October 27, 2015 Lecture 19 Name________________________

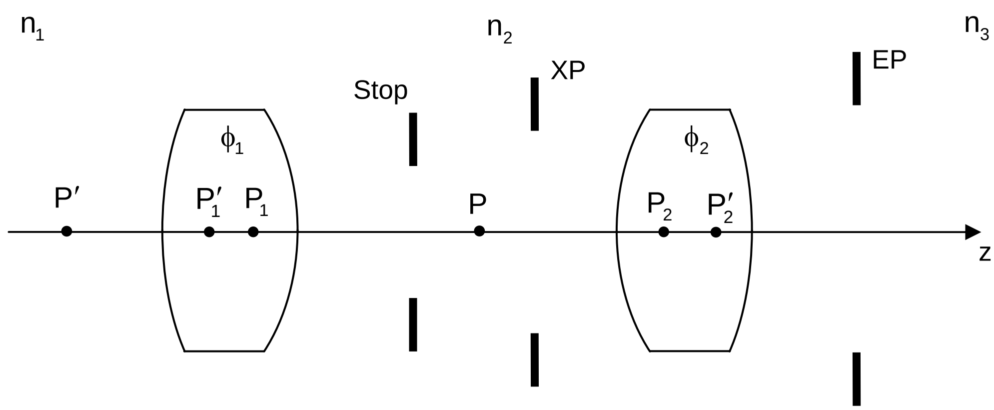
Closed book; closed notes. Time limit: 75 minutes.
An equation sheet is attached and can be removed. A spare raytrace sheet is also attached.
Use the back sides if required.
Assume thin lenses in air if not specified.
If a method of solution is specified in the problem, that method must be used.
Raytraces 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 conventions and reference definitions 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) (10 points) A 20 m object is to be imaged onto a 1 cm detector. The image must fill the detector size. The object is located at a distance of 100 m. Determine the approximate focal length of the required imaging lens.

Focal Length ≈ __________ mm

2) (10 points) An optical system is comprised of two elements separating indices of refraction n_1, n_2 and n_3. Subscript 1 designates element 1, subscript 2 designates element 2, and quantities without subscripts are associated with the total system.



Circle the index of refraction (and therefore the corresponding optical space) associated with each of the following:

EP:	n_1	n_2	n_3	XP:	n_1	n_2	n_3
P_1:	n_1	n_2	n_3	P'_1:	n_1	n_2	n_3
P_2:	n_1	n_2	n_3	P'_2:	n_1	n_2	n_3
P:	n_1	n_2	n_3	P':	n_1	n_2	n_3

3) (15 points) A ±15 mm high object is 150 mm to the left of the front vertex of a thick lens in air. The lens specifications are:

R1 = -100 mm	R2 = 50 mm
t = 10 mm	n = 1.55

Determine the focal length of the lens.
Determine the image size and the image location relative to the rear vertex of the lens.
Is the image erect or inverted? Real or virtual?

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).

Continues…

Focal length = __________ mm

Image: Real Virtual Erect Inverted

Image size = ±_________ mm Located ________ mm to the ______ of the rear vertex

4) (20 points) An afocal system consists of two positive thin lenses in air. The focal length of the first lens is 200 mm and the magnitude of the system magnification is 0.2.

$$|m| = 0.2$$

a) Complete the design of the system.

$f_2 =$ __________ mm $t =$ _________ mm

b) The second lens has a diameter of 10 mm, and the second lens serves as the system stop. Determine the EP and XP locations and sizes for the system.

NOTE: Use Gaussian Methods for this problem. No Raytrace is permitted.

Continues…

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

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

c) A cube of dimensions 10 mm x 10 mm x 10 mm is imaged by this optical system. What is the volume of the image of the cube?

Assume that the cube is a wire grid so that obscuration, the index of refraction of the cube and transparency are not issues.

Volume = ________ mm^3

5) (15 points) An optical system in air is comprised of two thin lenses:

L1: $f_1 = -100$ mm
L2: $f_2 = 50$ mm
$t = 50$ mm

An object is placed 300 mm to the left of the first lens. The object size is ± 10 mm. Use paraxial raytrace methods to determine the system focal length and the location and size of the image.

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 image size must be determined from a raytrace. 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.

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

Continues…

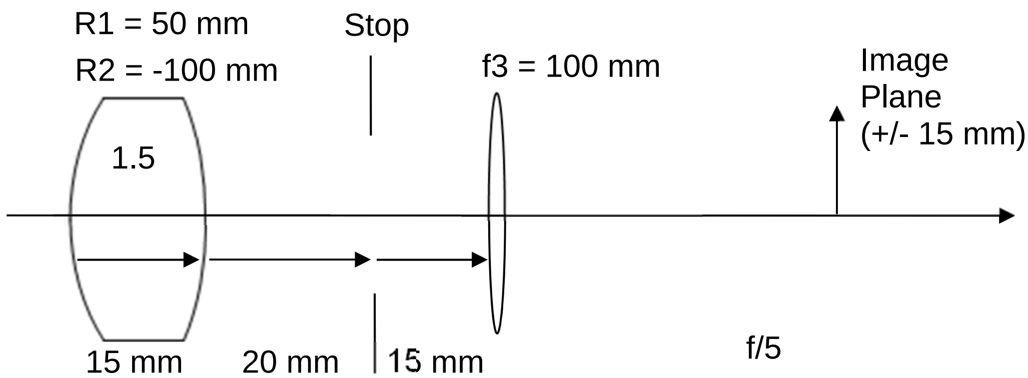
Method of Solution:

f = _________ mm

Image Location: ________ mm to the ______ of L2; Image Size = ±________ mm

6) (30 points) The following diagram shows the design of an optical system that is comprised a biconvex thick lens in air, a stop, and a thin lens in air. The index of refraction of the thick lens is 1.5.

The system operates at f/5. The object is at infinity.
The maximum image size is ± 15 mm.



Determine the following:
- System focal length.
- Back focal distance
- Entrance pupil and exit pupil locations and sizes.
- Stop diameter.
- Angular field of view (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.)

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

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

Stop Diameter = _________ mm

System Focal Length = _________ mm Back Focal Distance = _________mm

FOV = ± _______ deg in object space

Surface	0	1	2	3	4	5	6	7
C								
t								
n								
-ϕ								
t/n								
y								
nu								
u								
y								
nu								
u								
y								
nu								
u								
y								
nu								
u								
y								
nu								
u								

Continues…

Provide Method of Solution:

Continues

Continues…

Spare raytrace sheets

Surface	0	1	2	3	4	5	6	7
C								
t								
n								
-φ								
t/n								
y								
nu								
u								
y								
nu								
u								
y								
nu								
u								
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
Midterm

$$OPL = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$I = H = Ж = n\bar{u}y - nu\bar{y}$$

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

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