Geometrical Optics EOP 501
First Exam (in-class)
4 October 1999

1. Define (3 points each)

   (a) Numerical aperture

   (b) Wavefront

   (c) Virtual image

   (d) Meridional plane

2. Given two thin lenses, with focal lengths of 40 mm and -120 mm, find the effective focal length if both lenses are used together (in contact). (4 points)

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

4. Given a thin lens with 80-mm focal length and an object located 480 mm in front of the lens. Find the image distance and magnification. (4 points)

5. Why is the focal length of a simple glass lens longer for red light than blue light? (4 points)

6. Find the focal length of a 600-mm radius of curvature concave mirror. (3 points)

7. Given an object and image separated by 320 mm, find the focal length of the thin lens needed to produce a magnification of -1/3. (3 points)

8. Which (if any) of the following are conjugate planes? (1 point each)

   (a) Front principal plane and back principal plane.

   (b) Front focal plane and back focal plane.

   (c) Entrance pupil and exit pupil.

   (d) Aperture stop and field stop.

9. Given the following thin lens description

#	*ap*	*rd*	*th*	*rn*
1	6	40	0	1.6
2	6	90		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 focal length and f/number. (4 points)

   (b) Describe the shape of the lens (plano-convex, bi-convex, equi-convex, meniscus) and calculate its bending factor. (4 points)

10. True/False questions (1 point each)

    (a) ____ The f-stop settings of a camera lens usually vary by factors of $\sqrt{3}$.

    (b) ____ The human eye has a resolution of approximately 2 arc minutes.

    (c) ____ Geometrical optics is the limit as $\lambda \to \infty$.

    (d) ____ The hiatus is the distance between principal planes.

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First Exam (take-home)
4 October 1999

1. A ray inside a glass prism (index 1.52) is incident on a glass/water interface at an angle of 40° from the normal. Find the angle of refraction. Find the critical angle for total internal reflection. Assume an index of 1.33 for water. (4 points)

2. Given a column of fluid whose index varies as

$$n(z) = 1.52 - .02e^{-z/80})$$

where z is the axial distance along the column, what is the optical path of a ray propagating 50 mm along the axis? (4 points)

3. Given the following lens description

#	*ap*	*rd*	*th*	*rn*
1	7.15	60.415	1.4	BK7
2	7.15	-52.830	0.012	1.0
3	7.15	-51.552	0.6	SF1
4	7.15	-128.126		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) Find the system matrix. Assume BK7 has an index of 1.5168 and SF1 has an index of 1.71736 (4 points)

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

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

   (d) Find the locations of the principal planes. Use OSLO to generate a scale drawing of the lens. Mark the positions of the principal planes on this drawing. (3 points)

4. Given two concave mirrors, a primary mirror of radius of curvature 1200 mm and a secondary mirror of radius of curvature 650 mm. If the two mirrors are separated by 180 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 400 mm and the secondary has a diameter of 280 mm. (5 points)

5. Given the following thin lens description

#	*ap*	*rd*	*th*	*glass*
1	6	20	0	SF5
2	6	-60		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 the center thickness required to give an edge thickness of exactly 1 mm. (4 points)

   (b) Find the focal length of the resulting lens at 0.58756 μm (show your work) (3 points)

   (c) Use OSLO to find the focal length of the lens at 0.58756 μm if the axial thickness is 2.5 mm. Submit a drawing of the lens. (3 points)

   (d) Find the focal lengths at 0.48613 μm and 0.65627 μm. Show the difference between these focal lengths. (3 points)

6. Suppose that the lens above (center thickness 2.5 mm), were placed in water (index 1.33) with the image side of the lens in air.

   (a) Find the back focal distance and front focal distance of the resulting lens (0.58756 μm wavelength). (3 points)

   (b) Locate the object/image planes for a magnification of -1/4. (3 points)

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