Newton's Rings

Task and equipment

Information for teachers

Additional Information

When a parallel beam of light strikes a tapered film of air created between one plane and one spherical glass body, a pattern of concentric ring-shaped bands is formed due to interference of light waves. The arrangement is called the Newtonian chromatic glass and the interference pattern Newton's Rings.
These interference rings are brought about because a part of the light passes directly through the plane-parallel plate and the lens body and another part is first reflected at the lens surface and then at the glass plate (comp. Fig.).
The students should become familiar with the phenomenon of Newton's Rings; they should gather measurement data on the phenomenon in an experiment and learn to pull this data to a practical use.

Suggestions for Set-up and Performance

In order to keep the setup simple we advise carrying out the experiment with continuous light, although working with reflected light would supply higher contrast images of Newton's Rings.
The experimental laboratory should be darkened.
It is very important to work accurately when marking and measuring the image diameters D_n'. For this purpose we recommend recording the centres of the dark rings on a horizontal straight line running through the common centre of the circles.

Remarks

Before or after performing the experiment the students should be encouraged to look through the Newtonian chromatic glass with the aid of the measuring magnifier. The following − comparatively simple − modification to the experiment is based on this possibility:

Place the red filter on the table. On top of this place the Newtonian chromatic glass, lens upwards, and finally the measuring magnifier. Pick up the whole thing and look through the measuring magnifier towards bright light. In this way it is also possible to measure several diameters D_n on the scale of the measuring magnifier, providing that its plane boundary coincides with the horizontal common diameter of the rings. One drawback with this method is that you cannot measure more than n = 4 and the measuring accuracy is not very high.

When deriving the equation $4 \times R \times \lambda = D_{n+1}^2 - D_n^2$ the following should be taken into account: for monochromatic light of wavelength λ let r_n stand for the radius of the nth dark ring, and d_n for the distance of the convex surface from the plane-prallel plate for r_n. Hence:

$$(R - d_n)^2 + r_n^2 = R^2 ,$$

$$R^2 - 2 R d_n + d_n^2 + r_n^2 = R^2$$

$$-2 R d_n + d_n^2 + r_n^2 = 0$$

$r_n^2 = 2 R d_n - d_n^2$, and since $R >> d_n$

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

The waves passing straight through the Newtonian chromatic glass have a phase difference $\Delta = 2d_n = r_n^2 / R$ compared to the waves which are reflected twice on their passage. On the other hand, light waves which interfere with each other at adjacent rings have a phase difference of λ. Hence, for two adjacent dark rings the following relation can be derived:

$(r_{n+1}^2/R) - (r_n^2/R) = \lambda$ and hence

$$r_{n+1}^2 - r_n^2 = \lambda \times R$$

In fact, the diameters of the rings can be determined in the experiment more accurately than the radii. Since $D_n = 2 r_n$ we arrive at the following equation:

$D_{n+1}^2 - D_n^2 = 4 \times R \times \lambda$.

On the basis of this mathematical relation, and providing that we know the convex radius R, we can determine the wavelength λ. Conversely, we can determine the convex radius R of a lens if we use monochromatic light of a known wavelength λ.

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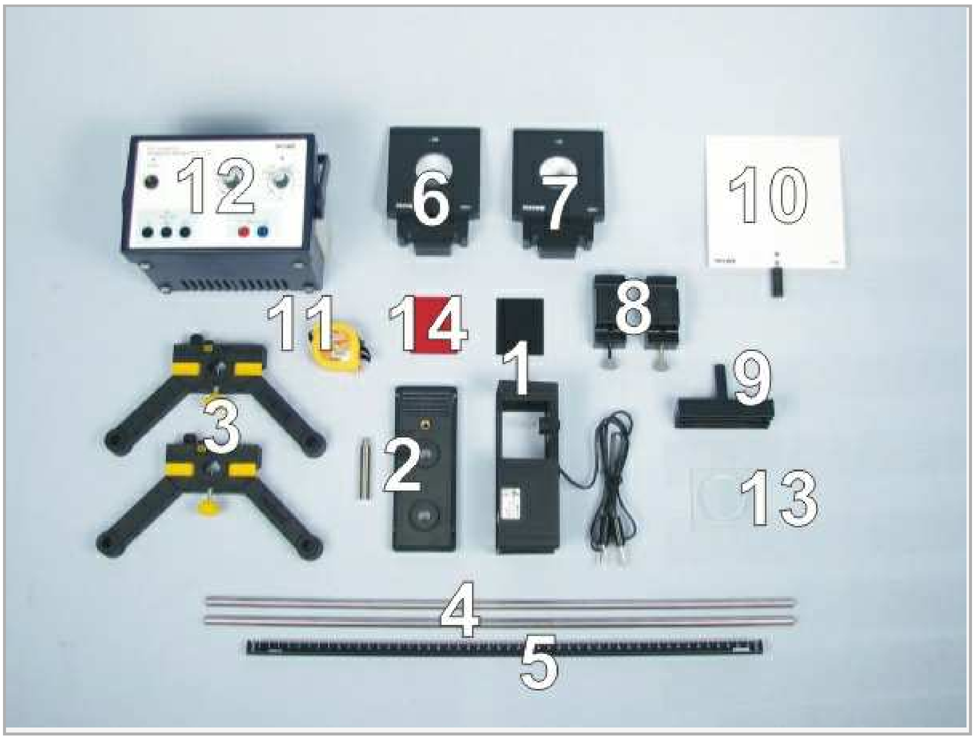
Task

How can we explain the phenomenon of Newton's Rings?

Direct a parallel beam of light through a Newtonian chromatic glass and with the aid of the resulting rings, determine the radius of the lens-shaped glass body.

Equipment



Position No.	Material	Order No.	Quantity
1	Light box, halogen 12V/20 W	09801-00	1
2	Bottom with stem for light box	09802-10	1
3	Support base, variable	02001-00	1
4	Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	2
5	Meter scale for optical bench	09800-00	1
6	Lens on slide mount, f=+50mm	09820-01	1
7	Lens on slide mount, f=+100mm	09820-02	1
8	Slide mount for optical bench	09822-00	2
9	Plate mount f.3 objects	09830-00	1
10	Screen, white, 150x150mm	09826-00	1
11	Measuring tape, l = 2 m	09936-00	1
12	PHYWE power supply DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A	13506-93	1
13	Plate and lens f. Newton rings	08551-00	1
14	Colour filter set, additive (red, blue, green)	09807-00	1
Additional material			
	White paper (DIN A4)		
	Paper clips		
	Ruler		

Set-up and procedure

Set-up

- Set up the optic bench with the two support rods and the support base and place the scale in position (Fig. 1 and Fig. 2).

Fig. 1

Fig. 2

- Assemble the light box according to Figures 3 and 4 and clamp it into the left part of the support base with the lens end pointing away from the optic bench (Fig. 5). Insert the light-tight diaphragm in front of the lens (Fig. 6).

Fig. 3

Fig. 4

Fig. 5

Fig. 6

- Position a lens with *f* = +50 mm onto the optic bench at approx. 5 cm (Fig. 7).

Fig. 7

- Set up a slide mount with a plate mount holding the Newtonian chromatic glass (plate with lens) at approx. 10 cm. Make sure that the lens is situated above a plate spring and that plate spring and lens face to the right (Fig. 8 and Fig. 9).

Fig. 8

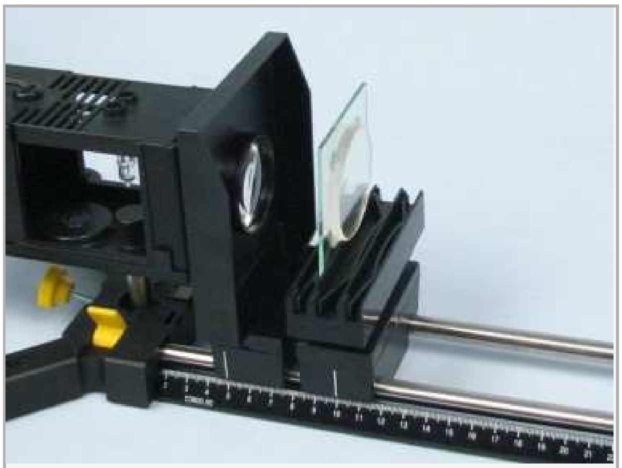


Fig. 9

- Position the lens with *f* = +100 mm at approx. 22 cm (Fig. 10) and the screen with slide mount at approx. 30 cm to the right of the optic bench (Fig. 11).

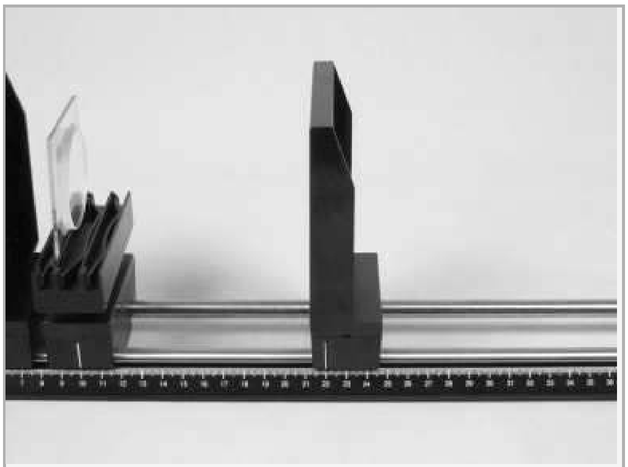


Fig. 10

Fig. 11

Procedure

- Connect the light box to the power supply (12 V~) (Fig. 12) and switch on the power supply.

Fig. 12

- Move the lens with f = +100 mm along the optic bench (Fig. 13) until a coloured pattern is focussed sharply on the screen.

- Observe the image and note your description under "Result - Observations 1" in the report.

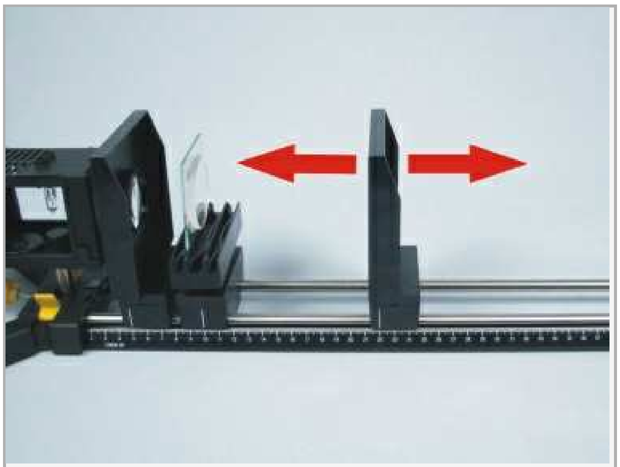


Fig. 13

- Insert a red filter into the well of the light box (Fig. 14); again observe and describe the ensuing image (under (2) in the report).

Fig. 14

- Fix a piece of paper to the screen with three paper clips (Fig. 15) without changing the position of the screen; if necessary, adjust until the image is focussed.

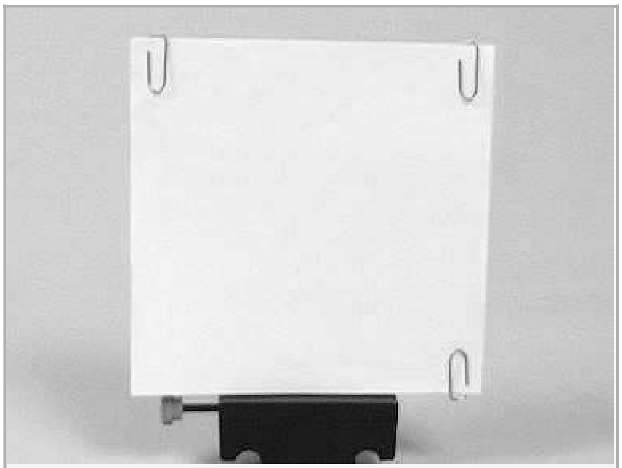


Fig. 15

- Measure the distances g (Newtonian chromatic glass − lens with f = +100 mm) and b (lens with f = +100 mm − screen) (Fig. 16).
- Note your results in the report.

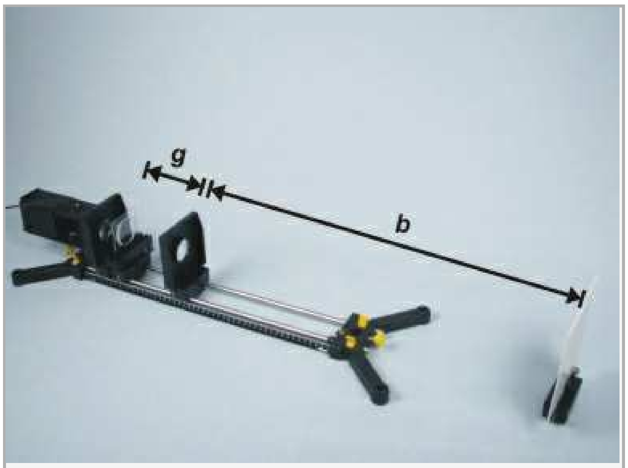


Fig. 16

- With a pencil mark the diameters of the dark rings on the paper and thus determine as many diameters D_n' as possible.
- Switch off the power supply.
- With a ruler measure the diameters D_n' and enter the values in Table 1 on the Results page; D_1' is the value for the smallest ring.

Report: Newton's Rings

Result – Observations 1

Note down your observations during the experimental part without red filter:

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Result – Observations 2

Note down your observations during the experimental part with red filter:

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Result – Observations 3

Enter the measured distances:

g = ... cm

b = ... cm

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Result – Table 1

1. Note your measurements in the table.
2. The following equation is valid for the dark rings created when monochromatic light passes through the Newtonian chromatic glass (comp. Fig. 17):

$$r_{n+1}^2 - r_n^2 = R \times \lambda.$$

3. Since D_n' can be measured more precisely than r_n' and hence D_n can be calculated more precisely than r_n, it is generally preferable to use the equation:

$$D_{n+1}^2 - D_n^2 = 4 \times R \times \lambda$$

which is valid because $D_n = 2 \times r_n$. Calculate the diameters D_n on the basis of the equation:

$$D_n / D_n' = g / b \text{ bzw. } D_n = D_n' \times (g / b)$$

and complete the table.

4. Note down the average value for $D_{n+1}^2 - D_n^2$ in the field bottom right of the table.

n	D_n' in mm	D_n in mm	D_n^2 in mm^2	$(D_{n+1}^2 - D_n^2)$ in mm^2
1	1 ±0	1 ±0	1 ±0	1 ±0
2	1 ±0	1 ±0	1 ±0	1 ±0
3	1 ±0	1 ±0	1 ±0	1 ±0
4	1 ±0	1 ±0	1 ±0	1 ±0
5	1 ±0	1 ±0	1 ±0	1 ±0
6	1 ±0	1 ±0	1 ±0	1 ±0

Evaluation – Question 1

Give an explanation of the formation of Newton's rings using Figure 18 below.

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Evaluation – Question 2

Calculate the approximate radius R of the chromatic glass lens used. (Wavelength of the red light used is approx. 630 nm; take the average value for $D_{n+1}^2 - D_n^2$ from Table 1).