Geometrical Optics EOP 501
Second Exam (in-class)
10 November 2003

1. Define (3 points each)
   (a) Interferogram

   (b) caustic

   (c) Wavefront error

   (d) Paraxial solve

2. True/False questions (1 point each)
   (a) **T F** A Keplerian telescope is constructed of two positive lenses separated by the difference of the focal lengths.
   (b) **T F** An afocal system is one with its object at infinity.
   (c) **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.
   (d) **T F** The Lagrange invariant is defined as $L = u_c y_a - u_a y_c$.
   (e) **T F** Vignetting can be eliminated by making each lens aperture height greater than $|y_c| + |y_a|$.
   (f) **T F** The fringes due to focal shift change from circular to elliptical when tilt is added.
   (g) **T F** Spherical aberration is a systematic variation in focus as a function of pupil radius.
   (h) **T F** field curvature and astigmatism are mapping aberrations.
   (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** Spherochromatism (change in spherical aberration with wavelength) is a fourth-order aberration.

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

#	*rd*	*th*	*rn*	*ap*	y_a	y_c	u_a	u_c
0		inf	1		0		0	0.5095254
1	14.47	2.2	1.61272	6.4	4.8	-4.05145	-0.12603	0.4223179
2	129.1	2.8	1	6.4	4.52273	-3.12235	-0.118179	0.6662616
3	-56.9	0.96	1.59551	4.8	4.01373	-1.25681	-0.08761	0.4093411
4	14.26	1.4	1	4.8	3.92963	-0.86385	0.02433	0.6170329
5		4.06	1			0	0.02433	0.6170329
6	62.72	2.1	1.61272	6.4	4.06244	2.50515	-0.00953	0.3674288
7	-38.35	?	1	6.4	4.04244	3.27675	-0.07995	0.5402069
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) 95 (b) 85 (c) 75 (d) 65 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) 0.008 wave, (b) 0.08 wave (c) 0.8 wave.

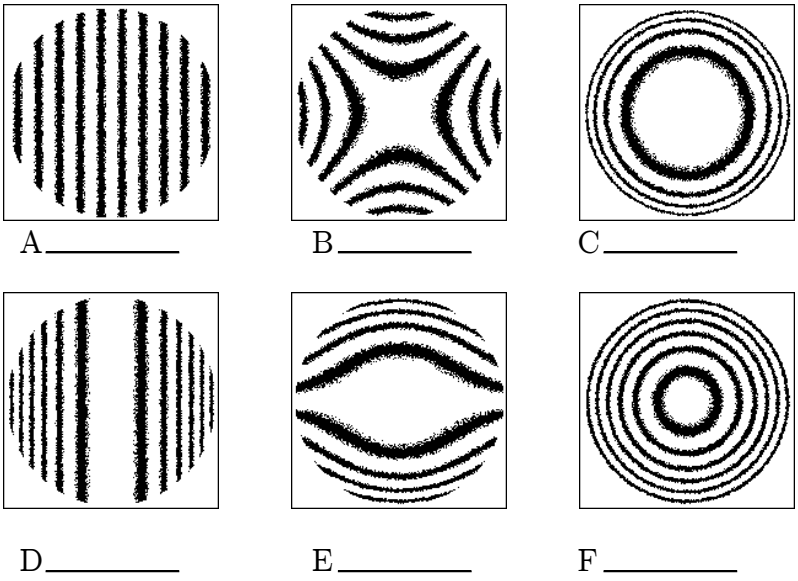
5. How are tranverse ray errors are related to the wavefront error? (2 points)

6. A wavefront with 1/2 wave focal shift has a spot diameter of _____ ϵ_0. (2 points)

7. If a wavefront has 1 wave of spherical aberration, what is the focal shift between paraxial and marginal focus (in waves)? (2 points)

8. Axial (longitudinal) chromatic aberration is the variation of _____ with wavelength. Transverse (lateral) chromatic aberration is the variation of _____ with wavelength (4 points)

9. 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_____

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Second Exam (take-home)
10 November 2003

1. Given the following lens description for a 95.84-mm focal length lens (f/1.6) with a half field of view of 9 degrees (infinite object). Assume an entrance pupil radius of 29.75 mm.

#	*rd*	*th*	*rn*	*ap*
OB		infinite	AIR	
1	53.0	19.5	BK7	30
2	-460	2.565	AIR	30
3	-139.7	5	F2	30
4	240.0	0	AIR	30
AST		37.05	?	
5	59.5	17.0	BK7	21.5
6	-42.2	0.94	AIR	21.5
7	-38.0	5.0	F2	21.5
8	-161	?	AIR	21.5
IM				

where *rd* is the radius of curvature, *th* is the axial thickness, *rn* is the glass name, and *ap* is the semi-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 60 mm and diameter 20 mm assuming a wavelength of 0.55 μm. If the wavefront at the supposed focal plane had four 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 $W(x, y) = (x^2 + y^2)y^2$. (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 300 mm and diameter 40 mm, an eyepiece of focal length 15 mm, diameter 5 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	4.8	0.053333	-3.9757	0.5
out	4.74257	-0.03047	3.21550	0.5301078

   Find the following (2 points each)

   (a) Focal length of the lens

   (b) transverse magnification

   (c) Diameter and location of exit pupil

   (d) Lagrange invariant

7. Find the transverse shift (mm) corresponding to a tilt wavefront of 5 waves (0.5 μm) for a f/4 lens of focal length 75 mm (object at infinity). Assume the reference point is the paraxial focus. (4 points)