MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2.71 Optics **Fall '04**

Problem Set #3 Posted Sept. 22, 2004 — Due Wednesday, Sept. 29, 2004

1. **Wanda's world** Your goldfish Wanda lives in a sphere of water (refractive index $n = 1.3$, radius $|R| = 20\text{cm}$). At one instance, Wanda has wandered to the center of here water world (see Fig. 1 below). Model Wanda as a stick perpendicular to the optical axis and the water sphere as a thick lens. You may ignore the effect of the glass container of Wanda's world

   a) Where is Wanda's image formed?

   b) Is the image real or virtual?

   c) Is the image erect or inverted?

   d) What is the magnification?

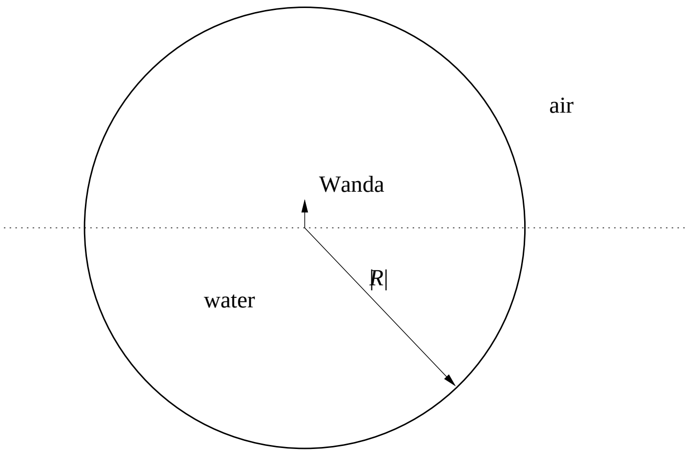

Figure 1: Wanda's world

2. 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 2. 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?

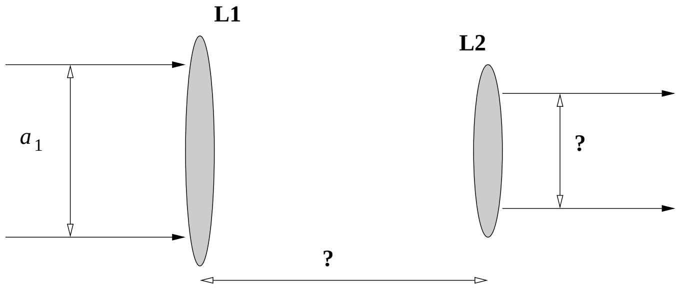

Figure 2

3. Work out the system matrix for the composite element shown in Figure 3 and use it to answer the following questions.

a) What is the optical power of this composite element?

b) If a plane wave is incident from the left, where will it focus?

c) This system is used to image an object at infinity. Is the image real or virtual?

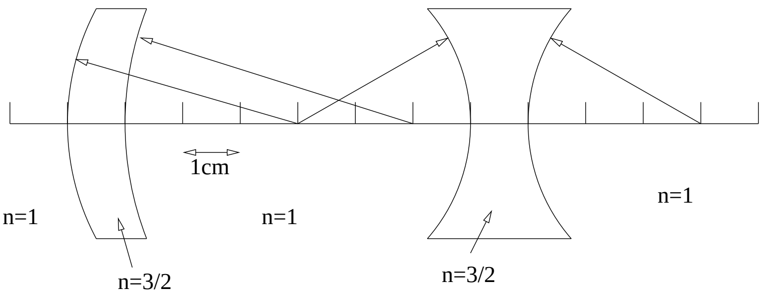

Figure 3

4. A thin bi-convex lens of index 1.5 is know 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?

5. You'd like to look through a lens at your pet Kitter 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 term of f.

6. 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 6. The refractive index satisfies the relationship $1 < n < 4/3$, and the medium surrounding the ball lens is air (refractive index = 1).

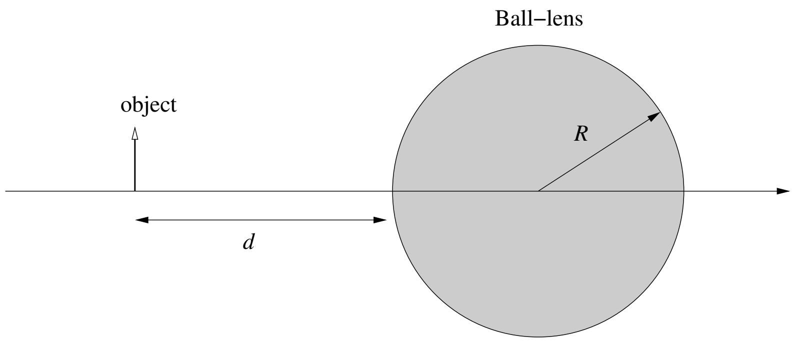

Figure 6

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 6, 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?

e) Locate the aperture stop and calculate the numerical aperture (NA) of the optical system of Figure 6.

f) Sketch how a human obeserver using the optical system of Figure 6 as input to her eye would form the final image of the object on her retina.