Birefringence:

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 quarter-wave plate retards one direction of polarization of light by a phase of $\pi/4$ relative to the other polarization. A material has an index of refraction of 1.6 along the slow axis and 1.4 along the fast axis. How thick should this material be cut for it to be a quarter wave plate for 400 nm light? What other larger thicknesses could the plate have and still work as a quarter waveplate? (Hint: at what thickness is there no change in polarization?)

2. [Hecht 8.39] Refer to p. 345 of the book.

Real and virtual images, and longitudinal magnification

A lens typically has an image side and an object side. A real image is formed on the image side, and is upside down. A virtual image is formed on the object side, and is right side up. If you were to put a screen at the position of a real image, the image would appear on the screen; however, if you put a screen at the position of a virtual image, you would not get an image on the screen. This is most evident with mirrors–you see a virtual image on the opposite side of the mirror, but if you put a screen behind the mirror, an image would not form on the screen.

In analyzing lens problems, we draw three rays:

- The ray from the object to the focal point on the same side of the lens. This ray emerges on the other side of the lens parallel to the optic axis.

- The ray from the object to the lens, parallel to the optic axis. This ray crosses the focal point on the opposite side of the lens.

- The ray through the object and through the center of the lens. This ray is unbent.

If these rays converge on the opposite side of the lens, then the point where they intersect is where the real image is formed. If the rays diverge, then they need to be extended to the same side of the lens, where a virtual image is formed.

1. An object (2 cm in height) is positioned 5 cm to the left of a positive thin lens with a focal length of 10 cm. Describe the resulting image (i.e. where it images and what the longitudinal and transverse magnifications are) using both the Gaussian and Newtonian equations. Draw appropriate ray diagrams. What is the minimum diameter the lens would have to have in order for you to be able to see the image?

2. A bug that is 1 cm tall is crawling towards a lens that has a focal length of 20 cm. How big does the bug appear when it is 15 cm away from the lens? 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? 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?

3. A lantern slide 8.0 cm high is located 3.50 m from a projection screen. Design a lens to meet the requirement of projecting an image 1.0 m high.