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) (10 points) You are riding in the passenger seat of a car traveling at 50 km/hour. You look out the passenger window and notice that objects close to the road appear to be "moving" faster than more distant objects. In fact, the mountains in the distance appear to be stationary.

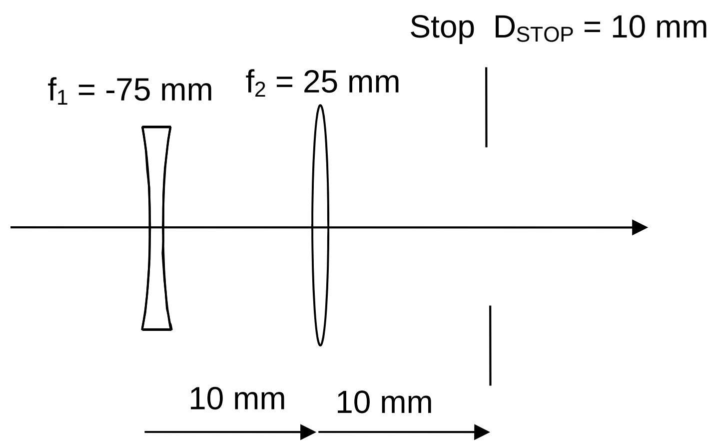
As an experiment, you take a picture out the open passenger window. The optical axis of the camera is perpendicular to the direction of motion of the car. A slow f/# is used, so depth of field is not an issue, and any recorded image blur will be due only to the motion of the car. You use a shutter speed of 0.01 sec.

The focal length of the camera lens is 50 mm, and the pixel size on the detector is 10 μm.

At what distance from the car will the motion blur equal the pixel size? Use and note reasonable assumptions.

Distance = _____________ m

3) (15 points) A 10 mm diameter stop is located to the right of an optical system comprised of two thin lenses in air as shown:



Determine the entrance pupil location and diameter. The entrance pupil is to be located relative to the first lens.

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

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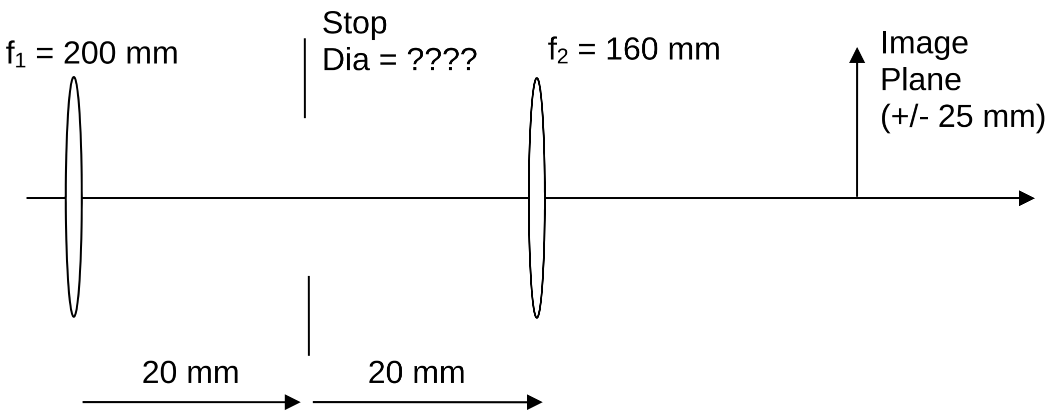
Continues…

EP: D_{EP} = ________ mm; Located ________ mm to the ________ of the first lens.

4) (25 points) The following diagram shows the design of an objective that is comprised of two thin lenses in air. The system stop is located between the two lenses.

The system operates at f/4.
The object is at infinity.
The maximum image size is +/- 25 mm.



Determine the following:
- Entrance pupil and exit pupil locations and sizes.
- System focal length and back focal distance.
- Stop diameter.
- Angular field of view (in object space).
- Required diameters for the two lenses for the system to be unvignetted over the specified maximum image size.

NOTE: This problem is to be worked using raytrace methods only. Gaussian imaging methods may not be used for any portion of this problem. The field of view must be determined from the chief ray.

Be sure to clearly label your rays on the raytrace form. 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.).

Entrance Pupil: ________ mm to the _______ of the first lens. D_{EP} = ________ mm

Exit Pupil: ________ mm to the _______ of the second lens. D_{XP} = ________ mm

System Focal Length = _________ mm Back Focal Distance = _________mm

Stop Diameter = _________ mm FOV = +/- _______ deg in object space

Lens 1 Diameter = _________ mm Lens 2 Diameter = _________ mm

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

Continues…

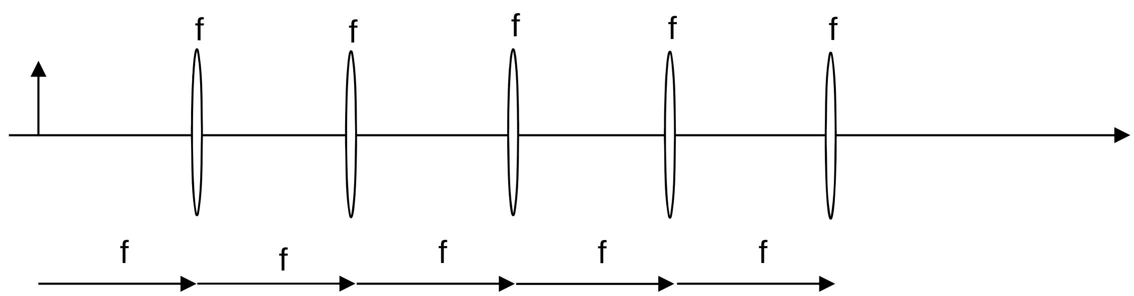
Provide Method of Solution:

Continues…

Provide Method of Solution:

5) (10 points) Consider the following optical system comprised of five identical thin lenses of focal length f that are each separated by this same distance f.

An object is located at the front focal point of the first lens element. Determine the image location and size by sketching rays. Please use a straightedge. No calculations are required or permitted.



6) (10 points) Using only 50 mm focal length thin lenses, provide the layout of a double-telecentric system with a lateral magnification of +1.0. You must use four of these thin lenses in your design. Provide a sketch of the system clearly indicating the spacings of the lenses and the location of the system stop.

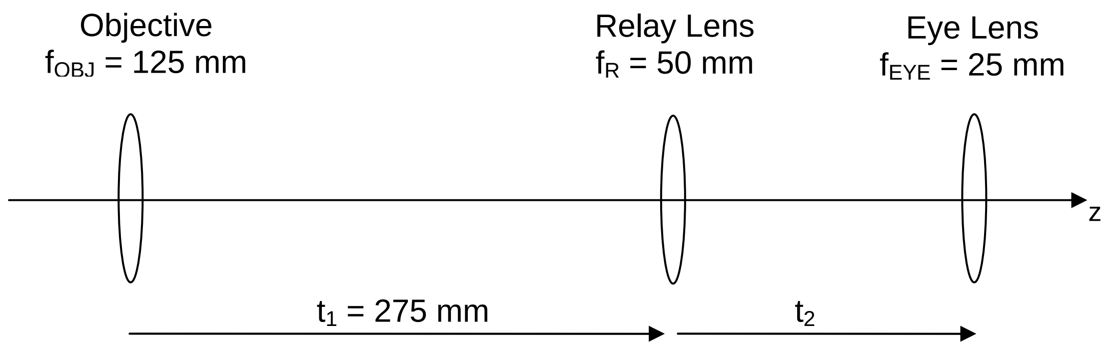
Note: The system magnification must be POSITIVE.
The lens diameters are not required.

7) (10 points) Design a thin-lens Petzval objective with the following specifications:

Separation of the two elements = 50 mm
Focal length = 100 mm
Back focal distance = 75 mm

f1 = _______ mm f2 = _______ mm

8) (15 points) A relayed Keplarian telescope is constructed with three thin lenses in air as shown. The objective lens serves as the system stop. The stop diameter is 25 mm.



Determine: The Magnifying Power of the telescope.
The Magnification of the relay m_R.
The separation between the Relay Lens and the Eye Lens.
The Eye Relief ER (or the location of the Exit Pupil) of the telescope.
The diameter of the Exit Pupil.

Provide a clear explanantion of your method of solution.

Note: The solution of this problem does not require the use of raytrace. However, a raytrace sheet is provided should you choose to use raytrace.

Continues…

MP = ________ m_R = ________ t_2 = ________mm

ER = _______ mm D_{XP} = _______ mm

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

Spare Raytrace Sheet:

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

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

$$OPL = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$I = H = Ж = n\bar{u}y - nu\bar{y}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$D \approx f/\#$ in µm

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

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

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

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

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

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

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

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

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

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

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

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

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

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