Optics, Spring 2016

Exercise 5, 23.2.2016

1. The lens equation (Hecht 4th ed., Ch. 5.2)

a) Derive the Newtonian form of the lens equation $x_0 x_i = f^2$ from the Gaussian lens equation.
b) Derive the Newtonian expression for the transverse magnifination: $M_T = -x_i/f = -f/x_0$.

2. Single lens (Hecht 4th ed., Ch. 5.2)

a) A 5-mm tall object is observed through a magnifying glass (biconvex lens). The focal length of the lens is 25 cm and the lens-object distance is 10 cm. Determine the image location, type (real or virtual) and size. Draw a ray diagram.
b) Suppose that an object positioned 10 cm to the left of a positive lens is imaged 30 cm to the right of the lens. Where will the image appear, if the object is moved to a distance of 2.5 cm from the lens? Calculate image size and type in both cases.
c) A 1 cm tall object is located 40 cm left from a biconvex lens (f = 20 cm). A biconcave lens (f = -50 cm) is placed on the right side of the first lens at a distance of 10 cm. Calculate the image location, size, orientation and type. Draw a ray diagram.

3. Angular magnification (Ch 5.7)

a) Explain why optical instruments (microscopes, telescopes etc) designed for visual use form the image at infinity.
b) Calculate the angular magnification for a refracting telescope having objective and eyepiece focal lengths of 1000 mm and 25 mm respectively. Calculate the exit pupil diameter, if the diameter of the objective lens is 15 cm.

4. Lens systems (Hecht 4th ed., Ch. 5.2)

a) Show that the magnification of a two-lens system is:

$$M_T = \frac{f_1 s_{i2}}{d(s_{o1} - f_1) - s_{01} f_1}.$$

b) A plane wave (object at infinity) is incident at a system of two biconvex lenses of focal lengths f_1 and f_2 separated by a distance of $f_1 + f_2$. How is the waveform altered by the system? Draw a ray diagram.

5. Apertures (Ch. 5.7)

a) A simple digital camera is composed of a thin lens, an aperture and a CCD sensor. A circular aperture of diameter 5 mm is placed in front of a biconvex lens (f = 20 mm) at a distance of 5 mm. Calculate the location and size of entrance and exit pupils. If an object is imaged to a 10 mm wide CCD sensor, describe the location and size of aperture and field stops.
b) A 50 mm camera lens with diameter of 5 cm is marked: "50 mm, f/1.9 - f/16". Calculate the range for the numerical aperture (NA).

6. Lens systems continued (Hecht 4th ed., Ch 5.2)

a) Two biconvex (positive) lenses L_1 and L_2 of focal lengths 10 cm and 20 cm are separated by a distance of 80 cm (See the figure). Calculate the size, location and orientation of the image corresponding to a 5-cm tall object located 15 cm from L_1. Draw a ray diagram.