MASSACHUSETTS INSTITUTE of TECHNOLOGY
Department of Electrical Engineering and Computer Science

*6.161 Modern Optics Project Laboratory*

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| Problem Set No. 2 | **Geometric optics** | Issued Tues. 9/20/2005 |
| Fall Term, 2005 | - | Due Tues. 9/27/2005 |

**Reading recommendation:** Class Notes, Chapter 2. Be neat in your work!

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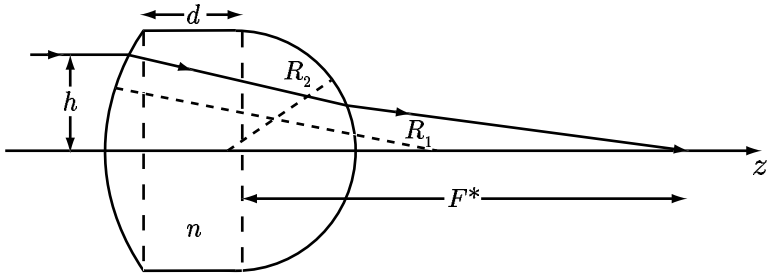
**Problem 2.1**




(a) A ray of light enters a cylindrically symmetric glass bead (thick lens) of refractive index $n$ at a height $h$ above its principal axis. The lens has entrance and exit faces with radii of curvature $R_1$ and $R_2$ as shown. Assuming the usual small-angle and thin-lens approximations hold, use the ray-matrix approach to determine the approximate distance $F^*$ at which the ray crosses the $z$-axis

(b) Now turn the lens around so the ray, still at a height $h$ above the principal axis, is incident of the $R_2$ facet first. What is the new value $F^{*\prime}$ of $F^*$?

(c) Comment on the use of such a bead as a lens. For example, does it have a well-defined focal length? What are its imaging properties?

(d) When $d = 0$, do you get the expected result for two lenses in series?

(e) When $d = 0$, show that your result for $F^*$ is in agreement with the lens maker's formula.

**Problem 2.2**

Consider a microscope with the geometry shown below.

(a) Use the ABCD matrix method to show that the effective focal length of the two-lens combination is $-F_1F_2/g$.

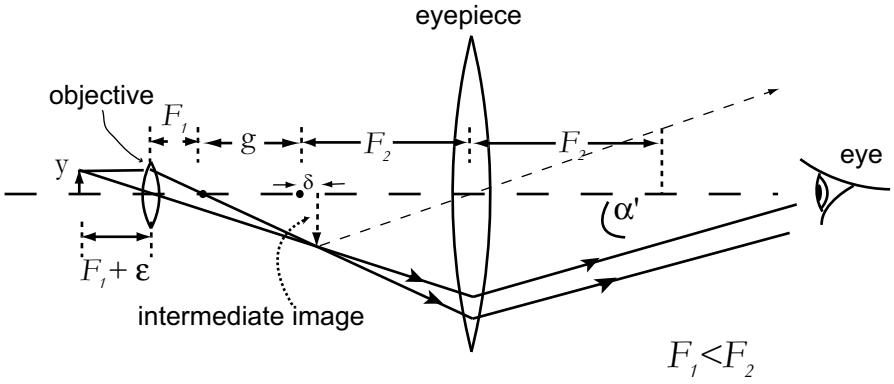



Figure 1: Ray diagram for a microscope

**Problem 2.3**

An object is located at $z = 0$ in the imaging system shown below.

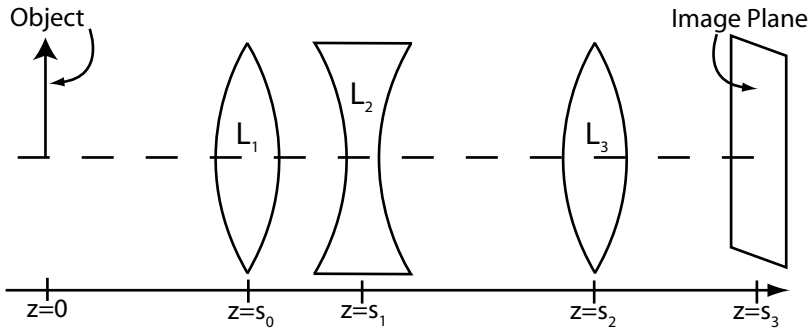



Figure 2: Diagram of a three-lens imaging system, with a biconcave thin lens between two biconvex thin lenses.

(a) Write an expression for the location of the image plane, $s_3$ (to help eliminate algebraic errors, we suggest using *Mathematica*, *Maple* or *Matlab* for this exercise).

(b) Write an expression for the image magnification.

Given that the focal length of each lens is given by $F_1 = 50$mm, $F_2 = -50$mm, $F_3 = 100$mm and the position of the lenses, respectively, along the $z$-axis are given to be $s_0 = 100$mm, $s_1 = 150$mm, $s_2 = 300$mm, answer the following questions.

(c) Given the values above, is the image real or virtual?

(d) What is the total magnification of the system? Given this magnification, is the image upside-down, or right-side up?