

Geometrical Optics EOP 501
Second Exam (in-class)
6 November 2002

1. Define (3 points each)

- (a) Interferogram
- (b) Strehl ratio
- (c) Wavefront error
- (d) Telecentric system

2. True/False questions (1 point each)

- (a) **T F** The longitudinal magnification for axially separated planes is the product of the transverse magnification of the planes.
- (b) **T F** A telephoto lens has an effective focal length larger than its back focal distance.
- (c) **T F** An afocal system is one with its object at infinity.
- (d) **T F** Fringes of tilt and focal shift can generally be introduced or compensated for by an adjustment in the reference arm of the interferometer.
- (e) **T F** The Lagrange invariant is defined as $L = nu_c y_c - nu_a y_a$.
- (f) **T F** Vignetting can be eliminated by making each lens aperture height greater than $|y_c| + |y_a|$.
- (g) **T F** The fringes due to focal shift change from circular to elliptical when tilt is added.
- (h) **T F** Spherical aberration is a systematic variation in focus as a function of pupil radius.
- (i) **T F** Some portrait lenses deliberately introduce spherical aberration.
- (j) **T F** Fourth-order astigmatism has a uniformly illuminated elliptical blur spot predicted by geometrical optics.
- (k) **T F** Diffraction effects are most important when the geometrical spot size is approximately the Airy diameter.

3. 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	1.581441	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 (16 points)

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

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

4. Identify the correct answers (1 point 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.

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

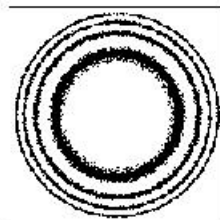
6. Identify the aberration or reference pattern from the following choices: spherical aberration, coma, astigmatism, focus, tilt, cylinder. (6 points)



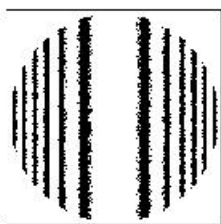
A _____



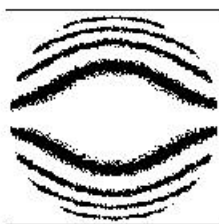
B _____



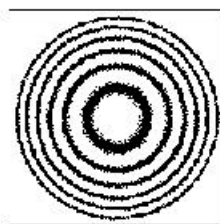
C _____



D _____



E _____



F _____

Geometrical Optics EOP 501
Second Exam (take-home)
6 November 2002

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 $0.55 \mu\text{m}$. 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. Find the transverse ray errors and Jacobian as a function of pupil position for $W(x, y) = (x^2 + y^2)^2 y$. (3 points)

4. Find the rms spot size and rms wavefront deviation for a wavefront with 1 wave of focal shift. (3 points)
5. Given a Keplerian telescope with an objective lens of focal length 400 mm and diameter 50 mm, an eyepiece of focal length 25 mm, diameter 12 mm. Find the following (6 points)
 - (a) Eye relief and exit pupil diameter.
 - (b) Angular magnification.
 - (c) Unvignetted object field of view.
6. 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
7. Find the transverse shift (mm) corresponding to a tilt wavefront of 4 waves ($0.5 \mu\text{m}$) for a $f/4$ lens of focal length 80 mm (object at infinity). Assume the reference point is the paraxial focus. (4 points)
8. Identify the magnitudes of astigmatism and focal shift in the following interferogram. (4 points)

