Geometrical Optics EOP 501
First Exam (in-class)
8 October 2002

1. Define (3 points each)
   (a) Abbe number

   (b) Newton's rings

   (c) Total internal reflection

   (d) Meridional plane

2. True/False questions (1 point each)
   (a) ____ The principal planes of a thick lens always lie within the lens.
   (b) ____ The f-stop settings of a camera lens usually vary by factors of $\sqrt{2}$.
   (c) ____ Paraxial optics assumes that an angle and its tangent are equal.
   (d) ____ The curvatures of the two surfaces in a meniscus lens have the same sign.
   (e) ____ The front and rear focal planes are conjugates.
   (f) ____ The hiatus is the distance between principal planes.
   (g) ____ Geometrical optics is the limit as $\lambda \to 1$.
   (h) ____ If you focus at the hyperfocal plane, the near depth of field is half the hyperfocal distance.
   (i) ____ Entrance and exit pupils have a magnification of unity.

3. Write a precise statement of Fermat's principle (4 points)

4. Given a thin lens with 120-mm focal length and an object located 300 mm in front of the lens. Find the image distance and magnification. (4 points)

5. Define the *axial* and *chief* rays of an optical system. (4 points)

6. Find the focal length of a 250-mm radius of curvature convex mirror. Identify explicitly whether the power is positive or negative. (3 points)

7. Given a thin lens of focal length 150-mm, find the object-to-image distance that allows the lens to form images of magnification -5/2 or -2/5. (3 points)

8. Given the following thin lens description

#	*ap*	*rd*	*th*	*rn*
1	10	40	0	1.5
2	10	?		1.0

where *ap* is the aperture height, *rd* is the surface radius of curvature, *th* is the center thickness, and *rn* is the refractive index.

   (a) Find the radius of curvature for the second surface if the focal length is 100. (2 points)

   (b) Describe the shape of the lens (plano-convex, bi-convex, equi-convex, meniscus) and calculate its bending factor. (2 points)

   (c) Find the radius of curvature for the second surface if the lens thickness is 3 and the focal length is 100. (4 points)

9. Define a *paraxial solve* and give an example. (3 points)

Geometrical Optics EOP 501
First Exam (take-home)
8 October 2002

1. Given a detector array with elements placed on 10 μm centers (blur diameter of 10 μm is allowed) and a f/4 50-mm focal length lens in front of this array. Suppose that the system is focussed at a distance of 2 meters. What is the near and far depth of field? Find the hyperfocal distance (4 points)

2. Given the following lens description

#	*ap*	*rd*	*th*	*rn*
1	12.5	109.16	6	BK7
2	12.5	-79.38	3	SF5
3	12.5	-226.03		1.0

   where *ap* is the aperture height, *rd* is the radius of curvature, *th* is the center thickness, and *rn* is the refractive index.

   (a) Produce a scale drawing of the lens using OLSO. (2 points)

   (b) Find the refractive index of the two glasses at $\lambda_d = 0.58765$ μm and the Abbe number of SF5. (2 points)

   (c) Find the focal length, f/number and location of the back focal plane. (3 points)

   (d) Find the location of the principal planes and the hiatus. (3 points)

   (e) Plot the focal length (or focal shift) vs. wavelength from 0.45 to 0.65 μm. (3 points)

   (f) Find the system matrix of the lens. (3 points)

   (g) Find object and image locations for a magnification of -1/3. (2 points)

   (h) Find the total edge thickness of the lens. (3 points)

3. Given a ray starting from location (2, -5, 1) with a direction vector of (3, 1, 2), let the ray intersect a plane mirror defined by $(2x + 5y - z - 6 = 0)$. Find the point of intersection, the angle of incidence, and the direction vector after reflection. (5 points)

4. Given two mirrors, a primary concave mirror of radius of curvature -240 mm and a secondary convex mirror of radius of curvature -80 mm. Light strikes the primary mirror first, then the secondary, and finally proceeds to the image plane. A hole is inserted in the primary mirror to let light pass through. If the two mirrors are separated by 90 mm, find the distance from the secondary mirror to the focal plane and the focal length of the system. Show a drawing of the system if the primary has a diameter of 160 mm and the secondary has a diameter of 40 mm. Find the minimum diameter for the secondary mirror that will intercept the on-axis cone of light from the primary mirror with the least obstruction. (5 points)

5. Given the following hemispherical lens description

#	*ap*	*rd*	*th*	*rn*
1	7.5	7.5	7.5	1.5
2	7.5	∞		AIR

where *ap* is the aperture height, *rd* is the surface radius of curvature, *th* is the center thickness, and *rn* is the refractive index.

   (a) Find focal length, back focal distance and principal planes. (4 points)

   (b) Find the axial distance from the rear surface to the point of intersection on the axis for rays entering parallel to the optical axis at heights of 3.5 cm and 0.1 cm. (6 points)

6. In class, we used an optical bench with an illuminated object at 10 cm and a viewing screen at 53 cm. The first task was to position a thin lens in two positions such that the object was imaged on the screen. The experimenter then recorded the position of the lens and the magnification. The results (two trials) follow:

m_1	position	m_2	position
-0.6	37.3	-1.8	25.2
-0.6	37.1	-1.75	25.3

Use this data to calculate the focal length of the lens and estimate the precision of the measurement. Use two methods for this calculation (5 points)

(see http://www.engr.udayton.edu/ElOptics/courses/eop541L/lab1.html, methods 2 and 3)