Geometrical Optics EOP 501
Second Exam (in-class)
7 November 2001

1. Define (3 points each)

   (a) Interferogram

   (b) Strehl ratio

   (c) Wavefront error

   (d) Telecentric system

2. How are tranverse ray errors are related to the wavefront error? (3 points)

3. True/False questions (1 point each)

   (a) ____ The longitudinal magnification for axially separated planes is the product of the transverse magnification of the planes.

   (b) ____ A telephoto lens has an effective focal length larger than its back focal distance.

   (c) ____ An afocal system is one with its object at infinity.

   (d) ____ Fringes of tilt and focal shift can generally be introduced or compensated for by an adjustment in the reference arm of the interferometer.

   (e) ____ The Lagrange invariant is defined as $L = nu_c y_c - nu_a y_a$.

   (f) ____ Vignetting can be eliminated by making each lens aperture height greater than $|y_c| + |y_a|$.

4. Define the Jacobian of the wavefront and explain its relationship to the ray density. (5 points)

5. Given the following lens and paraxial raytrace (object at infinity)

#	*rd*	*th*	*rn*	*ap*	y_a	y_c	u_a	u_c
0		1e20	1		0.0000			0.57735
1	26.4	4.16	1.61025	10	8.00748	-8.50148	-0.11495	0.480587
2	585	4.3	1	10	7.53044	-6.50704	-0.17724	0.767079
3	-81	1.13	?	8	6.76830	-3.20860	-0.08135	0.470486
4	27	3.9	1	8	6.67637	-2.67695	0.01512	0.686399
5		5.45	1			0	0.01512	0.686399
6	225	2.95	1.61025	9	6.81772	3.74087	-0.00209	0.419967
7	-54.7	?	1	9	6.81154	4.98978	-0.07937	0.620697
8					0.0000	?		

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

Find the following (18 points)

effective focal length	
f/number	
half-field of view (radians)	
image distance	
image height	
index of refraction after surface 3	
location and size of exit pupil	
# vignetting surfaces	
maximum unvignetted field	

Express the maximum unvignetted field as a fraction of the original field.

6. Identify the correct answers (2 points each)

   (a) ____ The central peak of an Airy pattern has approximately
   (a) 90 (b) 85 (c) 80 (d) 75 percent of the total energy.

   (b) ____ The collection of constants $\epsilon_o = \lambda/nu_a$ is approxmately
   (a) the size of an Airy disk, (b) the OPD for a Strehl ratio of 0.8, (c) both, (d) neither.

   (c) ____ A Strehl ratio of 0.8 corresponds to an rms wavefront variation of
   (a) 0.08 wave, (b) 0.12 wave (c) 0.8 wave.

7. Given a spherical wavefront of 5 waves with respect to a reference plane, wavelength of 0.55 μm and pupil radius of 25 mm, find the distance to the focal plane. (5 points)

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Second Exam (take-home)
7 November 2001

1. Given the following lens description for a 100-mm focal length lens (f/2.8) with a half field of view of 25 degrees (infinite object).

#	*rd*	*th*	*rn*	*ap*
OB		1e20	AIR	
1	42.97	9.8	LAK9	19.2
2	-115.33	2.1	LLF7	19.2
3	-306.84	4.16	AIR	19.2
AST		4.00	AIR	
5	-59.06	1.87	SF7	17.3
6	40.93	10.64	AIR	17.3
7	183.92	7.05	LAK9	16.5
8	-48.91	?	AIR	16.5
IM				

where *rd* is the radius of curvature, *th* is the axial thickness, *rn* is the glass name, and *ap* is the aperture height.

   (a) Use OSLO to provide a scale drawing of the lens and a paraxial ray trace table for the axial and chief rays. Draw the location of the principal planes, the entrance pupil, and the exit pupil on the drawing. Show the size of entrance and exit pupil. (5 points)

   (b) Find the following (5 points)

stop diameter	
hiatus	
back focal distance	
Lagrange invariant	
image height	

   (c) Draw the full-field vignetting diagram and find the percentage vignetted. (5 points)

2. Find the diameter of the Airy disk for a lens of focal length 80 mm and diameter 25 mm assuming a wavelength of 0.55 μm. If the wavefront at the supposed focal plane had two waves of defocus, find the longitudinal shift required to find the actual focal plane. (5 points)

3. Complete the following paraxial table (Lagrange invariant is 2) (5 points)

#	power	*th*	*ap*	axial y	chief y
0				0	-400
1			6	6	-3
2			4	3	-1
3			6	5	2
4				0	7

(a) Find the position and diameter of the stop of the system and the position (from first lens) and diameter of the entrance pupil. (5 points)

(b) Draw a full-field vignetting diagram and find the percentage of light vignetted. (5 points)

4. The input and output paraxial rays for a lens in air are given by

#	y_a	u_a	y_c	u_c
in	5.4801	0.014052	-0.9	0.087436
out	5.145022	-0.102998	0.696336	0.081648

Find the following (if possible) (2 points each)

(a) Focal length of the lens

(b) transverse magnification

(c) Diameter and location of exit pupil

(d) Hiatus

(e) Lagrange invariant