Experimental Physics III

Submission due: November 3, 2022, before the lecture starts

Exercise Sheet 3

3.1

Given is a dove prism in air as depicted in Figure 1 with a refractive index of $n = 1.51$. The arrangement of the setup is such that the two monochromatic light rays deriving from the object "F" are totally internally reflected at the base of the prism after they have been refracted at the left prism edge.

- Sketch the trace of the two light rays.
- Calculate the particular angles at which the rays are refracted or reflected until they leave the prism body.
- Indicate the orientation of the image of the letter "F".

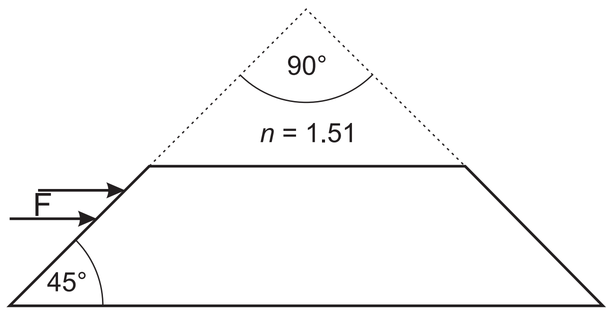

Figure 1: Prism that is truncated such that the light rays from the left object "F" are totally internally reflected at the prism base.

3.2

A lens with a focal length of 6 cm should serve as a magnifying glass for an object. The object is placed in the focal point of the magnifying glass. For one user the distance of clear visual view is 25 cm and for another it is 40 cm.

- Calculate the effective magnification for both users.
- Compare the size of the two images on the retina if both users utilize the magnifying glass to observe the same object.

3.3

A thin lens in air has the focal length f_a.

- Show that the following equation for the focal length f_w in water holds:

$$f_\mathrm{w} = \frac{(n_\mathrm{w}/n_\mathrm{a})\,(n - n_\mathrm{a})}{n - n_\mathrm{w}} f_\mathrm{a}, \qquad (1)$$

where n_w, n, and n_a are the refractive indices of water, the material of the lens, and air, respectively.

- Calculate the focal length in air and in water for a thin biconcave lens with a refractive index of 1.5, a radius of the first spherical surface of 30 cm, and 35 cm of the second one.

3.4

- A symmetric biconvex lens has radii of curvature of magnitude 10.0 cm. It is made up of glass with refractive indices 1.530 for blue light and 1.470 for red light. Calculate the two focal distances of the lens for the given light beams.

- An achromatic lens, that has a focal distance of $f = 30.0$ cm for all visible wavelengths of light, is composed of two lenses that are glued together: The material for the first lens is BK7, the material for the second one is SF11. The curvatures of the both lenses at the contact surface are equal (see Figure 2). The curvature r_1 is arched twice as much as the curvature r_3, i.e., $r_1 = r_3/2$. The refractive indices for red light ($\lambda_r = 706.5$ nm) are $n_{BK7,r} = 1.5129$ and $n_{SF11,r} = 1.7713$ and for blue light ($\lambda = 435.8$ nm) $n_{BK7,b} = 1.5267$, $n_{SF11,b} = 1.8252$, respectively. Calculate the radii of curvature r_1, r_2, and r_3.
  Hints: Use formulas for thin lenses as well as lenses that are positioned close to each other.

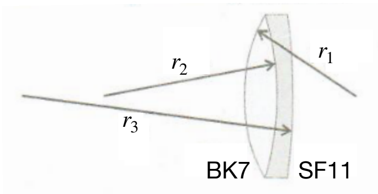

Figure 2: Lens composed of a biconvex thin lens made of BK7 and a concave-convex lens made of SF11.

3.5

- Show that an infinitesimal change dn of the refractive index of the material of a thin lens leads to an infinitesimal change df of the focal distance, i.e., show that:

$$\frac{\mathrm{d}f}{f} = -\frac{\mathrm{d}n}{n - n_a}, \tag{2}$$

  where n_a is the refractive index of air.

- Calculate the focal distance of a thin lens for blue light (with $n = 1.530$) using a discrete version of the upper equation if the focal distance for red light (with $n = 1.470$) is 20.0 cm.