

1. Two thin lenses, one with focal length  $+f$  and the other with focal length  $-f$  are mounted a distance  $d$  apart.
  - 1.a) Find the principal planes and focal planes of the combination as function of  $d$ .
  - 1.b) If an object is placed distance  $f$  in front of the first lens surface, where does the image form? (Express your answer in terms of distance away from the second lens).
  
2. A double concave lens made of glass with refractive index  $n = 1.53$  has surfaces of power 5D (*i.e.*, 5 diopters) and 8D. The lens is used in air and has an axial thickness of 3cm.
  - 2.a) Determine the position of its focal and principal planes.
  - 2.b) An object is placed at 30cm to the left of the first lens vertex; where will the image be formed?
  - 2.c) Repeat the last question using the thin lens approximation (*i.e.*, ignoring lens thickness). What is the percent error in determining the image location with this approximation?
  
3. 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 the diagram below. 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?

