

2.71 Optics

Fall '05

Problem Set #3

Posted Sept. 21, 2005 — Due Wednesday, Sept. 28, 2005

1. A parallel ray bundle of width a_1 is incident from the left on a two-lens system composed of two lenses **L1** (focal length f_1) and **L2** (focal length f_2) as shown in Figure 1. What should the separation between the two lenses be in order for a parallel ray bundle to emerge from the system? What is the width of this outgoing ray bundle?

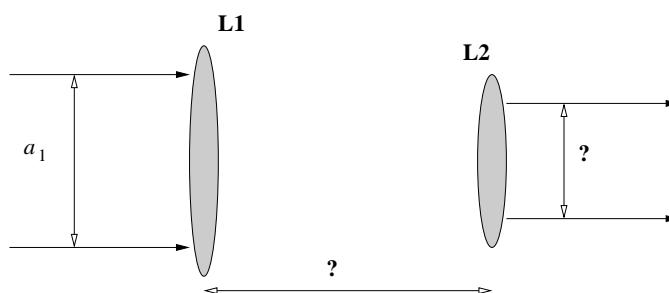


Figure 1

2. Work out the system matrix for the composite element shown in Figure 2 and use it to answer the following questions.
- What is the optical power of this composite element?
 - If a plane wave is incident from the left, where will it focus?
 - This system is used to image an object at infinity. Is the image real or virtual?

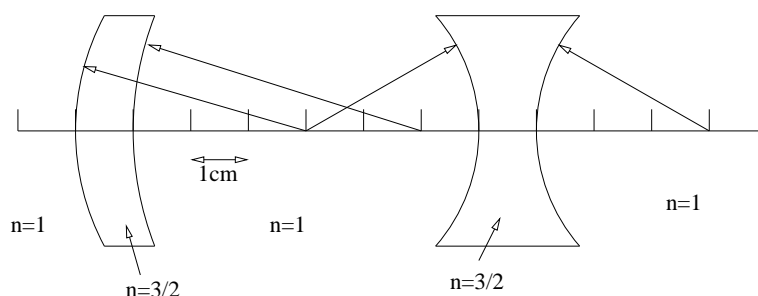


Figure 2

3. A thin bi-convex lens of index 1.5 is known to have focal length of 50cm in air when immersed in a transparent liquid medium, the focal length is measured to be 250cm. What is the refractive index n of the liquid?
4. You'd like to look through a lens at your pet Kitten and see it standing right side up shrunk to $1/3$ its normal height. If the absolute value of the focal length is f , determine what kind of lens is needed (*i.e.* positive or negative) as well as the object and image distances in terms of f .
5. We intend to use a spherical ball lens of radius R and refractive index n as magnifier in an imaging system, as shown in Figure 5. The refractive index satisfies the relationship $1 < n < 4/3$, and the medium surrounding the ball lens is air (refractive index = 1).

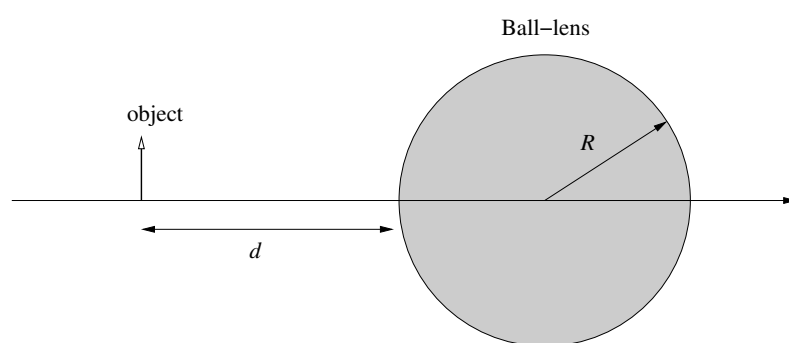


Figure 5

- a) Calculate the effective focal length (EFL) of the ball lens. Use the thick lens model with appropriate parameters.
- b) Locate the back focal length (BFL), the front focal length (FFL) and the principal planes of the ball lens.
- c) An object located at distance d to the left of the back surface of the ball lens, as shown in Figure 5, where

$$d = R \frac{4 - 3n}{4(n - 1)}$$

Show that the object is one half (EFL) behind the principal plane, and use this fact to find the location of the image plane.

- d) Is the image real or virtual? Is it erect or inverted? What is the magnification?

Please turn over

- e) Locate the aperture stop and calculate the numerical aperture (NA) of the optical system of Figure 5.
- f) Sketch how a human observer using the optical system of Figure 5 as input to her eye would form the final image of the object on her retina.