Assignment 5

OPTI 502 Optical Design and Instrumentation I

University of Arizona

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September 23, 2025

Exercise 1

a) In this case, the object is virtual and the image will be real and erected.

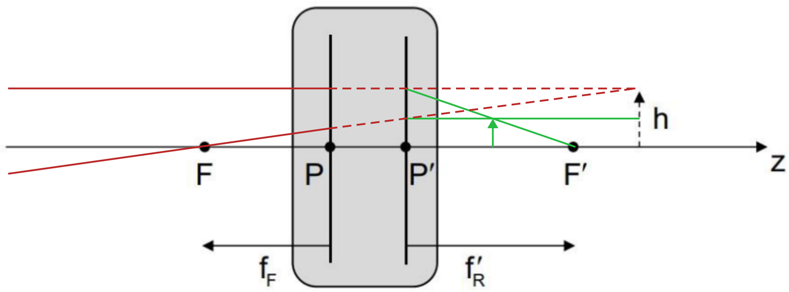

Figure 1

b) The object is virtual, and therefore the image will be real and erected.

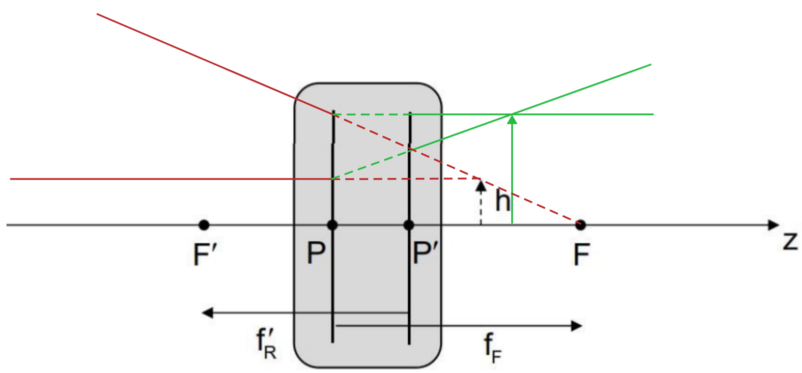

Figure 2

c) The object is virtual, and the image will be virtual and inverted.

Exercise 2

a) For a single refracting surface, we have that:

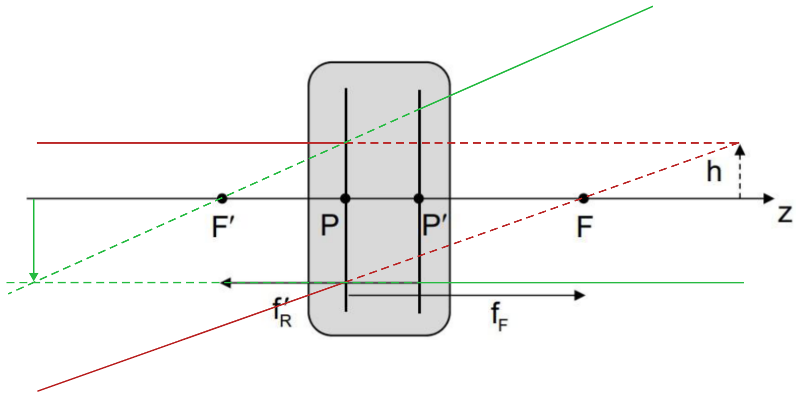

Figure 3

- Both nodal points are located at the center of curvature CC.
- Front and real principal planes are located at the vertex.
- The reduced thickness of the surface is the focal length of its thin lens representation.

We illustrate these quantities along with the vertex and the focal lengths in the following figure. We

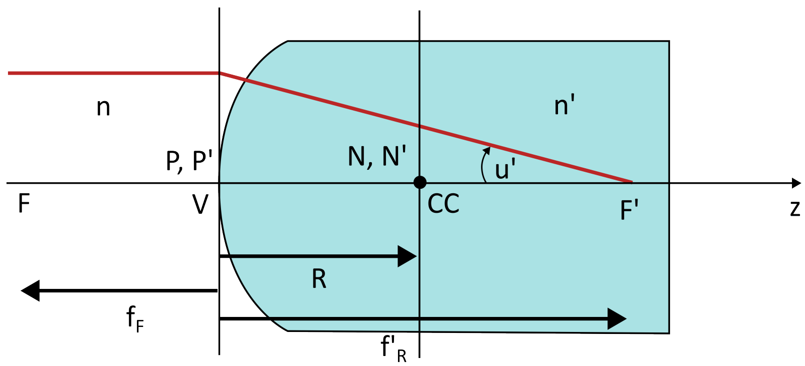

Figure 4: Illustration of cardinal point for a single refractive surface.

illustrate also some quantities of this surface:

$$C = \frac{1}{R} = 100\ m^{-1}, \quad \phi = (n' - n)C = 33.3\ m^{-1}, \quad f_E = \frac{1}{\phi} = 30\ mm,$$
$$f_F = -nf_E = -30\ mm, \quad f'_R = n'f_E = 40\ mm.$$

b) We use the following equation:

$$\frac{n'}{z'} = \frac{n}{z} + \frac{1}{f_E} \longrightarrow z' = \frac{n'zf_E}{nf_E + z}.$$

Replacing the physical values and the EFL:

$$z' = \frac{(1.333)(30)(100)}{(1)(30) + 100} = +30.7615\ mm.$$

Its height is determined by the magnification:

$$m = \frac{h'}{h} = \frac{z'/n'}{z/n} = \frac{30.7615/1.333}{100/1} = 0.231 \longrightarrow h' = mh = (0.231)(10\ mm) = 2.31\ mm.$$

c) The cube is divided in equal part by the optical axis, yielding a height of $h = 5\ mm$. Its last side is located 100 mm from the principal planes, as all their sides have the same sizes. Its first face is located 110 mm from the principal plane. Now, the area of one side is 100 mm^2. We want to find the equivalent (area of volume) of its image. We can address this problem by considering two lines at each side of the cube as two independent objects with (z_1, h_1) and (z_2, h_2). Then, we do imaging of both to get (z_1', h_1') and (z_2', h_2'). The difference between positions and heights allow us to construct the image dimension.

$$z_1 : \quad z_1' = \frac{(1.333)(30)(110)}{(1)(30) + 110} = +31.42\ mm$$
$$z_2 : \quad z_2' = \frac{(1.333)(30)(100)}{(1)(30) + 100} = +30.76\ mm$$

We do the same for the magnification to compute the corresponding heights:

$$m_1 = \frac{31.42/1.333}{110/1} = 0.214 \longrightarrow h_1' = m_1 h_1 = (0.214)(5) = 1.07\ mm$$
$$m_2 = \frac{30.76/1.333}{100/1} = 0.231 \longrightarrow h_2' = m_2 h_2 = (0.231)(5) = 1.16\ mm.$$

The other dimension remains the same 10 mm as it is seen at the same distance from the refractive surface. The area, would be the integration from z_1' to z_2' with the respective height which can be used to create a linear function (interpolation). However, we will assum the mean value between them to consider it as a constant value. Then, the are is:

$$A = \Delta z' \Delta h' = 2(z_2' - z_1')(\frac{h_1' + h_2'}{2}) = 1.472\ mm^2.$$

And the volume is this area multiplied by the remaining dimension:

$$\Delta x \cdot A = (10)(1.472) = 14.72\ mm^3.$$

Exercise 3

For a two positive lens system, we use Gaussian reduction to reduce the effect to a single thin lens. We first compute the overall optical power with the power of individual lenses:

$$\phi = \phi_1 + \phi_2 - \phi_1\phi_2 t = \frac{1}{40} + \frac{1}{40} - \frac{1}{40}\frac{1}{40} \cdot 20 = 0.038 mm^{-1} \longrightarrow f_E = \frac{1}{\phi} = 26.67\ mm.$$

The distances d and d' are the shift in the principal plane of the respective individual elelemnt, to the ones of the total system. In this case where $n = 1$, they are given by

$$d = \frac{\phi_2}{\phi} t = \frac{0.025}{0.038} 20 = 13.158\ mm, \quad \text{and} \quad d' = -\frac{\phi_1}{\phi} t = -\frac{0.025}{0.038} 20 = -13.158\ mm.$$

I think the distances are just relative, no absolute value can be given, what would be the reference then?

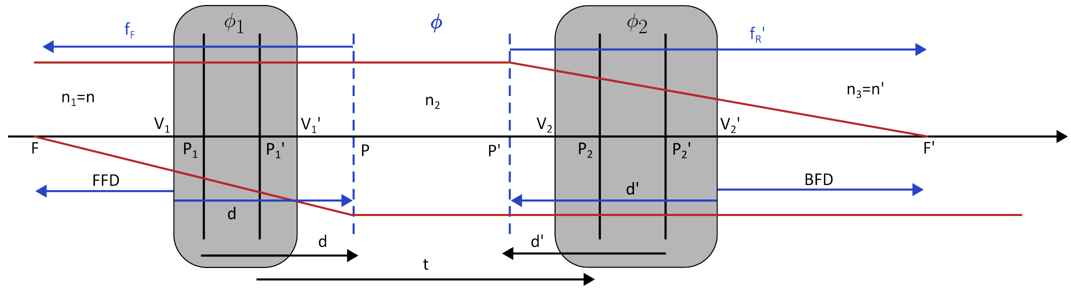

Figure 5: Gaussian reduction for two positive lenses.

Exercise 4

Exercise 5