UOWD
University of Wollongong in Dubai

Lab Experiment:
Lenses and Optical Instruments

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Two Experiments:

1) - Lens Equation
2) - Galileo telescope

Experiment 1 Lens equation

Exercises

- Determine the focal length f of a lens from the image distance b and the object distance g.
- Measure the image distance b, the image size B, and the magnification factor A as functions of the object distance g.

Basic principles

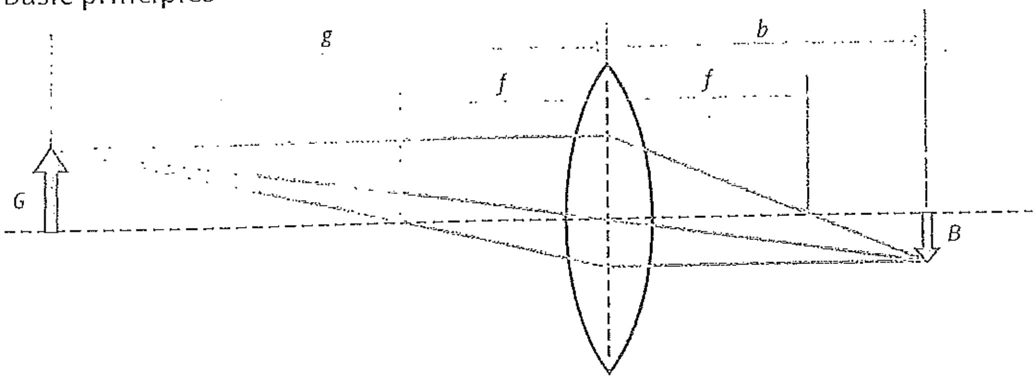

Fig. 1: Formation of an image of an object of size G by a converging lens with a focal length f.

A converging lens can produce a magnified or a reduced image of an object. The magnification factor A, which is the ratio of the image size B to the object size G, depends on the image distance b and the object distance g. The quantities are related by the imaging equation:

$$A = \frac{B}{G} = \frac{b}{g}$$

in which G is the size of the object to be imaged and B is that of its image. The object distance and the image distance cannot be varied independently of each other, but are connected by the lens equation:

$$\frac{1}{b} + \frac{1}{g} = \frac{1}{f}$$

Apparatus required

From basic set for Kröncke optical system (U8477100)

1 Optical lamp
1 Optical bench
4 Optical saddles
1 Holding clip
1 Screen, white
1 Slide with numeral 1
1 Lens, $f = +150$ mm

Also required

1 Transformer, 12 V, 25 VA (U8475470)
1 Ruler

Experiment set-up

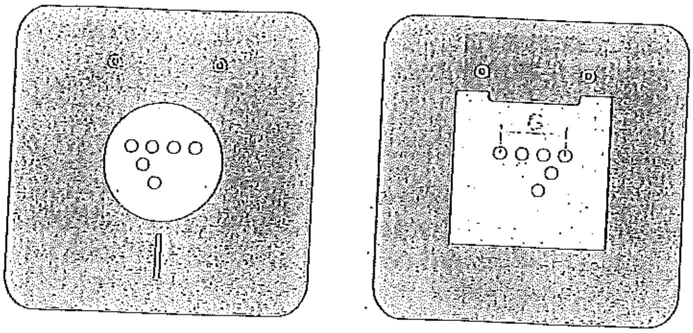

Fig. 2: Slide with numeral 1 in holder, viewed along the direction of the light beam (left) and against the direction of the light beam (right).

1) Measure the length of the "1" with the ruler in millimetres and enter the value as the object size *G* in the table.

2) Fix the slide in a holder with the "1" horizontal and at the centre of the opening in the holder.

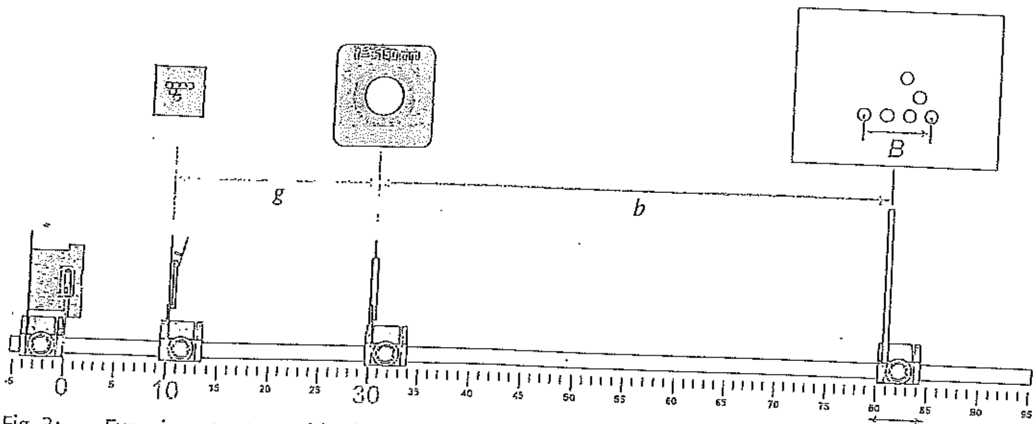

Fig. 3: Experiment set-up; side view.

3) Position the optical lamp, the holder and the lens with $f = +150$ mm on the optical bench as shown in Figure 3.

4) Connect the optical lamp to the voltage output terminals of the 12-V transformer.

Experiment procedure

1) Set up the screen at the end of the optical bench and slowly move it towards the lens until a sharp image of the "1" is obtained.

2) Measure the distance between the slide and the lens and enter the value as the object distance *g* in the table (see Fig. 3).

3) Measure the distance between the lens and the screen and enter the value as the image distance *b* in the table (see Fig. 3).

4) Measure the size of the "1" image on the screen with the ruler and enter the value as the image size *B* in the table (see Fig. 3).

5) By moving the lens, adjust the object distance to $g = 250$ mm and move the screen until a sharp image of the "1" is obtained.

6) Measure the image distance *b* and the image size *B* and enter the values in the table.

7) Repeat the measurements for the other object distances g listed in the table.

8) Calculate the ratios B/G and b/g and enter the results in the table.

9) From the measured values of the object distance g and the image distance b, use the lens equation to calculate the focal length f and enter the results in the table.

10) From the calculated focal length values, determine the average value of f, and set the object distance g to $2f$, twice the focal length.

11) For the latter special case, measure the image distance b and the image size B and enter the values in the table.

Data table:

$G = 23$ mm

g / mm	b / mm	B / mm	$\frac{b}{g}$	$\frac{B}{G}$	f / mm
200					
250					
300					
450					
600					
				Average of focal length values:	
$2f =$					

Review and evaluation of results

a) Describe the appearance of the image of the "1" on the screen.

b) How does the image size depend on the image distance?

c) How does the image size depend on the object distance?

d) How are the ratios B/G and b/g related to each other?

e) What is the focal length of the lens?

f) For which object distances is the image reduced and for which is it magnified?

g) When are the image and the object of equal size?

Ray Optics

Work sheet

KRÖNCKE OPTICS

Experiment 2 Galileo telescope

Exercises

- Construct a model of a Galileo telescope.
- Determine the angular magnification and the required distance between the lenses as functions of their focal lengths.

Basic principles

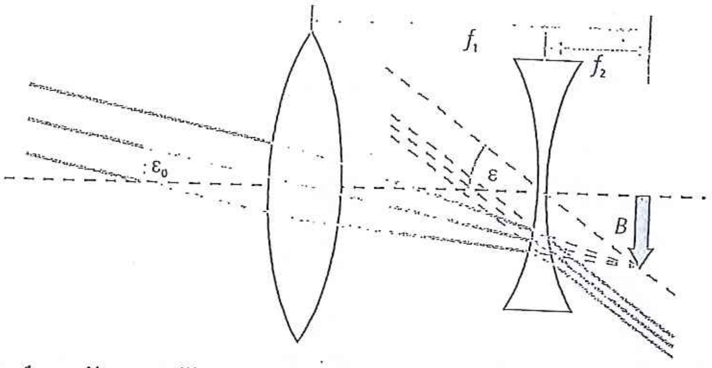

Fig. 1: How a Galileo telescope magnifies the angle of vision ε_0 for a distant object.

When a far distant object is viewed through a Galileo telescope it appears larger, because the telescope magnifies the angle of vision that the object subtends at the eye of the observer. The angular magnification is achieved by using a converging lens and a diverging lens separated by a distance d that is exactly equal to the sum of their focal lengths, taking into account the fact that the focal length of any diverging lens is treated as negative:

$$d = f_1 + f_2$$

The converging lens, the objective, gives rise to a real inverted image of the distant object in its focal plane, with size B given by:

$$B = f_1 \cdot \varepsilon_0$$

This image is then viewed with the eye focused on infinity through the diverging lens, the ocular. The resulting increased angle of vision is given by:

$$\varepsilon = \frac{B}{|f_2|} = \frac{f_1}{|f_2|} \cdot \varepsilon_0$$

Thus, the original angle of vision ε_0 subtended at the naked eye by the object has been magnified by the factor:

$$A = \frac{f_1}{|f_2|}$$

Apparatus required

From basic set for Kröncke optical system (U8477100)

1 Optical bench
2 Optical saddles
1 Lens, f = +150 mm
1 Lens, f = +300 mm
1 Lens, f = -100 mm

Experiment set-up

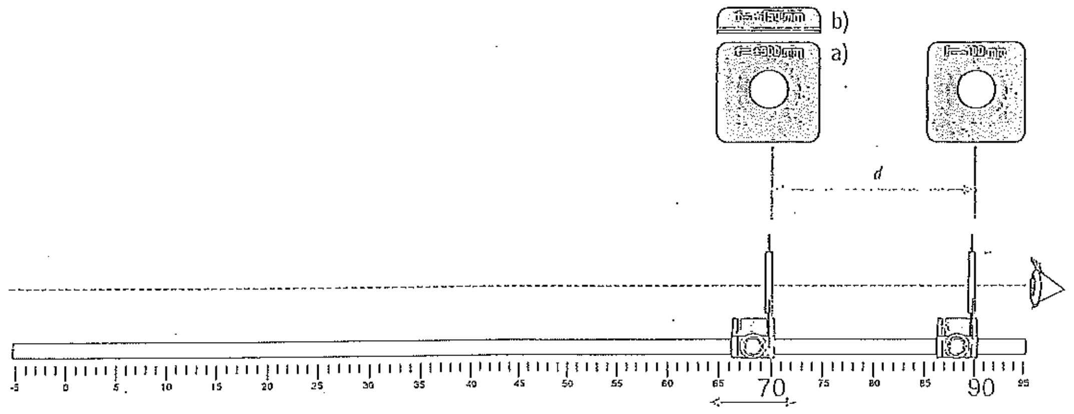

Fig. 2: Experiment set-up; side view.

Set up the –100 mm lens (the ocular) and the +300 mm lens (the objective) on the optical bench as shown in Figure 2.

Experiment procedure

Use the telescope model to view far distant objects such as houses or trees, or – all the better for estimating the angular magnification – a distant wall-mounted ruler divided into two differently coloured parts.

1) Look through both lenses at the distant object, and obtain a sharp image by moving the objective lens.
2) Measure the distance *d* between the ocular and the objective and enter the value in the table.
3) Calculate the sum of the focal lengths, $f_1 + f_2$, and compare it with the distance *d* between the lenses.
4) Look at the telescope image with one eye and look past the lenses at the object itself with the other eye.
5) Compare the directly viewed object with its magnified image, estimate the angular magnification *A*, and enter the value in the table.
6) Calculate the ratio $\frac{f_1}{|f_2|}$ and compare it with the estimated angular magnification *A*.
7) Repeat the experiment with the +150 mm lens instead of the +300 mm lens.

Data table:

f_1 / mm	f_2 / mm	d / mm	f_1+f_2 / mm	A	$\frac{f_1}{f_2}$
150	-100				
300	-100				

Review and evaluation of results

a) Describe the size and appearance of the image seen through the ocular.

b) What is the distance between the lenses that gives a sharp image?

c) What is the relationship between the angular magnification A and the ratio $\frac{f_1}{|f_2|}$?

d) Which of the objective focal lengths gives the greatest angular magnification?

e) What is the relationship between the angular magnification and the length of the telescope?