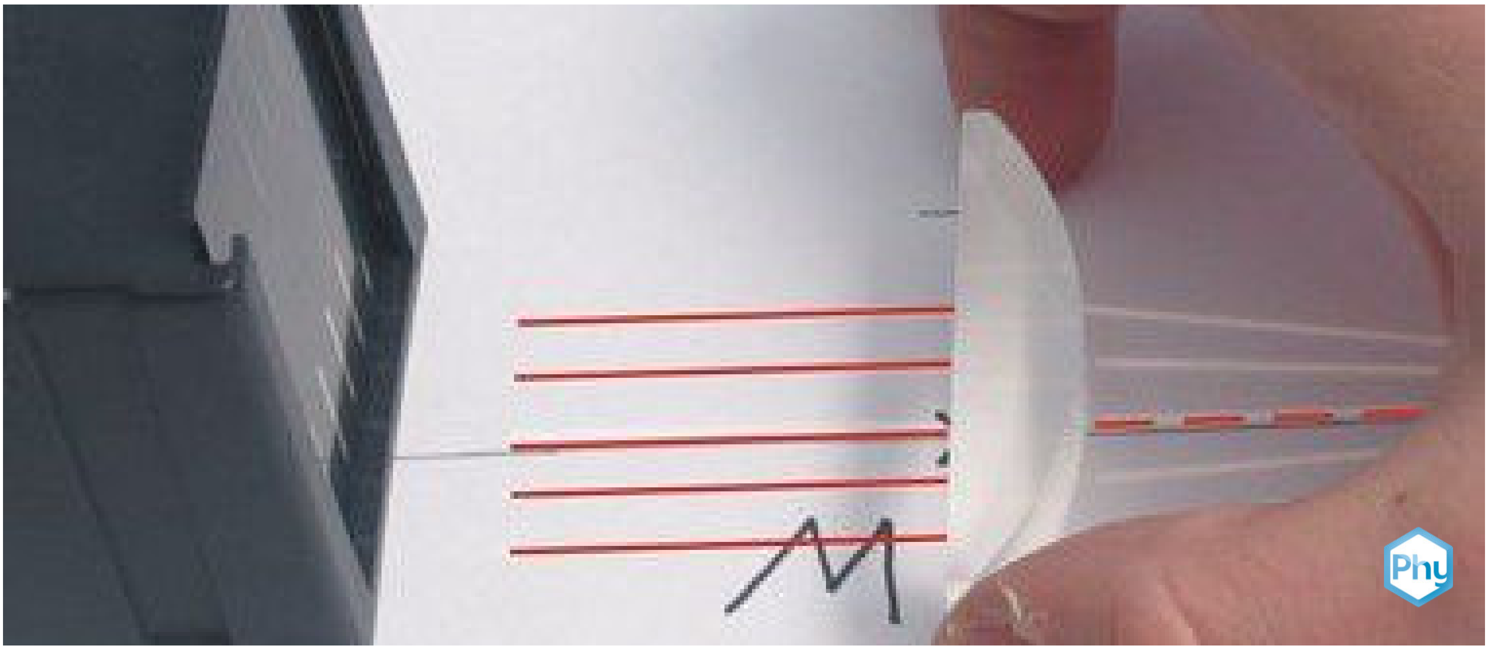
# Chromatic aberration



After the first partial experiment (large aperture), in which the coloured edges of the light cones can be easily observed, the aim of the further experiments is to recognise the pronounced colour decomposition with the help of the examination of narrow light beams close to and far from the axis.

Physics > Light & Optics > Optical devices & lenses

| Difficulty level | Group size | Preparation time | Execution time |
|---|---|---|---|
| medium | 2 | 10 minutes | 10 minutes |

This content can also be found online at:

http://localhost:1337/c/63303191bdd06200034b24be

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# Teacher information

## Application

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Chromatic lens aberration

Spherical and chromatic aberration are the two best-known aberrations of a lens, and complex lens systems (achromats) are built into high-quality optical devices to correct them.

Chromatic aberration is caused by the wavelength-dependent refraction at a lens. Short-wave light (blue) is usually refracted more strongly than long-wave (red) light. After refraction behind the lens, the light rays do not meet at one point on the optical axis and imaging errors occur.



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## Other teacher information (1/4)

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**Prior knowledge**

The students should already have knowledge of the course of rays on convex lenses and prisms and be able to apply the law of refraction.

**Principle**

When white light is refracted through a plano-convex lens, a decomposition of the individual light beams into the spectral colours occurs depending on the distance of the incident light beams to the optical axis.

## Other teacher information (2/4)

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**Learning objective**

This experiment offers good opportunities to repeat both the law of refraction and the refraction of light at the prism at the end of the material section "Refraction at lenses" in application to a new situation. It also provides an outlook on the composition of white light from different colours up to the wavelength dependence of refraction.

**Tasks**

After the first partial experiment (large aperture), in which the coloured edges of the light cones can be easily observed, the aim of the further experiments is to identify the pronounced colour decomposition with the help of the examination of narrow light beams close to and far from the axis.



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# Other teacher information (3/4)

## Note

In connection with the study of colour decomposition on a concave lens, possibilities of correcting lens aberrations with a suitable combination of convex and concave lenses can be discussed.

Since the point of intersection of the refracted light bundles cannot be fixed unambiguously due to the spherical aberration that occurs and the small focal length, an investigation of the refraction of monochromatic light at the plano-convex lens would not yield an unambiguous result.

# Other teacher information (4/4)

## Notes on set-up and procedure

By observing the specified position of the lens and the light box and by carefully adjusting the experimental set-up with the help of a light beam incident along the optical axis, an optimal experimental result is achieved. The flat surface of the lens must lie exactly on the vertical line of the line cross.

The colour decomposition on a concave lens is much less visible than on a convex lens. It only occurs when the light beam passes through the lens very far away from the axis.

Since the lens of the light box also has chromatic aberrations, it is essential to use the light beam produced with the slit diaphragm in the fourth part of the experiment, which passes through the light box lens on the optical axis.

With suitable darkening of the room, almost all colours of the spectrum can be observed.



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## Safety instructions

The general instructions for safe experimentation in science lessons apply to this experiment.

# Student information



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## Motivation

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Spherical and chromatic aberration are the two best-known aberrations of a lens, and complex lens systems (achromats) are built into high-quality optical devices to correct them.

Chromatic aberration occurs when light is refracted depending on its wavelength. For example, when refracted by a prism, white light is split into its spectral colour and a rainbow can be observed.

Splitting light into its spectral colours

## Task

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Experimental setup

### What are colour defects of a lens?

- Investigate the colour decomposition of white light when it is refracted by a plano-convex lens.



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# Equipment

| Position | Material | Item No. | Quantity |
|---|---|---|---|
| 1 | Light box, halogen 12V/20 W | 09801-00 | 1 |
| 2 | Block,planoconvex lens,fl+100mm | 09810-04 | 1 |
| 3 | Block, planoconcave lens,fl-100mm | 09810-05 | 1 |
| 4 | PHYWE Power supply, 230 V, DC: 0...12 V, 2 A / AC: 6 V, 12 V, 5 A | 13506-93 | 1 |



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## Additional equipment

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| Position | Material | Quantity |
|---|---|---|
| 1 | Ruler (approx. 30cm) | 1 |
| 2 | White paper (DIN A4) | 1 |
| 3 | Eraser | 1 |

## Set-up

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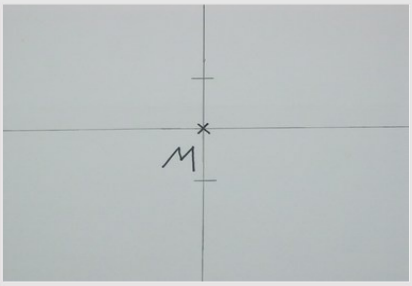
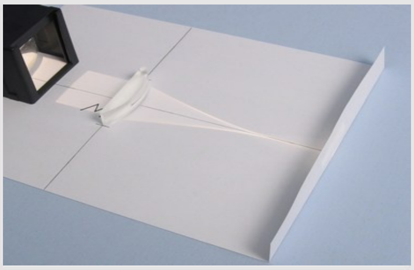
- Draw a right-angled cross of lines at a distance of about 12 cm from the left edge of your sheet. Let the intersection of the lines be $M$.
- Draw at a distance of 3 cm from $M$ one mark each of the vertical lines.
- Fold the sheet upwards as a screen about 2 cm from the right edge.
- Place the plano-convex lens (roughened side down) with the flat surface against the vertical line of the line cross within the two marks.
- Place the light box with the lens side but without the aperture on the left edge of the sheet opposite the flat surface of the lens.





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## Procedure (1/4)

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- Connect the light box to the power supply unit (12 V ~).

### 1st experiment

- Move the light box until the wide beam of light falls completely through the lens in the direction of the optical axis.
- Observe the edges of the light cones in the area of the focal point. Note your observations.

## Procedure (2/4)

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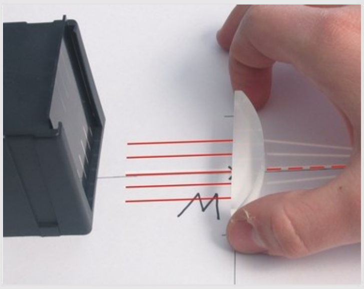

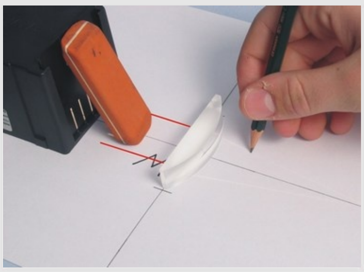

### 2nd experiment

- Insert the five-slit diaphragm on the lens side of the light box and move the light box until the central light beam runs exactly along the optical axis.
- Observe the edges of the narrow beams of light as they hit the screen and note your observations.
- Fade out the inner three light beams and mark the red and blue edges of the two light beams on the folded edge (screen), as well as the centre of each of the two light beams directly behind the lens.
- Draw the course of red or blue light, i.e. connect the centre of the light beam (lens) with the red or blue edge (screen).



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## Procedure (3/4)

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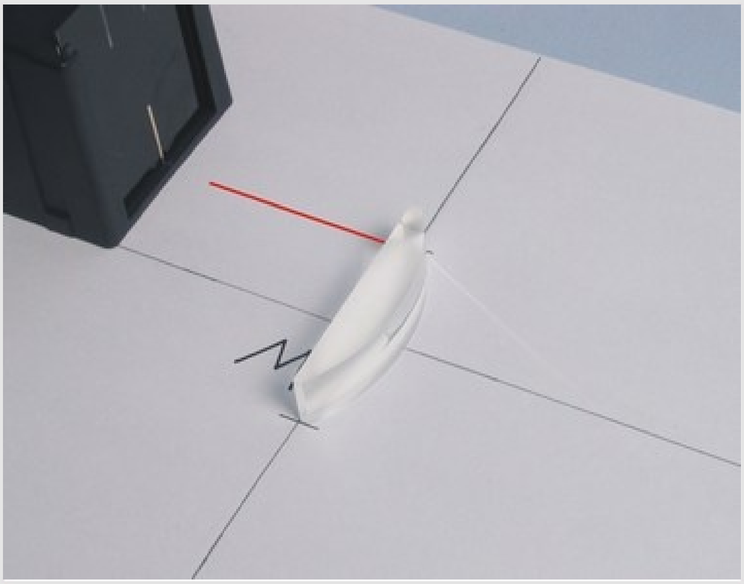

### 3rd experiment

- Insert the ice slit diaphragm into the light box and move the light box up or down until the light beam passes through the lens at the very edge.
- Describe the position and sequence of the colours to be observed behind the lens.

## Procedure (4/4)

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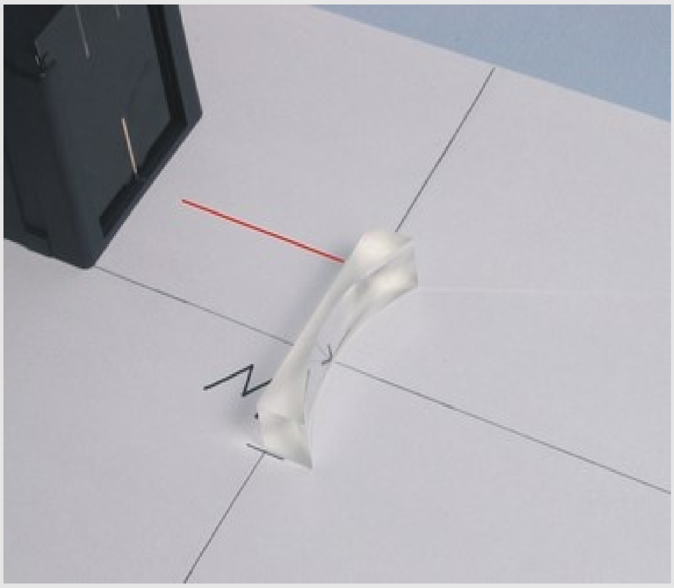
### 4th experiment

- Now replace the plano-convex lens with the plano-concave lens and repeat the 3rd experiment.
- Write down your observations.
- Switch off the power supply and remove the light box and the model body from the paper.





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# Report

## Task 1

10°

What colours occur when white light is refracted through a plano-convex lens?

- Depending on the distance of the incident light beams from the optical axis, the individual light beams are split into two colours (red and yellow).
- Depending on the distance of the incident light beams to the optical axis, a decomposition of the individual light beams into the spectral colours occurs.
- The white light is refracted at the plano-convex lens and is still recognisable as white after refraction.



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## Task 2

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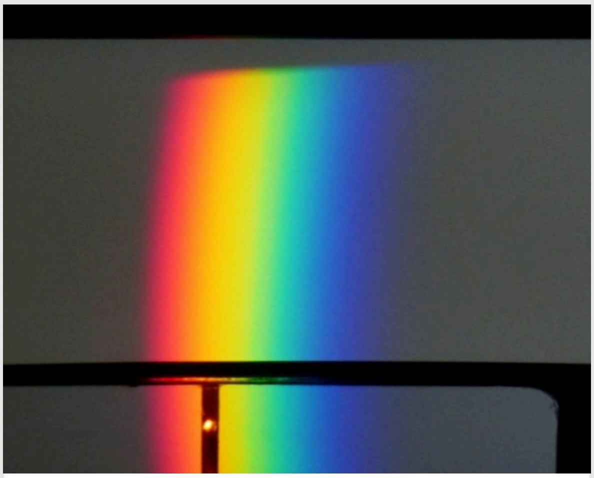
10°

Evaluate the truth of the following statement:

The colour decomposition is better and more intensive the further the light beams move away from the optical axis after the common intersection point (light beams far from the axis).

- True
- False

Check



Representation of the spectral colours

## Task 3

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What could be the cause of the different intensity of the colour shine on a convex lens?

Drag the words into the correct boxes!

White light beams incident ______ the optical axis are ______ refracted when passing through a plano-convex lens as those ______ from the axis. With the latter, however, the colour decomposition can be observed far ______. So there must be a connection between refraction and light colour.

- not as strongly
- better
- near
- far

Check



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## Task 4

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Which statement results from the second partial experiment about the focal length for red and blue light?

- The focal point for blue light is in the same place as that for red light, so the focal length is identical.
- The focal point for red light is slightly closer to the lens than that for blue light, so the focal length is different.
- The focal point for blue light is slightly closer to the lens than that for red light, so the focal length is different.

Check

## Task 5

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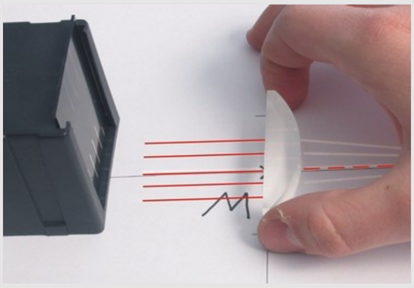
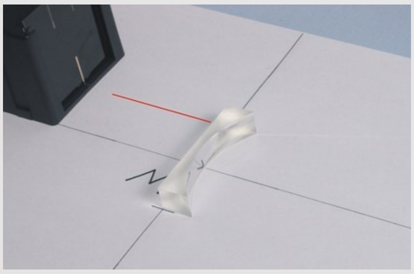
Is the position and order of colour decomposition on a convex lens different from that on a concave lens?

In the case of refraction at a concave lens, the order of the colours (with respect to the optical axis) is reversed to the order of colour decomposition at a convex lens.

In the case of refraction at a concave lens, the order of the colours (in relation to the optical axis) is identical to the order of colour decomposition at a convex lens.







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## Additional task

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Camera lens as an example of a lens system

Evaluate the truth of the following statement:

There are lenses or lens systems with almost no chromatic aberration.

- True
- False

Check

| Slide | Score / Total |
|---|---|
| Slide 19: Colour appearance during the refraction of white light | 0/1 |
| Slide 20: Colour decomposition intensity | 0/1 |
| Slide 21: Causes of the different colour intensities | 0/4 |
| Slide 22: Focal length of red and blue light | 0/1 |
| Slide 23: Difference in colour decomposition on different lenses | 0/1 |
| Slide 24: Lens systems without colour defects | 0/1 |

**Total** 0/9

Solutions Repeat



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