Determining the focal lengths at collecting lenses using Bessel's method

Objects of the experiment

- Determination of the focal length of collecting lenses by the Bessel's method.

Principles

The focal length of lenses can be determined by a variety of means. The basis for the different procedures are the laws of imaging.

In this experiment the method of Bessel is used to determine the focal length of lenses. In this method object and the observation screen are set up at a fixed overall distance s apart. Between this points there are two lens positions x_1 and x_2 at which a sharply focused image of the object is produced on the observation screen.

From the lens laws we can derive the following relationship for the focal length:

$$f = \frac{1}{4} \cdot \left(s - \frac{(x_1 - x_2)^2}{s} \right) \qquad (I)$$

x_1, x_2: lens position 1 and 2 for sharp images

s: distance between screen and lamp

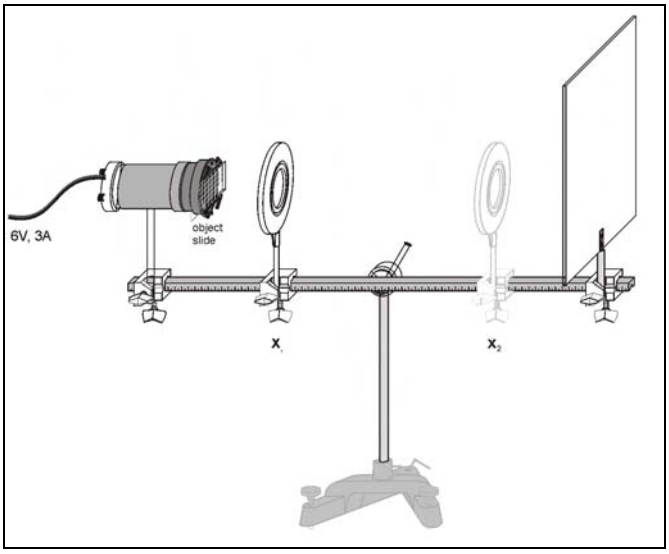

Fig. 1: Schematic diagram of the experimental setup for determining the focal length of lenses with the Bessel's method: There are two positions x_1 and x_2 where the lens produces a sharp image of the object on the screen.

Apparatus

1 Lamp, 6 V/30 W	450 51
1 Lamp housing	450 60
1 Aspherical condenser	460 20
1 Transformer	521 210
1 Lens f = +50 mm	460 02
1 Lens f = +100 mm	460 03
1 Set of two transparencies	461 66
1 Translucent screen	441 53
1 Small optical bench	460 43
1 Stand base, V-shape, 20 cm	300 02
3 Leybold multiclamp	301 01
1 Steel tape measure, 2m	311 77

Setup

- Set up the lamp with the aspherical condenser on the far left on the optical bench as depicted in Fig. 1.
- Insert the transparency into the diaphragm holder of the lamp. To improve measurement accuracy a transparent paper can be inserted between condenser lens and transparency.
- Set up the translucent screen at the right end of the optical bench.
- Position a lens between the diaphragm holder of lamp and the translucent screen.

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Carrying out the experiment

The experiment should be performed in a darkened room.

- Position the translucent screen at a distance of about 50 cm apart from the transparency (object).
- Position the lens f = +100 mm in the middle between the diaphragm holder of the lamp and the translucent screen.
- Displace the clamp with lens towards the object until a sharp image of the object is observed on the screen and measure the distance b_1 between the screen and the lens (Fig. 2).
- Shift the lens towards the translucent screen until a sharp image is observed again. It might be necessary to adjust the lamp for observing the small image of the object.
- Measure the distance b_2 between the lens and the screen.
- Determine the difference $\Delta = x_1 - x_2 = b_1 - b_2$.
- Measure the distance s between the object and the translucent screen.
- Repeat the experiment for the lens f = +50 mm.

Note: *The distance s between the lamp and the object has to be adjusted according to the focal length of the lens. To determine small focal lengths the distance s has to be chosen shorter than for large focal length.*

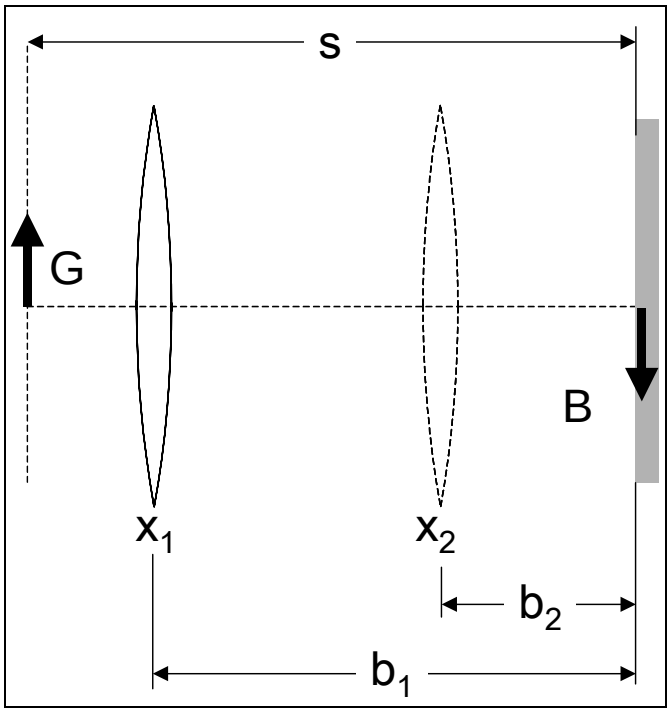

Fig. 2: Schematic sketch of the geometry of Fig. 1.
G: object size
B: image size
b_1, b_2: image distance
s: distance between screen and object

Measuring example

Table. 1: Comparison of the measured f_{exp} and given focal length f.

Lens	x_1	x_2	Δ	s	f_{exp}
f' =+100 mm	37 cm	14 cm	23 cm	50 cm	98.6 mm
f =+50 mm	23.3 cm	6 cm	17,3 cm	30 cm	50.1 mm

Evaluation and results

Bessel's method provides an accurate way of determining focal lengths of lenses. This method can also be applied to lens systems.

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