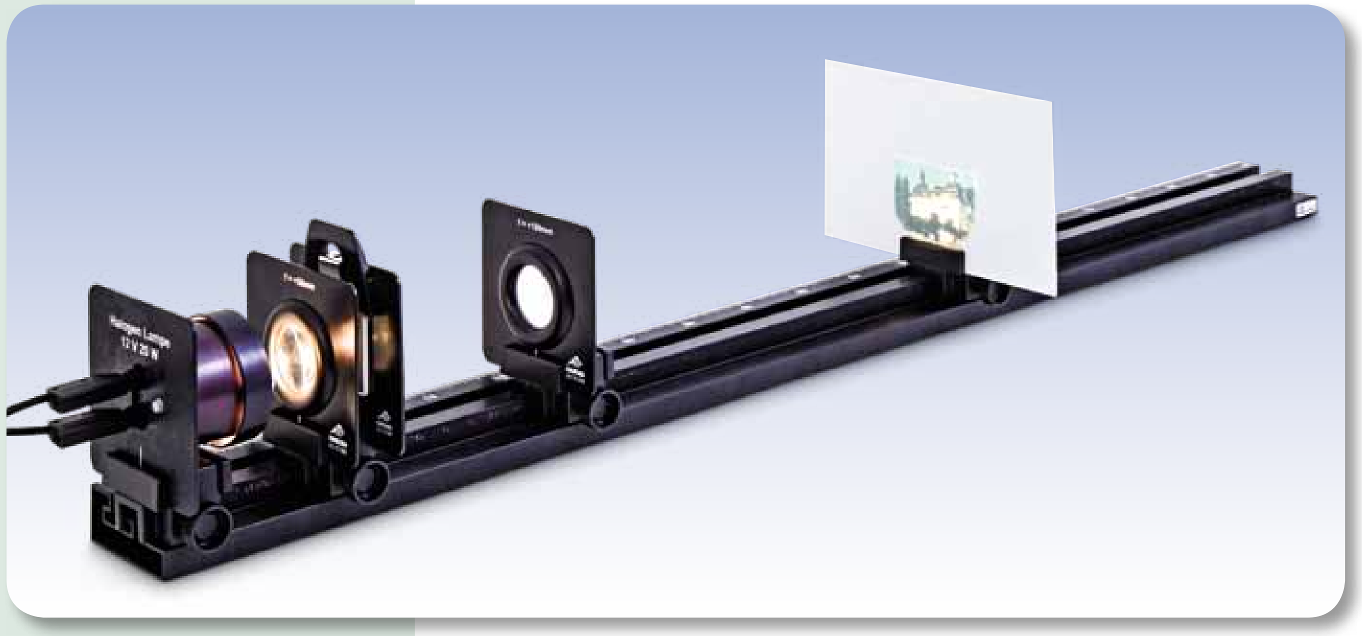
LENS EQUATION



EXPERIMENT PROCEDURE

- **Determine the two positions of a thin lens where a sharp image is formed.**
- **Determine the focal length of a thin lens.**

OBJECTIVE

Determine the focal length of a lens using the Bessel method

SUMMARY

On an optical bench it is possible to set up a light source, a lens, a screen and an object to be imaged in such a way that a well focussed image appears on the screen. Using the geometric relationships between the ray paths for a thin lens, it is possible to determine its focal length.

REQUIRED APPARATUS

Quantity	Description	Number
1	Optical Bench K, 1000 mm	**1009696**
4	Optical Rider K	**1000862**
1	Optical Lamp K	**1000863**
1	Transformer 12 V, 25 VA (230 V, 50/60 Hz)	**1000866 or**
	Transformer 12 V, 25 VA (115 V, 50/60 Hz)	**1000865**
1	Convex Lens K, f = 50 mm	**1000869**
1	Convex Lens K, f = 100 mm	**1010300**
1	Clamp K	**1008518**
1	Set of 4 Image Objects	**1000886**
1	Projection Screen K, White	**1000879**

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BASIC PRINCIPLES

The focal length f of a lens refers to the distance between the main plane of the lens and its focal point, see Fig.1. This can be determined using the Bessel method (devised by *Friedrich Wilhelm Bessel*). This involves measuring the various separations between the optical components on the optical bench.

From Fig.1 and Fig. 2 it can be seen that the following relationship must apply for a thin lens:

(1) $$a = b + g$$

a: distance between object G and image B
b: distance between lens and image B
g: distance between object G and lens

By plugging these values into the lens equation

(2) $$\frac{1}{f} = \frac{1}{b} + \frac{1}{g}$$

f: focal length of lens

the following is obtained:

(3) $$\frac{1}{f} = \frac{a}{a \cdot g - g^2}$$

This corresponds to a quadratic equation with the following pair of solutions:

(4) $$g_{1,2} = \frac{a}{2} \pm \sqrt{\frac{a^2}{4} - a \cdot f}\ .$$

A sharp image is obtained for each of the object distances g_1 and g_2. The difference e between them allows the focal length to be determined:

(5) $$e = g_1 - g_2 = \sqrt{a^2 - 4af}$$

The difference e is the difference between the two lens positions P_1 and P_2, which result in a focussed image.

EVALUATION

A formula for the focal length of a thin lens can be derived using the Bessel method from equation (4) $f = \frac{a^2 - e^2}{4a}$

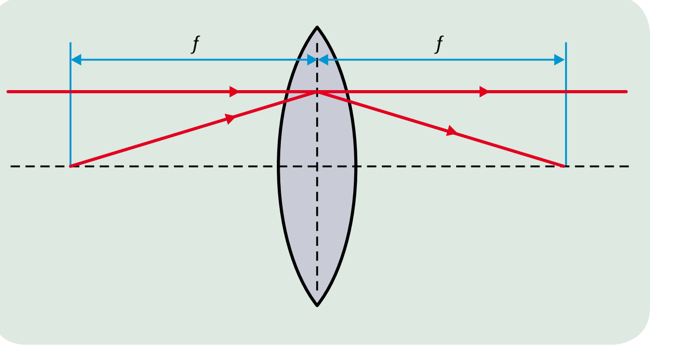

Fig. 1: Schematic showing the definition of focal length for a thin lens

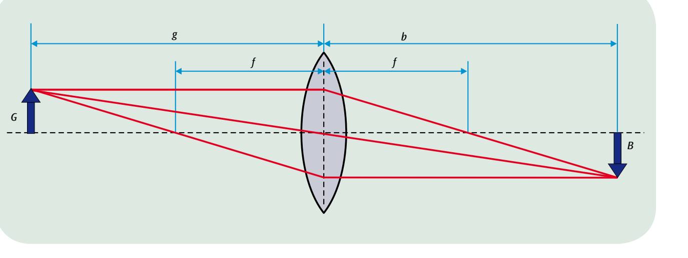

Fig.2: Schematic of ray paths through a lens

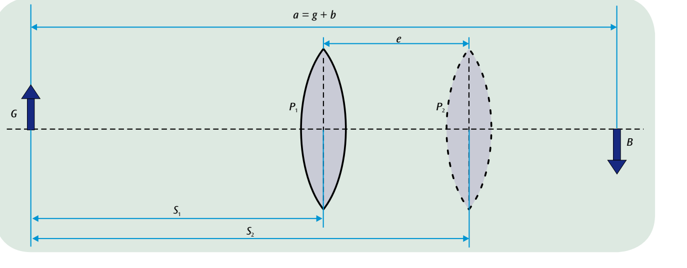

Fig.3: Schematic showing the two lens positions which result in a well focussed image on the screen