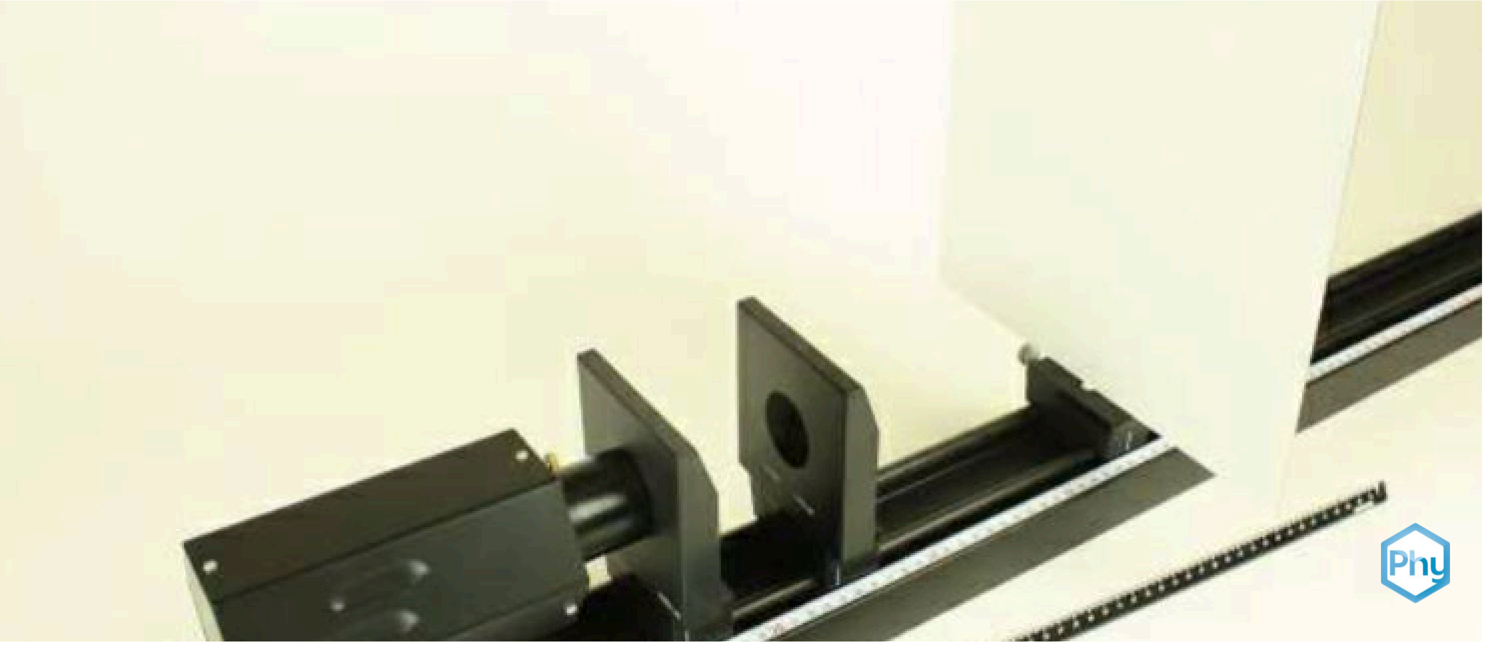
The pinhole camera



The students will learn to determine the size of the image in relation to the distance to the subject and the image width. In addition, the influence of the aperture diameter on the image will be investigated.

Physics > Light & Optics > Optical devices & lenses

Difficulty level	Group size	Preparation time	Execution time
medium	2	20 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/66e7d80861916c0002c67266

General information

Application

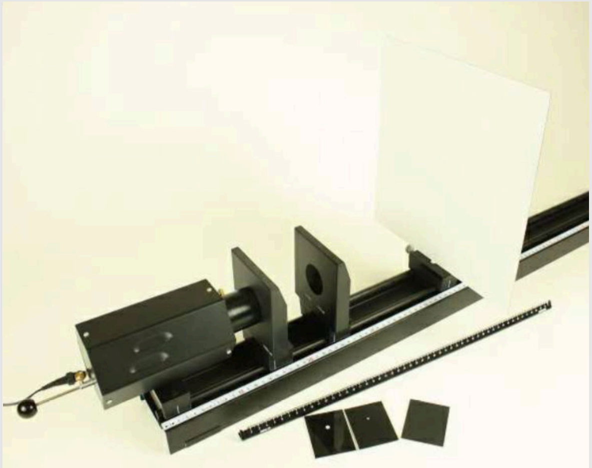


Figure 1: Experimental setup

In this experiment, we are experimenting with the so-called pinhole camera. They are used in numerous areas. For example, in the field of X-ray, gamma ray or particle radiation, pinhole apertures can no longer be dispensed with in order to obtain an image. But pinhole cameras can also be found in everyday life. Well-known examples are the sun flecks that can be observed on the forest floor when the sun shines. The gaps in the leaves act as pinholes.

Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (1/2)

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Prior knowledge

The students should have knowledge of the rectilinear propagation of light and the mapping law.

Principle

Objects can be imaged on a screen using a simple pinhole aperture, which produces real and reversed images.

Other information (2/2)

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Learning objective

The students will learn to determine the size of the image in relation to the distance to the subject and the image width. In addition, the influence of the aperture diameter on the image will be investigated.

Tasks

1. Generating the real and the inverted image on the screen depending on the aperture diameter.

2. Determining the relationship between the size of the image and object and the width of the object and image.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Safety instructions

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The general safety instructions for experimentation in science lessons apply.

Theory (1/3)

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An object can be imaged on a screen with the help of a small hole. As the light propagates in a straight line, each individual point on the pinhole camera creates a single point of light on the screen. In this case, the image is called a real image. Due to the rectilinear propagation, the image is upside down (Fig. 2).

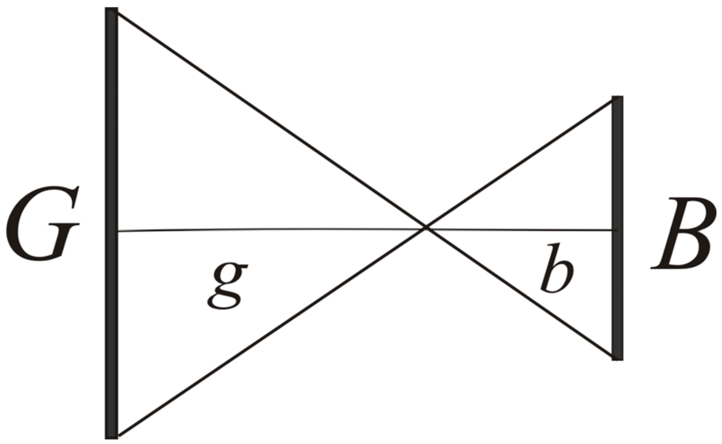

Figure 2

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Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
www.phywe.de

Theory (2/3)

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The image can be observed for any image and object width. A change from $b$and $g$only affects the size of the image.

The following applies:

The larger the image width with the same object width, the larger the image and the smaller the object width with a fixed image width, the smaller the image.

The image size B is related to the object size Gas the object range $g$to the image width b.

The quotients B/G and b/g are the same size.

This relationship is also known as the mapping law: $\frac{B}{G} = \frac{b}{g}$.

Theory (3/3)

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When using apertures of different sizes, the diameter of the individual pixels changes, but the distance between the dots and therefore the image size (distance between the centres of the outer dots) remains the same for all apertures.

The larger the diameter of the aperture, the larger and brighter the pixels. With a large aperture diameter, however, the individual dots overlap. The image becomes blurred, which can also explain the slight deviation in image size.

If an object, e.g. a burning candle, is depicted with many closely spaced pixels, a small aperture provides a sharper but also darker image. To produce a brighter image, the exposure time must be increased.

Remark:

The mapping law can also be derived using the ray theorem.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
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Equipment

Position	Equipment	Item no.	Quantity
1	Experimental light LED HEX1	08130-99	1
2	Optical profile bench, l = 1000 mm	08370-00	1
3	Perforated apertures, d = 1, 2, 3 and 5 mm	09815-00	1
4	Rider for optical profile bench	09822-00	2
5	Setting with scale on rider	09823-00	2
6	Shade, metal, 300 mm x 300 mm	08062-00	1
7	Ruler, l = 200 mm, plastic	09937-01	1
8	Aperture holder, clip-on	11604-09	2
9	Perl L	11609-00	1

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Robert-Bosch-Breite 10
37079 Göttingen
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info@phywe.de
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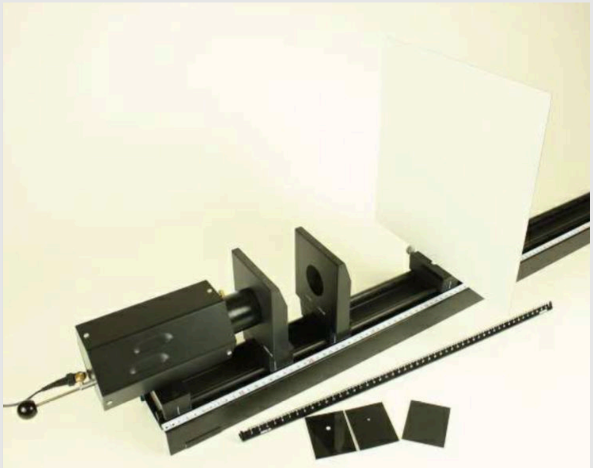
Setup and procedure

Structure (1/2)

- Insert the experimental light into the hole in the rider and screw it tight. The rider is then placed on the beginning of the optical bench so that the white line is at 2.0 cm.
- The light is connected to the power supply via the power supply unit. The LED can be moved in the housing using the horizontal slider so that it is positioned at the top of the housing.



Experimental setup

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Structure (2/2)

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- The aperture holder is placed on the mount of the rider. The Perl L (as an object) is pushed into the front slot of the aperture holder. To avoid reflections, the rider with the Perl L is moved away from the experimental light directly in front of the light. The white line of the rider is positioned at 15.0 cm on the optical bench.
- The pinhole (d= 2 mm) in the second aperture holder is placed on the mount of the second rider and positioned with the white line at 24.0 cm on the optical bench.
- When measuring the actual aperture position, make sure that it is 0.5 cm from the line mark.
- The screen should initially be positioned at 45 cm on the optical bench. To do this, a rider is attached to this position and the screen is inserted into the hole.
- If necessary, the room must be darkened.

Procedure (1/3)

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Attempt 1:

- The image of the Perl L is observed on the screen (see Fig. 3) and compared with the original Perl L.
- A piece of paper is used to cover part of the bead L and the image produced by the perforated chambera is observed.

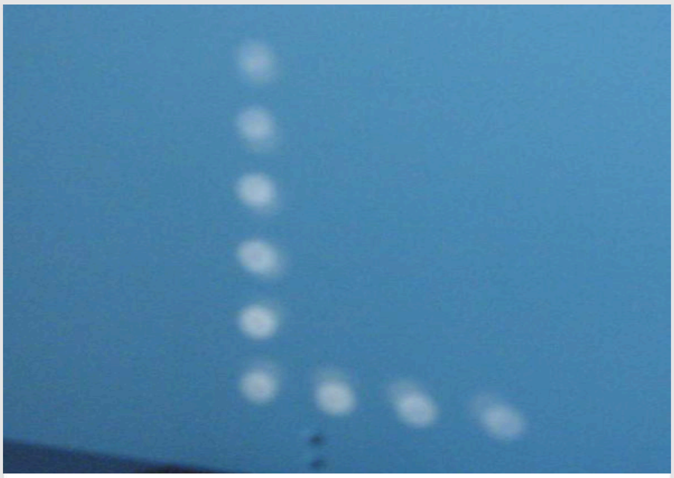

Figure 3

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
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info@phywe.de
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Procedure (2/3)

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Attempt 2:

- While the image continues to be observed, the screen should be gradually moved up to 35 cm and back down to 45 cm (change in image width).
- The process is repeated with the screen remaining fixed. Instead, the tab with the pearl L aperture is now moved (changing the object width).
- Finally, various distances for object widths $g$and image width b(observe the notes on the aperture position from the assembly). This must be noted. The size of the object $G$and picture $B$is measured for each distance combination (distances between the outer edges of the outer points).

Procedure (3/3)

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Attempt 3:

- The set-up is returned to its original state, with the screen positioned at 35 cm for this part of the experiment in order to obtain a clearer image. (For the original positioning of the bead L and pinhole diaphragm, see setup)
- The pinhole (d= 2 mm) is now pressed one after the other against the perforated panels with d= 1, 3 and 5 mm diameter.
- The diameter and brightness of the dots must be observed. The image size for each pinhole Bmeasure.

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info@phywe.de
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Evaluation (1/2)

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Attempt 1:

The pearl L is displayed on the screen (Fig. 3) with the image upside down. Covering parts of the pearl L causes the dots in the image to disappear.

Attempt 2:

If the shade is moved in the direction of the luminaire (the image width $b$reduced) and the object width g (distance between bead L and pinhole) is left the same, the image becomes smaller.

If, on the other hand, the bead L socket is moved away from the lamp (the object width $g$is reduced) and the image width is left the same, i.e. the screen is not moved, the image is enlarged.

Evaluation (2/2)

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Attempt 3:

If the 2 mm pinhole is replaced with a smaller pinhole with a diameter of 1 mm, the image is darker overall and the dots are smaller. If, on the other hand, a larger diameter (3 or 5 mm) is used, the image is brighter and the dots correspondingly larger. With the largest aperture with a diameter of 5 mm, the dots overlap a little.

The image size is the same for all apertures.

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