

Geometrical Optics EOP 501
Second Exam (in-class)
3 November 1999

1. Define (3 points each)

(a) hyperfocal distance

(b) Strehl ratio

(c) Airy radius

(d) Spot diagram

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 average of the transverse magnification of the planes.

(b) ____ Increasing the diameter of the exit pupil by a factor of two reduces the diffraction-limited spot size by a factor of four.

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

(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) ____ Geometric ray density at the image is inversely proportional to the Jacobian of the wavefront error at the pupil.

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

4. The axial ray determines the location of _____ and the size of _____. The chief ray determines the location of _____ and the size of _____. (4 points)

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

#	rd	th	rn	ap	y_a	u_a	y_c	u_c
0		2e10	1.000		0.0000	4e-10	-3.49e9	0.1745
1	26.4	4.15	1.610	10	8.0000	-0.1148	-2.5699	0.1453
2	585	4.3	1.000	10	7.5235	-0.1770	-1.9670	0.2319
3	-81	1.13	1.581	7.8	6.7624	-0.0813	-0.9700	0.1423
4	27	3.9	1.000	7.8	6.6706	0.0150	0.0000	0.2075
6	225	2.95	1.610	10.9	6.8112	-0.0021	1.1308	0.1270
7	-54.7	?	1.000	10.9	6.8050	-0.0793	1.5054	0.1876
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 (12 points)

effective focal length	
f/number	
half-field of view (radians)	
image distance	
image height	
# vignetting surfaces	

6. Identify the correct answers (2 points each)

- (a) ____ Interferogram fringes represent contours of constant
(a) intensity, (b) phase, (c) color (d) amplitude.
- (b) ____ The central peak of an Airy pattern has approximately
(a) 90 (b) 85 (c) 80 (d) 75 percent of the total energy.
- (c) ____ The collection of constants $\epsilon_o = \lambda/nu_a$ is approximately
(a) the size of an Airy disk, (b) the OPD for a Strehl ratio of 0.8, (c) both, (d) neither.
- (d) ____ 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.
- (e) ____ If the central diffraction peak decreases by one-half, the size of the spot
(a) decreases by two, (b) increases by two (c) remains the same (d) depends on the type of aberration.

7. Given the following ray data, find the maximum unvignetted field (h). (3 points)

ap	y_a	y_c
12	10	6
10	8	4
10	9	-3
12	10	-5

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Second Exam (take-home)
3 November 1999

1. Given the following lens description for a 99.9-mm focal length lens (f/4.5) with a half field of view of 30.11 degrees (infinite object).

#	<i>rd</i>	<i>th</i>	<i>rn</i>	<i>ap</i>
OBJ		1e20	AIR	
1	41.0	1.6	LF8	13
2	25.76	3.6	SK3	12
3	-583.8	8.1	AIR	12
4	-44.76	1.6	LF8	9.5
5	44.76	3.0	AIR	9.5
AST		5.1	AIR	?
7	583.8	3.6	SK3	12
8	-25.76	1.6	LF8	12
9	-41.00	?	AIR	13
IMG				

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. Given a detector array with elements placed on 5 μm centers (blur diameter of 5 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? (5 points)

3. Find the diameter of the Airy disk for a lens of focal length 200 mm and diameter 50 mm assuming a wavelength of $0.55 \mu\text{m}$. If the lens were stopped down to f/16, what would be the Airy diameter? (5 points)
4. Complete the following paraxial table (Lagrange invariant is 0.75) (5 points)

#	power	th	ap	axial y	chief y
0				0	-400
1			8.5	8	-3
2			6.5	6	-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)
5. The input and output paraxial rays for a lens are given by

#	y_a	u_a	y_c	u_c
in	8.00	0.0266667	-5.835109	0.248499
out	7.197909	-0.123164	-4.240754	0.370372

Find the following (2 points each)

- (a) Focal length of the lens
- (b) transverse magnification
- (c) Diameter and location of exit pupil
- (d) axial ray angle of incidence
- (e) Lagrange invariant