October 31, 2013 Lecture 20 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 value is provided. The proper sign convention for the quantity 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) The detector in a camera has width of 6 mm. The image of a 12 m tall building fills the detector. The camera is 30 m away from the building. Approximately what focal length lens is used?

Focal Length = __________ mm

2) (15 points) Two imaging configurations are given, each showing an object. Determine the image location and size by using a ray construction. Make use of the properties of the principal planes and focal points. Both real and virtual objects are shown. Indicate if the image is real or virtual.

Positive Thin Lens – Real Object

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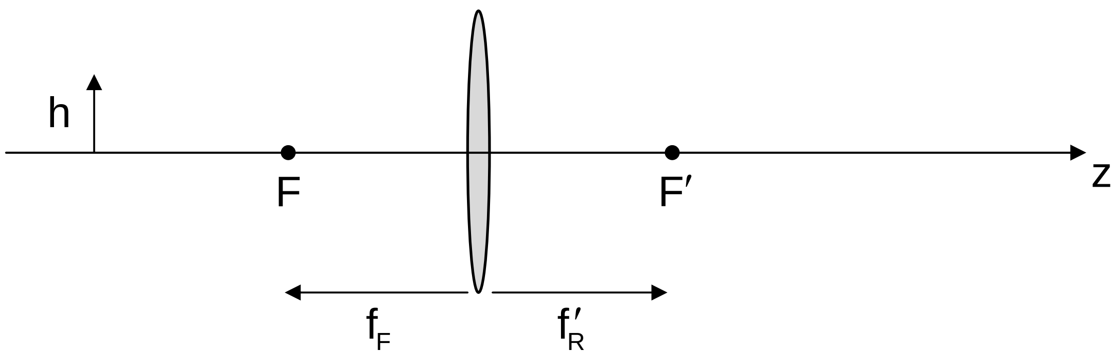
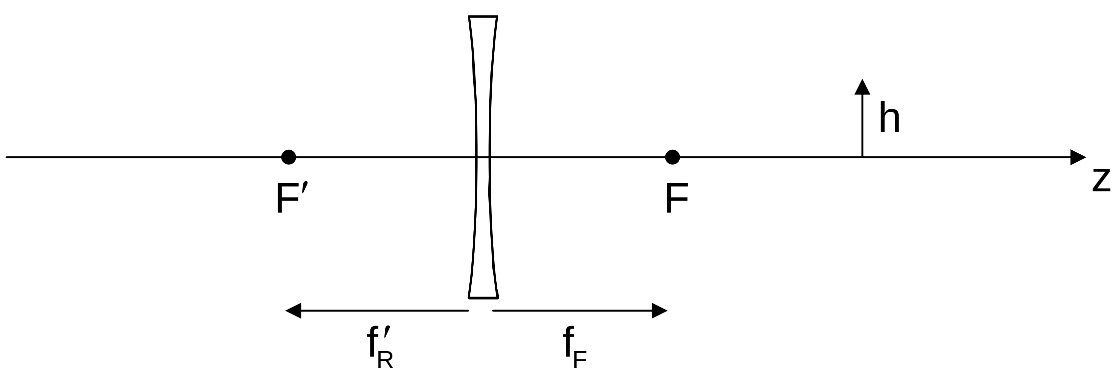
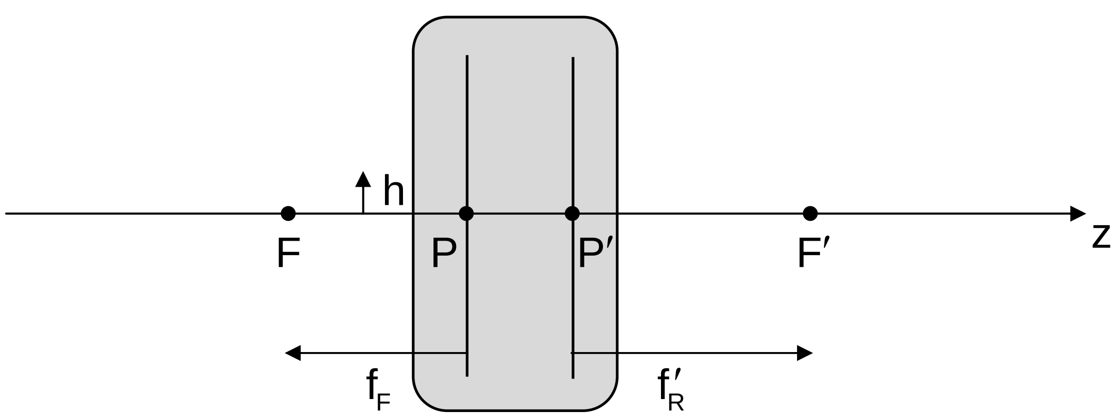


Negative Thin Lens – Virtual Object



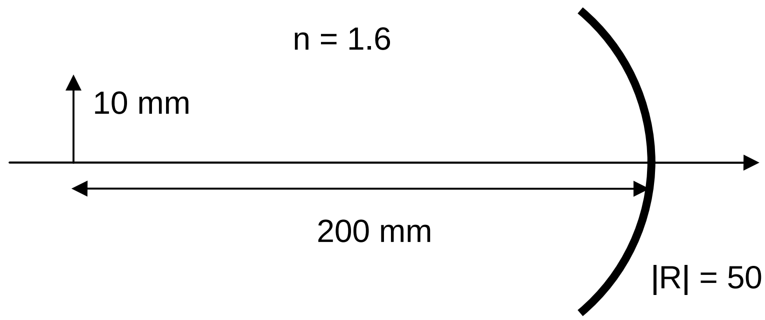
Positive System – Real Object



3) (15 points) As shown below, a concave reflecting surface is immersed in a liquid with an index of refraction of 1.6. The magnitude of the radius of curvature of the surface is 50 mm. A 10 mm high object is 200 mm to the left of the mirror.

a) Where is the image and how big is it?
b) The fluid is now drained from the system (replaced by air). Where is the image and how big is it?

NOTE: Only Gaussian methods may be used for this problem.



a) Image size is _______ mm and it is located _______ mm to the ______ of the surface.

b) Image size is _______ mm and it is located _______ mm to the ______ of the surface.

4) (15 points) A thick lens in air has the following specifications:

R1 = -25 mm	R2 = 50 mm
t = 20 mm	n = 1.55

A second optical system produces a real image that is projected into this lens. This image serves as a virtual object for the thick lens. The virtual object has a height of +/- 5 mm and is located 15 mm to the right of the first surface of the thick lens.

Determine the size and location of the image produced by the thick lens.

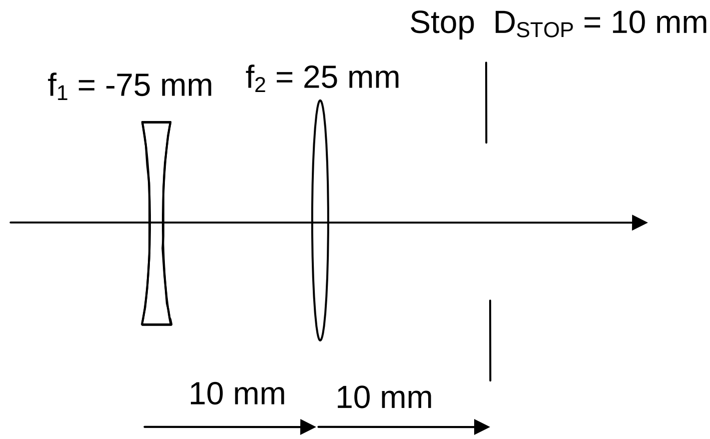
NOTE: This problem is to be worked using raytrace methods only. Two rays must be traced: One for image location and one for image size. Gaussian imaging methods may not be used for any portion of this problem. Be sure to clearly label your rays on the raytrace form.

Continues with a raytrace form on the next page…

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

Image size = +/- _______ mm;   Located ________ mm to the _______ of the rear vertex.

5) (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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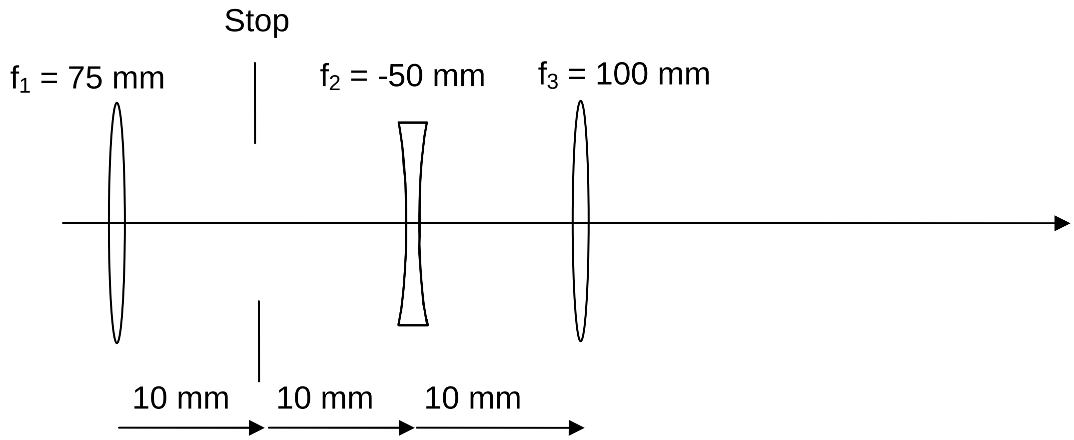
Continues…

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

6) (30 points) The following diagram shows the design of an optical system that is comprised of three thin lenses in air.

The infinite conjugate f/# of the system is f/4. (This is NOT the working f/#)

The object is located 500 mm to the left of the first lens. The object size is +/- 50 mm.



Determine the following:
- System focal length.
- Back focal distance
- Entrance pupil and exit pupil locations and sizes.
- Stop Diameter.
- Image size and location.

NOTE: This problem is to be worked using raytrace methods only. All answers must be determined directly from the rays you trace. The image size and location must be determined from the marginal and chief rays associated with the object. Gaussian imaging methods may not be used for any portion of this problem. 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 third lens. D_{XP} = ________ mm

Stop Diameter = _________ mm

System Focal Length = _________ mm Back Focal Distance = _________mm

Image Size = +/- _______ mm; Located _______ mm to the _______ of the third lens.

Surface	0	1	2	3	4	5	6	7
f								
-ϕ								
t								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								

Continues…

Provide Method of Solution:

Continues…

Spare raytrace sheets

Surface	0	1	2	3	4	5	6	7
f								
-ϕ								
t								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								
y								
u								

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

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

OPTI-502 Equation Sheet
Midterm

$$OPL = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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