

## Lenses

In many materials, the indices of refraction are not the same in all directions. The simplest example of this are uniaxial materials, which have one axis along which the index of refraction is different. These materials can be used as waveplates to change the polarization of light.

1. A bug that is 1 cm tall is crawling towards a lens that has a focal length of 20 cm.
  - (a) How big does the bug appear when it is 15 cm away from the lens?
  - (b) How much bigger does the bug appear when it is 10 cm away from the lens than when it is 8 cm away from the lens?
  - (c) If the bug is crawling at a rate of 1 cm/second when it is 10 cm away from the lens, how quickly is its size changing?
2. A screen is 3 focal lengths from the object. Where will we need to put the lens to get a focused image?
3. Two-lens system:
  - (a) First lens is placed 2 focal lengths from the object. The screen is 8 focal lengths from object; where should we put a second identical lens to get an image? What will it look like?
  - (b) Now we move the screen so that it is 10 focal lengths away from the object. What position of the second lens (with the same focal length as the first) gives the maximum magnification of this image?
4. Lens is placed at 0.7 focal lengths from object so that no real image is formed. If we put another lens of the same focal length right next to the first one, will there be an image? If so, where?
5. Bessel's method uses the relationship

$$f = \frac{L^2 - D^2}{4L}$$

to determine the focal length of an unknown lens. ( $L$  is a fixed distance from object to screen;  $D$  is distance between two positions of a lens that give focused images.)

- (a) If you want to use Bessel's method to find the focal length of a lens whose focal length is approximately 5 cm, what is the minimum distance from object to screen that you need in order to make this measurement?
  - (b) If the distance between the object and the screen is 40 cm, and the focal length is approximately 5 cm, what do you expect the distance  $D$  to be?
6. A convex lens with a 10 cm focal length focuses an image of an object that is 16 cm away from the lens. When a concave lens of unknown radius is placed halfway between the object and the convex lens, the position of the screen at which the image is focused moves back by  $\frac{50}{3}$  cm. Find the focal length of the concave lens.