

Name_____

Closed book; closed notes. Equation sheets are attached and can be removed.

Spare raytrace forms are also attached.

Use the back sides if required. The time limit is 2 hours.

Calculators are permitted, but do not use any pre-stored information or programs.

If a method of solution is specified in the problem, it must be used.

Note any assumptions you make in solving the problems.

Show your work. Present it in a neat and logical fashion.

Distance Students: Please return the original exam only; do not FAX an additional copy.

1) (5 points) The letter “A” is imaged by an aberration free thin lens (stop at the lens). A real image is produced. The top half of the lens is now blocked by an opaque card. What happens to the image?

2) (10 points) A stop of diameter 20 mm is located 75 mm to the right of a 200 mm focal length thin lens. Use Gaussian methods to determine the location and size of the system entrance pupil.

EP Location: _____ to the _____ of the lens

EP Diameter = _____

3) (25 points) A system is comprised of three thin lenses. The following partially-completed raytrace of the system is the starting point for this problem, and will be completed during various parts of the problem. Extra lines/rays are provided.

Be sure to properly label your raytraces.

	Object	EP	Lens 1	Lens 2	Lens 3	XP	Image
Surface	0	1	2	3	4	5	6
f			100 mm	-100 mm	100 mm		
$-\phi$							
t			40 mm	60 mm			

Potential Chief Ray:

\tilde{y}			4.0 mm	0.0 mm	-6.0 mm		
\tilde{u}			-0.1	-0.1			

y							
u							

y							
u							

y							
u							

y							
u							

y							
u							

a) Which element serves as the System Stop (circle one)?

Lens 1

Lens 2

Lens 3

b) Determine the Entrance and Exit Pupil locations.

EP: Located _____ to the _____ of the first lens.

XP: Located _____ to the _____ of the third lens.

c) Determine the system Focal Length and its Back Focal Distance (BFD).

$f =$ _____

BFD = _____

d) The System Stop has a diameter of 20 mm. Determine the diameters of the Entrance Pupil and the Exit Pupil.

Entrance Pupil Diameter = _____

Exit Pupil Diameter = _____

Continues...

e) For distant objects, the system has an unvignetted Field of View of +/- 10 deg. What is the image height in the image plane for this FOV? What are the required Lens Diameters to support this FOV?

Image Height = _____

Lens 1 Diameter = _____

Lens 2 Diameter = _____

Lens 3 Diameter = _____

4) (30 points) A 5X Keplerian telescope is comprised of two thin lenses separated by 120 mm. The objective lens is 50 mm in diameter, and the eye lens is 12 mm in diameter. This telescope is to be used with a human eye with a 4 mm diameter pupil. The eye is placed at the exit pupil of the telescope. For distant objects, what is the unvignetted object field of view (in degrees) of this system?

A blank raytrace sheet is on the next page.

Surface	0	1	2	3	4	5	6
f							
$-\phi$							
t							
y							
u							
y							
u							
y							
u							
y							
u							

Continues...

Unvignetted FOV = +/- _____ degrees

5) (30 points) A ball lens is used as a 100X objective in a microscope with an optical tube length of 200 mm. The optical tube length is the distance from the rear focal point of the objective to the intermediate image presented to the eyepiece of the microscope. The ball lens is a sphere of radius R with an index $n = 1.500$.

Determine the required radius of curvature for the ball R and the object-side working distance provided by this objective.

Blank page follows...

Blank page follows...

Radius of Curvature R = _____

Working Distance = _____

Spare raytrace forms:

Surface	0	1	2	3	4	5	6
C							
t							
n							
$-\phi$							
t/n							
y							
nu							
u							
y							
nu							
u							

Surface	0	1	2	3	4	5	6
f							
$-\phi$							
t							
y							
u							
y							
u							
y							
u							
y							
u							

OPTI-502 Equation Sheet

$$\text{OPL} = nl$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$\gamma = 2\alpha$$

$$d = t \left(\frac{n-1}{n} \right) = t - \tau$$

$$\phi = (n' - n)C$$

$$\frac{n'}{z'} = \frac{n}{z} + \phi$$

$$f_E = \frac{1}{\phi} = -\frac{f_F}{n} = \frac{f'_R}{n'}$$

$$m = \frac{z'/n'}{z/n} = \frac{\omega}{\omega'}$$

$$m = \frac{f_{F2}}{f'_{R1}} = -\frac{f_2}{f_1}$$

$$\bar{m} = \frac{n'}{n} m^2$$

$$\frac{\Delta z'/n'}{\Delta z/n} = m_1 m_2$$

$$m_N = \frac{n}{n'}$$

$$P'N' = PN = f_F + f'_R$$

$$\tau = \frac{t}{n} \quad \omega = nu$$

$$\phi = \phi_1 + \phi_2 - \phi_1 \phi_2 \tau$$

$$\delta' = \frac{d'}{n'} = -\frac{\phi_1}{\phi} \tau \quad \text{BFD} = d' + f'_R$$

$$\delta = \frac{d}{n} = \frac{\phi_2}{\phi} \tau \quad \text{FFD} = d + f_F$$

$$\omega' = \omega - y\phi$$

$$y' = y + \omega' \tau'$$

$$f/\# \equiv \frac{f_E}{D_{EP}} \quad \text{NA} \equiv n |\sin U| \approx n |u|$$

$$f/\#_w \equiv \frac{1}{2\text{NA}} \approx \frac{1}{2n|u|} \approx (1-m)f/\#$$

$$I = H = n\bar{u}y - nu\bar{y}$$

$$\bar{u} = \tan(\theta_{1/2})$$

$$\text{MP} = \frac{10\text{in}}{f} = \frac{250\text{mm}}{f}$$

$$\text{MP} = \frac{1}{m}$$

$$m_V = m_{\text{OBJ}} \text{MP}_{\text{EYE}}$$

$$L = \frac{M}{\pi} = \frac{\rho E}{\pi}$$

$$\Phi = LA\Omega \quad \Omega \approx \frac{A}{d^2}$$

$$E = \frac{\pi L_o}{4(f/\#_w)^2}$$

$$\text{Exposure} = E \Delta T$$

$$a \geq |y| + |\bar{y}| \quad \text{Un}$$

$$a = |\bar{y}| \quad \text{and} \quad a \geq |y| \quad \text{Half}$$

$$a \leq |\bar{y}| - |y| \quad \text{and} \quad a \geq |y| \quad \text{Full}$$

$$\text{DOF} = \pm B' f / \#_w$$

$$L_H = -\frac{fD}{B'} \quad L_{\text{NEAR}} = \frac{L_H}{2}$$

$$D = 2.44\lambda f / \#$$

$$D \approx f / \# \quad \text{in } \mu\text{m}$$

$$\text{Sag} \approx \frac{y^2}{2R}$$

$$v = \frac{n_d - 1}{n_F - n_C}$$

$$P = \frac{n_d - n_C}{n_F - n_C}$$

$$\delta = -(n-1)\alpha$$

$$\frac{\delta}{\Delta} = v \quad \frac{\varepsilon}{\Delta} = P$$

$$\frac{\alpha_1}{\delta} = -\left(\frac{1}{v_1 - v_2}\right)\left(\frac{v_1}{n_{d1} - 1}\right)$$

$$\frac{\alpha_2}{\delta} = \left(\frac{1}{v_1 - v_2}\right)\left(\frac{v_2}{n_{d2} - 1}\right)$$

$$\frac{\varepsilon}{\delta} = \left(\frac{P_1 - P_2}{v_1 - v_2}\right)$$

$$n = \frac{\sin[(\alpha - \delta_{\text{MIN}})/2]}{\sin(\alpha/2)}$$

$$\theta_C = \sin^{-1}\left(\frac{n_S}{n_R}\right)$$

$$\frac{\delta\phi}{\phi} = \frac{\delta f}{f} = \frac{1}{v}$$

$$\text{TA}_{\text{CH}} = \frac{r_P}{v}$$

$$\frac{\phi_1}{\phi} = \frac{v_1}{v_1 - v_2} \quad \frac{\phi_2}{\phi} = -\frac{v_2}{v_1 - v_2}$$

$$\frac{\delta\phi_{\text{dC}}}{\phi} = \frac{\delta f_{\text{Cd}}}{f} = \frac{\Delta P}{\Delta v}$$