Name________________________

Closed book; closed notes. Time limit: 120 minutes.
An equation sheet is attached and can be removed. A spare raytrace sheet is also attached.
Use the back sides if required.
Assume thin lenses in air if not specified.
As usual, only the magnitude of a magnification or magnifying power may be given.
If a method of solution is specified in the problem, that method must be used.
Raytraces must be done on the raytrace form. Be sure to indicate the initial conditions for your rays.
You must show your work and/or method of solution in order to receive credit or partial credit for your answer.
Provide your answers in a neat and orderly fashion.
Only a basic scientific calculator may be used. This calculator must not have programming or graphing capabilities. An acceptable example is the TI-30 calculator. Each student is responsible for obtaining their own calculator.
Note: On some quantities, only the magnitude of the quantity is provided. The proper sign convention must be applied.

Distance Students: Please return the original exam only; do not scan/FAX/email an additional copy. Your proctor should keep a copy of the completed exam.

1) (5 points) A 100 mm focal length thin lens (in air) in made out of glass N-LaSF46A. The glass code for this glass is 904313. What is the longitudinal chromatic aberration of this lens?

Longitudinal Chromatic Aberration = δf = _________mm

2) (15 points) A 6x Keplerian telescope is constructed out of two thin lenses.

The focal length of the objective lens is 360 mm, and this lens serves as the syetem stop.

a) Determine the focal length of the eye lens, the telescope length and the eye relief (the distance between the eye lens and the exit pupil)

f_{EYE} = ________mm t = __________mm ER = _________mm

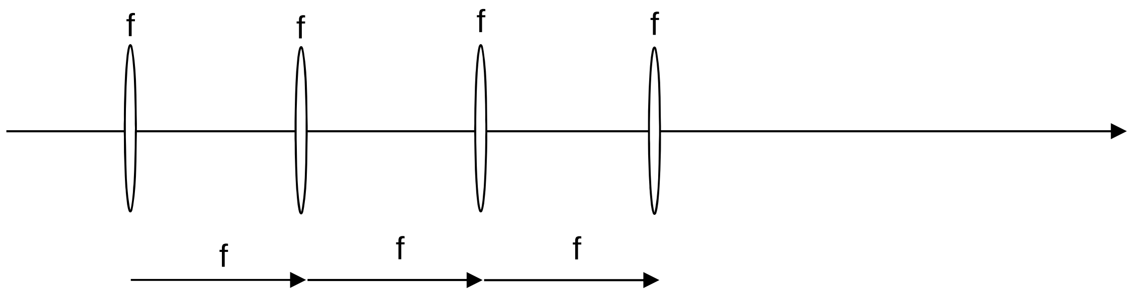
b) The objective lens has a diameter of 50 mm. What is the required eye lens diameter for the telescope to have an unvignetted field of view of +/- 2 degrees in object space?

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

D_2 = __________ mm

3) (10 points) Consider the following optical system comprised of four identical thin lenses of focal length f that are each separated by this same distance f.

Determine the rear focal length f'_R of this system by sketching rays. No calculations of any type are required or permitted.



f'_R = ___________

4) (20 points) A doubly-telecentric system is constructed out of two thin lenses in air. The magnification of the system is $|m| = 0.33333$

An object is located 100 mm to the left of the first element of the system, and its conjugate image is located 25 mm to the right of the second element of the system.

Determine the system layout by providing the focal lengths of the two lenses, the required spacing and the stop position.

Continues…

f_1 = __________ mm f_2 = __________ mm t = __________ mm

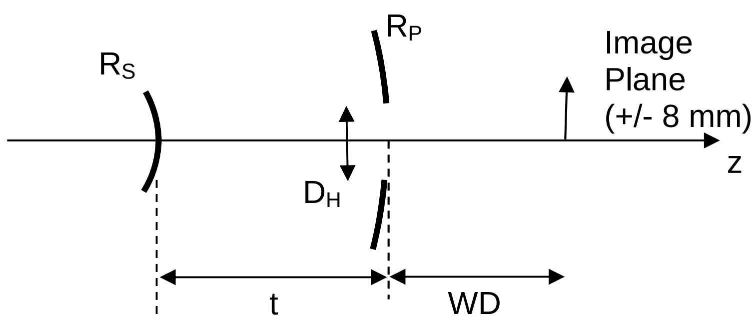
Stop Location: ________________________________

5) (25 points) A Cassegrain Objective consists of a concave primary mirror and a convex secondary mirror. The system stop is located at the primary mirror. The working distance is defined from the vertex of the primary mirror to the image plane. For the purposes of this problem, assume that the mirrors have zero thickness.

The object is at infinity. The maximum image size is +/- 8 mm. The system operates at an f-number of f/4.

The system specification is (only the magnitudes of the quantities are provided):

R_P = 500 mm R_s = 125 mm t = 200 mm



Determine the following:
- System focal length and the working distance.
- Diameter of the Primary Mirror D_P
- The location and diameter of the Exit Pupil
- The required diameter of the Secondary Mirror D_S and required diameter of the Hole in the Primary Mirror D_H the system to be unvignetted over the specified Image Size.
- The angular Field of View of the system in Object Space

NOTE: This problem is to be worked using raytrace methods only. All answers must be determined directly from the rays you trace; for example, the FOV must be determined from the chief ray. Raytraces must be done on the raytrace form. Be sure to clearly label your rays on the raytrace form. A method of solution explaining your procedure and calculations must be provided. Gaussian imaging methods may not be used for any portion of this problem.

Your answers must be entered below. Be sure to provide details on the pages that follow to indicate your method of solution (how did you get your answer: which ray was used, analysis of ray data, etc.)

System Focal Length = __________ mm Working Distance = __________ mm

Primary Mirror Diameter D_P = __________ mm

Secondary Mirror Diameter D_S = __________ mm

Diameter of the Primary Mirror Hole D_H = __________ mm

Exit Pupil: _________ mm to the ________ of the primary mirror vertex.

D_{XP} = _________ mm FOV = +/- ________ deg in object space

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

Provide Method of Solution – This is a required portion of the problem:

Continues…

Continues…

6) (10 points) An optical system is comprised of two thin lenses in air. The first lens has a focal length of 100 mm and the second lens has a focal length of 200 mm. The two lenses are separated by 75 mm. An object is located 200 mm to the left of the first lens. Determine the image location relative to the second lens and the image magnification.

NOTE: Use Gaussian Reduction and Gaussian Imaging for this problem. **Cascaded imaging may not be used (you may not image through one surface and then use this image as an object for the other surface).**

Image is located ________ mm to the ________ of the lens. Magnification = ______

7) (15 points) A 200 mm x 300 mm monochrome monitor is to be viewed at a distance of 0.5 m. The desired image quality is to be excellent as determined by matching the resolution of the eye. The image was captured on a 10 mm x 15 mm detector.

The camera lens has a focal length that matches the FOV of a 38 mm lens on a 35 mm camera (the film size is 24 x 36 mm).

The camera is designed using the hyperfocal condition so that objects between 2 m and infinity meet the above image quality or blur condition.

What is the required focal length of the imaging lens?

What is the required f/# for the imaging lens?

What is the approximate resolution of the system in pixels (assume the blur size equals the pixel size)?

Blank page follows…

Resolution: _______x_______ pixels f = ________ mm f/#: _______

Spare Raytrace Sheet:

Surface	0	1	2	3	4	5	6
C							
t							
n							
$-\phi$							
t/n							
y							
nu							
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Spare Raytrace Sheets:

Surface	0	1	2	3	4	5	6
C							
t							
n							
$-\phi$							
t/n							
y							
nu							
u							
y							
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Surface	0	1	2	3	4	5	6
f							
$-\phi$							
t							
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OPTI-502 Equation Sheet

$$OPL = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\omega' = \omega - y\phi \qquad n'u' = nu - y\phi$$

$$\phi = -\frac{\omega'_k}{y_1}$$

$$y' = y + \omega'\tau' \qquad y' = y + u't'$$

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

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

$$I = H = Ж = n\bar{u}y - nu\bar{y}$$

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

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

$$MP = \frac{1}{m} \qquad MP = m_R MP_K$$

$$m_V = m_{OBJ} MP_{EYE}$$

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

$$\Phi = L A \Omega \qquad \Omega \approx \frac{A}{d^2}$$

$$E' = \frac{\pi L_O}{4(f/\#_W)^2}$$

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

$$a \ge |y| + |\bar{y}| \qquad \text{Un}$$

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

$$a \le |\bar{y}| - |y| \quad \text{and} \quad a \ge |y| \qquad \text{Full}$$

$$DOF = \pm B' f/\#_W$$

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

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

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

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

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

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

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

$$\frac{\delta}{\Delta} = \nu \qquad \frac{\varepsilon}{\Delta} = P$$

$$\frac{\alpha_1}{\delta} = -\left(\frac{1}{\nu_1 - \nu_2}\right)\left(\frac{\nu_1}{n_{d1} - 1}\right)$$

$$\frac{\alpha_2}{\delta} = \left(\frac{1}{\nu_1 - \nu_2}\right)\left(\frac{\nu_2}{n_{d2} - 1}\right)$$

$$\frac{\varepsilon}{\delta} = \left(\frac{P_1 - P_2}{\nu_1 - \nu_2}\right)$$

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

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

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

$$TA_{CH} = \frac{r_P}{\nu}$$

$$\frac{\phi_1}{\phi} = \frac{\nu_1}{\nu_1 - \nu_2} \qquad \frac{\phi_2}{\phi} = -\frac{\nu_2}{\nu_1 - \nu_2}$$

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