

Geometrical Optics EOP 501
Second Exam (in-class)
1 November 2000

1. Define (3 points each)

(a) Interferogram

(b) Strehl ratio

(c) Airy radius

(d) Paraxial solve

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) ____ Wavefront error is the difference in optical path between a reference sphere and the actual wavefront, measured in waves and defined as a function of unit-radius pupil coordinates.

(c) ____ Small amounts of aberration decrease the Strehl ratio and increase the diameter of the central maximum.

(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 $L = nu_c y_a - nu_a y_c$.

(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	y_c	u_a	u_c
0		1e20	1		0.0000			0.3697
1	21.5	2	1.622861	7	5.55556	-2.99023	-0.09917	0.27766
2	-124.1	5.26	1	7	5.35721	-2.43491	-0.18783	0.46282
3	-19.1	1.25	1.620577	5	4.36920	-0.00049	-0.02831	0.28558
4	22	4.69	1	5	4.33382	0.35649	0.07637	0.47286
6	328.9	2.25	1.622861	6.8	4.69201	2.57520	0.04159	0.28837
7	-16.7	?	1	6.8	4.78558	3.22303	-0.11100	0.34777
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 (16 points)

effective focal length	
f/number	
half-field of view (radians)	
image distance	
image height	
location of stop	
# 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 approximately
(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. Plot the Strehl definition as a function of rms wavefront deviation for both quadratic and gaussian Strehl approximations. Find the rms wavefront deviation required for a Strehl definition of 0.25 (for both approximations). (5 points)

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Second Exam (take-home)
1 November 2000

1. Given the following lens description for a 98.52-mm focal length lens ($f/5.6$) with a half field of view of 15 degrees (infinite object).

#	rd	th	rn	ap
OB		1e20	AIR	
1	17.0	4.5	BK7	9.3
2	-62.57	0.006	AIR	9.3
3	-61.86	1.3	SF2	9.3
4	60.45	11.45	AIR	9.3
AS		9.54	AIR	?
6	-10.61	1.4	KF9	6.0
7	-24.76	0.011	AIR	7.0
8	-24.25	2.40	SF1	7.0
9	-18.57	?	AIR	7.0
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. Given a detector array with elements placed on $5\text{ }\mu\text{m}$ centers (blur diameter of $5\text{ }\mu\text{m}$ is allowed) and a $f/4$ 80-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 100 mm and diameter 25 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 1.8) (5 points)

#	power	th	ap	axial y	chief y
0				0	-400
1			6	5.95	-2.5
2			4	3.20	-0.5
3			6	5.00	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	26.323681	0.087746	-9.514575	0.217613
out	24.496574	-0.210279	4.853947	0.226258

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 (if surface radius is 56.94).
- (e) Lagrange invariant