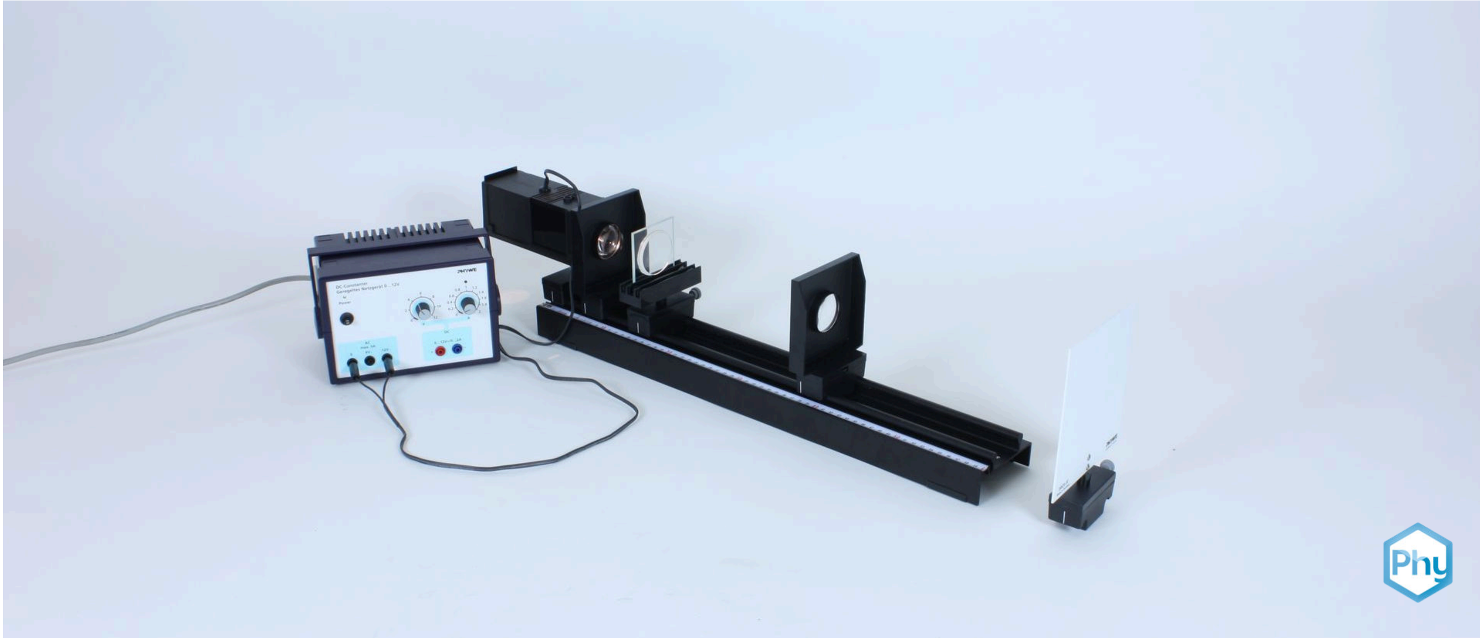
Newton's rings



Physics | Light & Optics | Diffraction & interference

Difficulty level	Group size	Preparation time	Execution time
easy	1	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/6257f2188f56090003409157

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Teacher information

Application

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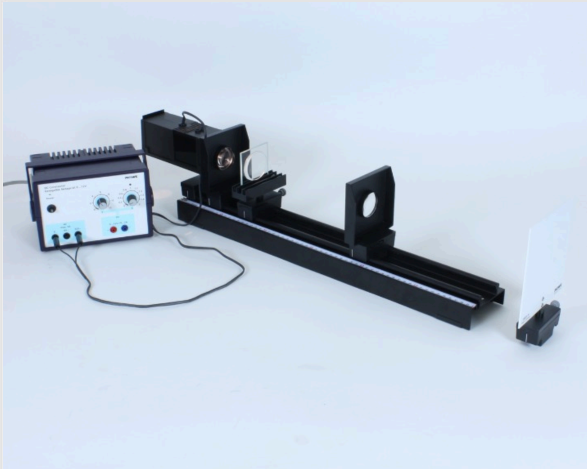

Test setup

When a parallel beam of light impinges on a wedge of air bounded by a planar and a spherical glass body, interference produces a pattern of concentric ring-shaped fringes. The arrangement is called Newtonian color glass, the interference pattern Newtonian rings.

By evaluating Newton's rings, conclusions can be drawn about the quality and shape of the spherical lens, provided that the wavelength used is known.

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Other teacher information (1/6)

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Prior

Students do not need any special prior knowledge for this experiment.

Principle

The interference rings occur because some of the light passing through the plane-parallel plate and lens body passes directly through the array and some is reflected on its way first at the surface of the lens and then at the glass plate, creating a path difference.

Other teacher information (2/6)

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Learning

The experiment is designed to illustrate the wave character of light to the students. The students learn how to determine the radius of the lens from the interference pattern.

Tasks

Students will learn how Newton's rings are formed and practice an application of this phenomenon by obtaining measurements experimentally and processing them further.

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Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

Other teacher information (3/6)

Notes on structure and implementation

Because of the simpler setup, the experiment with transmitted light was suggested, although the work with reflected light gives more contrasty images of Newton's rings. The experiment room should be well darkened.

Special care is required for marking and determining the image diameters D_n'. It is recommended to record the position of the centers of the dark rings on a horizontal straight line which passes through the common center of the circle.

Other teacher information (4/6)

Notes

Before or after the experiment, the students should be encouraged to look through the Newtonian color glass and use the observation optics. This is the basis for the following experimental variant, which requires relatively little effort:

The red filter is placed on the table, on top of it the Newtonian color glass with the lens pointing upwards, and on top of it the observation optics. The whole thing is now lifted and one looks through the observation optics towards bright light. Then it is also possible to determine some Dn on the scale of the observation optics, if its plane boundary line coincides with the horizontal diameter of all rings. A disadvantage of this variant is that one can measure at most up to n = 4 and that one must accept a large relative error.

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

Other teacher information (5/6)

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Notes

To derive the equation
$4 \cdot R \cdot \lambda = {D_{n+1}}^2 - {D_n}^2$
\The following considerations can be made: r_n is for monochromatic light of wavelength $\lambda$the radius of the n-th dark ring, $d_n$the distance of the sphere surface from the plane-parallel plate for r_n. Then applies:

$(R - d_n)^2 + {r_n}^2 = R^2$

$R^2 - 2Rd_n + {d_n}^2 + {r_n}^2 = R^2$

$-2Rd_n + {d_n}^2 + {r_n}^2 = 0$

${r_n}^2 = 2Rd_n - {d_n}^2$and because of $R >> d_n$

$d_n = {r_n}^2 / 2R$

Other teacher information (6/6)

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Notes

The wave trains passing smoothly through the Newtonian color glass have a path difference compared to the wave trains reflected twice on their way. $\Delta = 2d_n = {r_n}^2 / R$. On the other hand, the light waves interfering at adjacent rings have against each other a path difference of λ. Therefore, for two dark rings that follow each other, we get:

$({r_{n+1}}^2 / R) - ({r_n}^2 / R) = \lambda$ and from it ${r_{n+1}}^2 - {r_n}^2 = \lambda \cdot R$.

The diameters of the rings can be determined experimentally more precisely than the radii. Due to $D_n = 2r_n$ you then get: ${D_{n+1}}^2 - {D_n}^2 = 4R\lambda$.

With the help of this relation it is possible to determine the wavelength λif the spherical radius R is known, or vice versa, e.g., determine the radius of curvature of a lens when experimenting with monochromatic light of known wavelength.

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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 instructions for safe experimentation in science education apply to this experiment.

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Student Information

PHYWE

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de

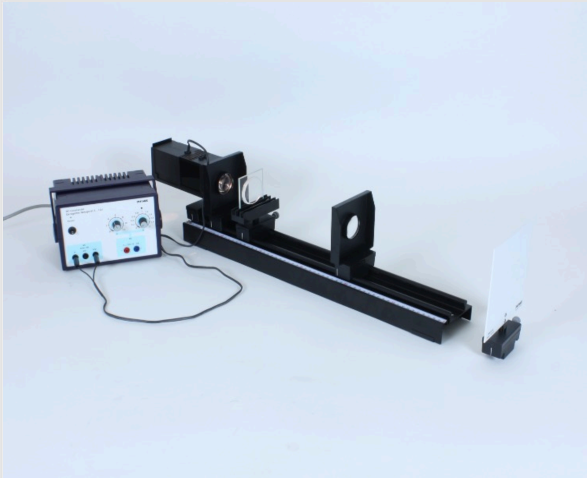
Motivation

The sun as a natural light source

Light is defined as the range of the electromagnetic spectrum that is visible to humans. With diffraction objects, such as a lens, a special phenomenon of light - interference capability - can be observed, indicating a wave character of light.

But what does an interference pattern look like and what physical laws underlie it? These questions are investigated in this experiment.

Tasks



The experimental setup

1. Send a parallel beam of light through a Newtonian color glass and determine the radius of the lens-shaped glass body with the help of the resulting rings.

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

Equipment

Position	Material	Item No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Bottom with stem for light box	09802-20	1
3	Optical profile-bench for student experiments, l = 600 mm	08376-00	1
4	Colour filter set, additive (red, blue, green)	09807-00	1
5	Lens on slide mount, f=+50mm	09820-01	1
6	Lens on slide mount, f=+100mm	09820-02	1
7	Slide mount for optical bench	09822-00	2
8	Screen, white, 150x150 mm	09826-00	1
9	Plate mount for three objects	09830-00	1
10	Plate and lens f. Newton rings	08551-00	1
11	PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
12	Measuring tape, l = 2 m	09936-00	1

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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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Structure (1/4)

Experiment 1

- Set up the optical bench with the two tripod rods and the variable tripod base and apply the scale (Fig. 1).

Figure 1

Structure (2/4)

- Assemble the light as shown in Figures 2 and 3 and clamp it into the left part of the tripod base so that the lens side faces away from the optical bench (Fig. 4).
- Slide the opaque screen in front of the lens of the light (Fig. 5).

Figure 2

Figure 3

Figure 4

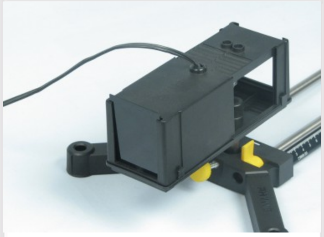

Figure 5

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Structure (3/4)

- Place the lens with f = +50 mm on the optical bench at about 5 cm (Fig. 6).
- Place the rider with plate holder and Newtonian color glass (plate with lens) at about 10 cm. Note that the lens is above a leaf spring and that the leaf spring and lens point to the right (Fig. 7 and Fig. 8).
- Place the lens with f = +100 mm at about 22 cm (Fig. 9).

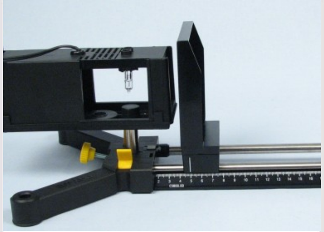

Figure 6

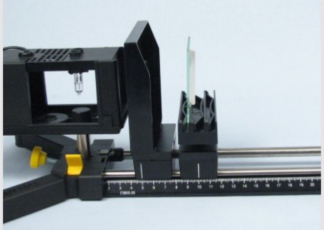

Figure 7

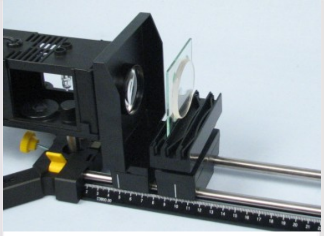

Figure 8

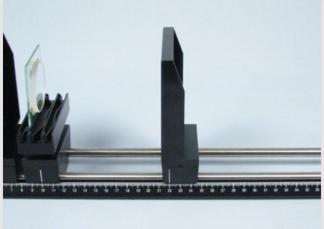

Figure 9

Structure (4/4)

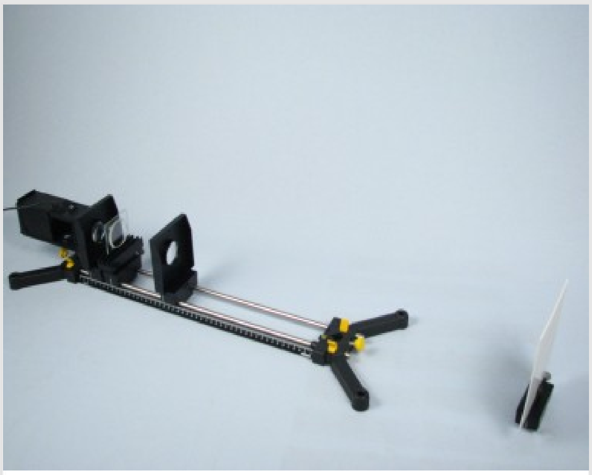

Figure 10

- Position the screen with rider approx. 30 cm to the right of the optical bench (Fig. 10).

Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
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Implementation (1/4)

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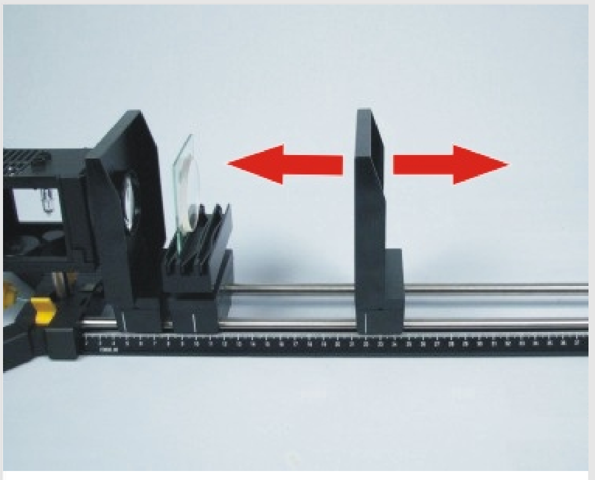

Figure 11

- Connect the lamp to the power supply (12 V~) and switch on the power supply.
- Move the lens with f = +100 mm on the optical bench (Fig. 11) until a sharp image of a colored pattern appears on the screen.
- Observe the picture and write down your observations.

Implementation (2/4)

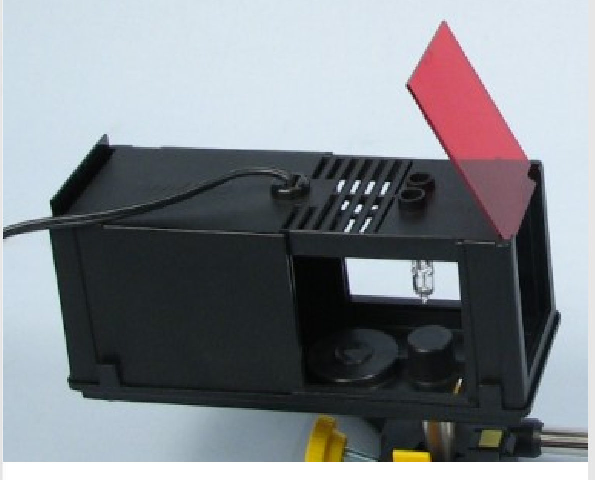

Figure 12

- Slide the red filter into the shaft of the light (Fig. 12).
- Again, observe the image and describe it.

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37079 Göttingen

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

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Implementation (3/4)

- Attach a paper to the screen with 3 paper clips (Fig. 13) without changing the location of the screen; refocus the image if necessary.
- Measure the distances g (between the color glass and the lens with f = +100 mm) and b (between the lens with f = +100 mm and the screen) (Fig. 14) and note the results.

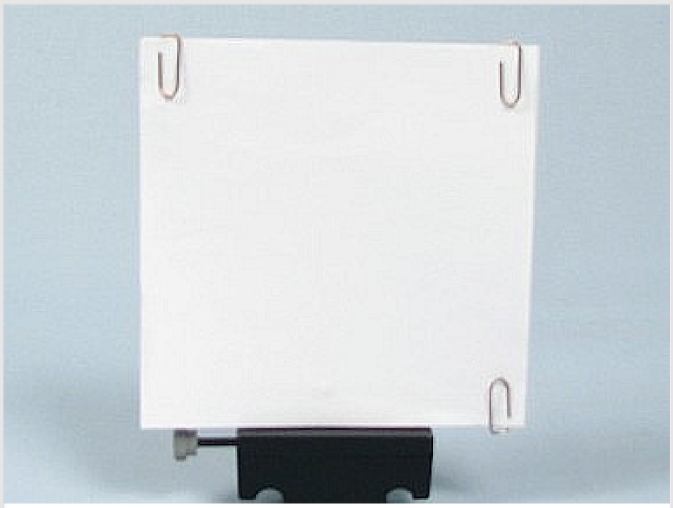

Figure 13

Procedure (4/4)

- Use a pencil to mark the diameters of the dark rings shown on the paper and determine as many diameters as possible in this way. D'_n .
- Turn off the power supply.
- Measure the diameters with a ruler D'_n and note the values; D'_1 is the value for the smallest ring.

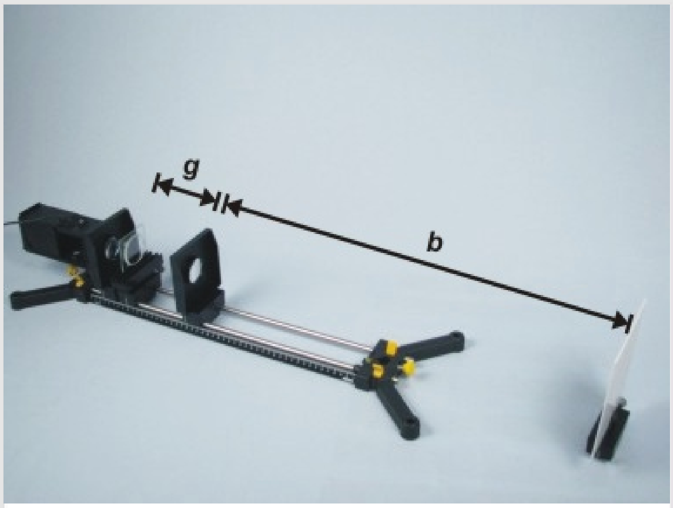

Figure 14

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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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Report

Task 1

Drag the words into the correct boxes!

When the light from the glass plate hits the ______, some of it passes through the lens immediately. Another part is reflected at the ______ of the lens and then at the surface of the ______ before it too passes the lens. It has a ______.

Ist $\Delta = (2n-1)\cdot(\lambda/2)$ then the light components ______ with the wavelength λ off, for $\Delta = n \cdot \lambda$ ______ them.

reinforce | surface | extinguish | lens | walk difference compared to the first part Δ | glass plate

Check

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Robert-Bosch-Breite 10
37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
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Task 2

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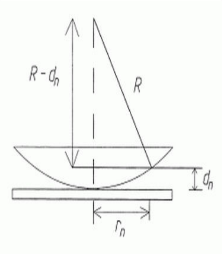

Figure 15

For the dark rings, which are formed when monochromatic light passes through the Newtonian color glass (cf. Fig. 15):
${r_{n+1}}^2 - {r_n}^2 = R\lambda$ **.**

What formula is obtained with the relation $2r_n = D_n$?

- $8R \cdot \lambda = {D_{n+1}}^2 - {D_n}^2$
- $4R \cdot \lambda = {D_{n+1}}^2 - {D_n}^2$
- $(1/4)R \cdot \lambda = {D_{n+1}}^2 + {D_n}^2$

Task 3

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Calculate the diameters D_n with the help of the equation $D_n/D'_n = g/b$. Then determine the mean value for ${D_{n+1}}^2 - {D_n}^2 = g/b$ to then calculate the radius R of the lens using the formula from Rec. 2. (The wavelength of the red color filter light is about 630 nm). What value do you obtain for R?

- $R \approx 12\,\mathrm{m}$
- $R \approx 10\,\mathrm{m}$
- $R \approx 8\,\mathrm{m}$

Check

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

Slide	Score / Total
Slide 23: Formation of the interference rings	0/6
Slide 24: Equation of Newton's rings	0/1
Slide 25: Radius of the lens	0/1

Total 0 / 8

Solutions   Repeat

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Robert-Bosch-Breite 10
37079 Göttingen

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

info@phywe.de
www.phywe.de