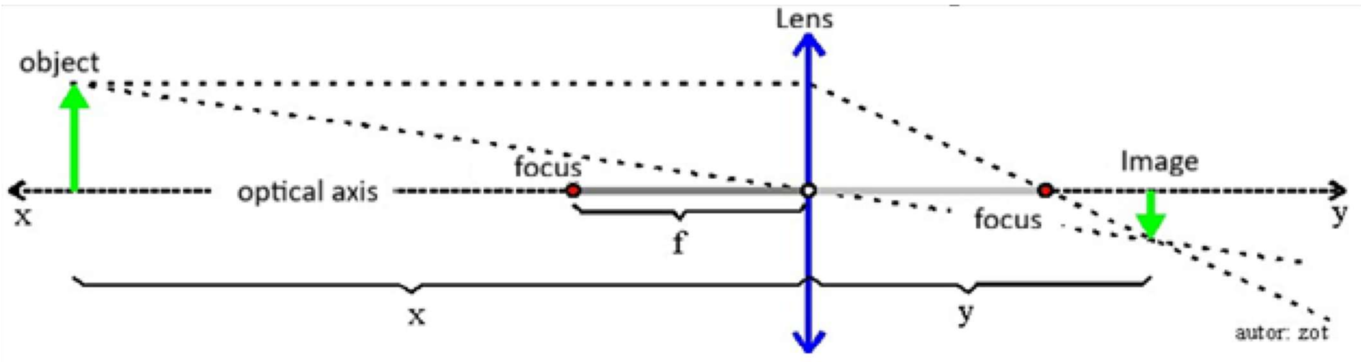
Experiment “L E N S E S”

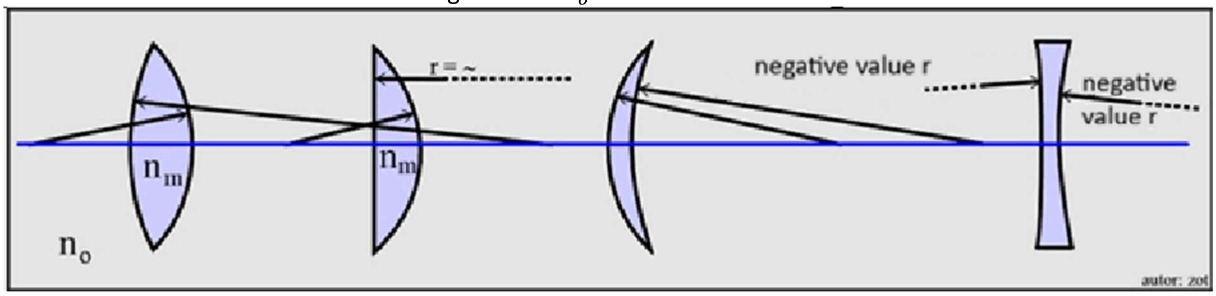
Construction of a real–inverted–reduced image formed by a converging lens:



The Gaussian lens equation for thin lenses has the form:

$$\frac{1}{f} = \frac{1}{x} + \frac{1}{y}$$

The focal length depends on the shape of the lens, the refractive index of the lens material n_m, and the refractive index of the surrounding medium $n_o$in which the lens is located.



$$\frac{1}{f} = \left(\frac{n_m}{n_0} - 1\right)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

A negative value of the focal length means that the lens is diverging. If $f > 0$, then:

$$\frac{1}{f} = \frac{1}{x} + \frac{1}{y} \Rightarrow y = \frac{fx}{x - f}$$

A negative value of $y$means that the image is virtual. In the case when $f < 0$, meaning a diverging lens, the image is always virtual and always reduced, regardless of the position of the object, that is, regardless of the value of x.

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Preparation Questions

1. Explain the phenomenon of refraction of light.
2. Give the definition of the refractive index of light.
3. Give the definitions of the focal point, focal length and main optical axis.
4. Thin lens equation.
5. Draw the formation of images obtained using thin lenses for different positions of the object in relation to the thin lens.
6. Discuss lens defects: spherical aberration, chromatic aberration and astigmatism.
7. Characterize the images formed by converging, positive, and diverging, negative, lenses.
8. Give the definition of a lens.
9. Radius of curvature of a lens.
10. Types of lenses.
11. Discuss the geometrical conditions for forming real and virtual, imaginary, images for converging and diverging lenses.
12. Path of rays through lenses.
13. Graphical method of image construction in a lens — give the minimum and maximum number of rays that can be drawn when constructing the image of the examined object.
14. Define the optical power of a lens and give its dimension and unit.
15. Discuss the function of the lens in the human eye, visual defects, myopia and hyperopia, and their correction using spectacle lenses.

Course of the Exercise

1. Turn on the lamp power supply.
2. Set the screen in the extreme position, as far as possible from the illuminated object.
3. Set the lens in such a position that the image of the object is clearly visible on the screen.
4. Read the value of length y, from the screen to the lens.
5. Read the value of length x, from the lens to the illuminated object.
6. Change the position of the screen so that the distance from the screen to the illuminated object is reduced, obtaining a less clear image of the object.
7. Change the position of the lens so that the length $x$is increased, obtaining a clear image on the screen.
8. Repeat steps 4 to 7 until ten values of $y$and ten values of $x$are obtained.
9. Perform calculations according to the instruction and prepare a trial graph in a spreadsheet.
   In the calculations, remember to use the basic SI units for all angles.
10. Prepare a measurement protocol and measurement uncertainties.

NOTE:

- The value of measurement uncertainty Δyshould be determined by establishing the range of length $y$for which the image obtained on the screen is clear.
- The illuminated object, as well as the lighting itself, must not be moved, and in particular, they must not be moved away from each other.

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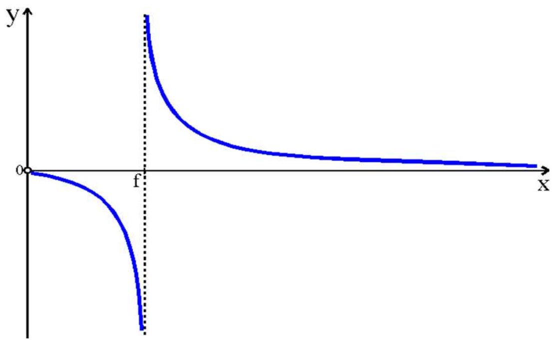
Methodological Template

Student 1: Determination of the focal length of a thin lens.
Student 2: Verification of the lens equation.

Theoretical Basic



The lens equation:

$$\frac{1}{f} = \frac{1}{x} + \frac{1}{y} \Rightarrow y = \frac{fx}{x-f}$$

can be written in the form:

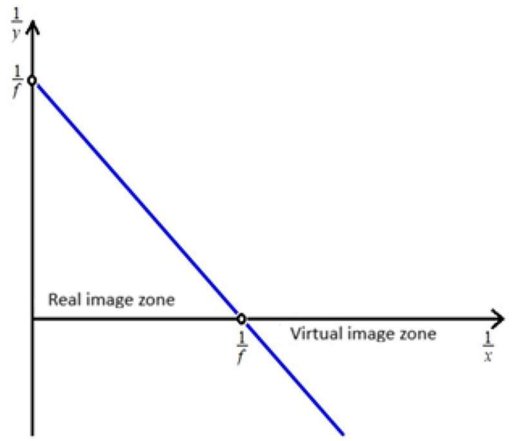
$$\underbrace{\frac{1}{y}}_{Y} = \underbrace{-1}_{a} \cdot \underbrace{\frac{1}{x}}_{X} + \underbrace{\frac{1}{f}}_{b},$$

and presented on a graph as a linear function:

$$Y = a \cdot X + b$$

The focal length of the lens can be read from the graph in two ways:

- as the reciprocal of the intercept coefficient b,
- as the reciprocal of the zero point X_0.



Therefore, in order to determine the focal length of the lens, one should: • perform measurements of the dependence of the distance of the sharp image y from the lens as a function of the distance of the object x from the lens, • prepare a graph of the dependence: $\frac{1}{y}$ as a function of $\frac{1}{x}$ • extend the best-fit straight line until it intersects one of the axes of the coordinate system, • read from it the value of the focal length as the reciprocal of the intercept coefficient of the graph or as the reciprocal of the zero point.	Therefore, in order to verify the lens equation, one should: • perform measurements of the dependence of the distance of the sharp image $y$from the lens as a function of the distance of the object $x$from the lens, • prepare a graph of the dependence: $\frac{1}{y}$ as a function of $\frac{1}{x}$ • analyse its linearity.

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Report Guidelines – Determination

Student 1: Determination of the focal length of a thin lens.

Methodology (conceptual plan of the exercise)

I. Course of the Exercise

II.1. Course of Activities

II.2. Sketch of the measurement setup

II. Results

II.1. Measurement results

		1	2	3	4	5	6	7	8	9	10
x	[cm]										
y	[cm]										

Δx = ...

Δ*y* = ...

II.2. Calculations (example calculations - referring, for example, to measurement no. 7)

$$\frac{1}{x} = \ldots$$

$$\frac{1}{y} = \ldots$$

$$\Delta\frac{1}{x} = \left|\frac{1}{x} - \frac{1}{x + \Delta x}\right| = \ldots$$

$$\Delta\frac{1}{y} = \left|\frac{1}{y} - \frac{1}{y + \Delta y}\right| = \ldots$$

III.3. Measurement results

		1	2	3	4	5	6	7	8	9	10
$\frac{1}{x}$	[...]										
$\frac{1}{y}$	[...]										
$\Delta\frac{1}{x}$	[...]										
$\Delta\frac{1}{y}$	[...]										

IV.4. Graph

- calculation of: $f = \frac{1}{b}$ the reciprocal of the intercept coefficient for the best-fit straight line or: $f = \frac{1}{X_0}$ the reciprocal of the zero point for the best-fit straight line
- calculation of: $f' = \frac{1}{b'}$ the reciprocal of the intercept coefficient for the deviated straight line or: $f' = \frac{1}{X_0'}$ the reciprocal of the zero point for the deviated straight line
- calculation of the accuracy of the method: $\Delta f = | f - f' |$

V.5. Summary

The determined value of … is …

Accuracy of the method: …

Additional conclusions, observations, causes of measurement uncertainties.

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Report Guidelines – Verification

Student 2: Verification of the lens equation.

Methodology (conceptual plan of the exercise)

I. Course of the Exercise

II.1. Course of Activities

II.2. Sketch of the measurement setup

II. Results

II.1. Measurement results

		1	2	3	4	5	6	7	8	9	10
x	[cm]										
y	[cm]										

Δx = ...

Δy = ...

II.2. Calculations (example calculations - referring to measurement no. 3)

$$\frac{1}{x} = \ldots$$

$$\frac{1}{y} = \ldots$$

$$\Delta\frac{1}{x} = \left|\frac{1}{x} - \frac{1}{x + \Delta x}\right| = \ldots$$

$$\Delta\frac{1}{y} = \left|\frac{1}{y} - \frac{1}{y + \Delta y}\right| = \ldots$$

III.3. Wyniki Measurement results

		1	2	3	4	5	6	7	8	9	10
$\frac{1}{x}$	[...]										
$\frac{1}{y}$	[...]										
$\Delta\frac{1}{x}$	[...]										
$\Delta\frac{1}{y}$	[...]										

IV.4. Graph

V.5. Summary

Since on the graph … it is possible to draw a straight line passing through all measurement uncertainty rectangles, there are no grounds to conclude a deviation from …

Alternatively:

The deviation from linearity in the range … may result from …

Additional conclusions, observations, causes of measurement uncertainties.