

# BIOL/PHYS 438 Assignment # 5:

## OPTICS

Thu. 1 Mar. 2007 — finish by Thu. 15 Mar.

### 1. CATARACT OPERATION:

(a) BA's right eye was producing blurred images because the lens was getting "cloudy" and scattering some light. A cataract operation was performed where the natural lens was replaced by an artificial lens....

The natural lens had  $n = 1.413$  and radii of curvature  $r_1 = 10$  mm and  $r_2 = 7.8$  mm when focused at infinity. What was its focal length?

(b) It was replaced by an artificial symmetric lens with  $r = r_1 = r_2$  made from crown glass ( $n = 1.52$ ), what radius  $r$  gives the same focal length as before?

(c) What should be the radius of curvature if the lens were made from silicate flint glass with  $n = 1.65$ ?

### 2. IMAGING BY THE HUMAN EYE:

Find the distance  $i_1$  of first image  $I_1$  made by the human cornea ( $r = 7.8$  mm) of an object placed at  $o_1 = 250$  mm. Assume that the index of refraction of the material behind the cornea is  $n = 1.336$ .

This image serves as the (virtual) object (object distance  $o_2 = -i_1$ ) from which the eye lens creates a real image  $I_2$  on the retina at the image distance  $i_2 = 20$  mm. The eye lens must contract to create a sharp image of such a close-distance object. Find the radius of curvature of the eye lens when focused at the object, assuming that the lens contracts symmetrically so that  $r_{250} = r_1 = r_2$ .

### 3. FLY EYES:

Flies have compound eyes with many individual photo detectors. Assume the facet eyes of a certain fly consist of tiny light pipes of  $d = 50$   $\mu\text{m}$  diameter, length  $L = 200$   $\mu\text{m}$  and  $n_e = 1.52$ , mounted on a hemispherical shell of radius  $r_1$  and capped by a conical structure of height  $B = 50$   $\mu\text{m}$  and  $n_e = n_c = 1.52$ . The top diameter of each cone is  $D = 100$   $\mu\text{m}$ . The light pipes and cones have cylindrical geometry. Typically  $r_2 = 2$  mm. The tissue between these optical structures has  $n_t = 1.33$ .

(a) How many facet eyes are there in each compound eye if the cones touch each other?

(b) What is the critical angle  $\theta_{\text{cr}}$  of total internal reflection in the light pipe?

(c) What is the acceptance angle  $\beta$  for the light pipe section by itself, figure (ii)?

(d) What is the cone angle  $\delta$ ?

(e) Explain qualitatively why the acceptance angle  $\gamma$  for light pipe and cone, figure (iii), is smaller than  $\beta$ .

(f) Name 5 other animals that have compound eyes.

### 4. NOW YOU SEE ME, NOW YOU DON'T:

(a) Find and sketch 3 examples of optical illusions. Explain how the eye has been deceived in each case.

(b) Describe one example of an optical trick used by an animal to hide from or scare off its predators.

(c) Describe an example of an animal that appears colorful due to either interference or diffraction, and explain in words what the "optical components" do to the light waves to generate the colors.