October 18, 2012 Lecture 18 Name___________________________

Closed book; closed notes. Time limit: 75 minutes.
An equation sheet is included 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.
You must show your work and/or method of solution in order to receive credit or partial credit for your answer.
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) (10 points) An 8 m tall building is imaged with a camera using a 90 mm focal length lens. The camera is 45 m away from the building. Approximately how large is the image of the building?

Image Size = ___________ mm

2) (10 points) For a thin lens in air with a focal length f, it is well known that the minimum object-to-image distance L is 4f. This assumes a real object and a real image. Derive this result.

$$\frac{d}{dx}(uv) = u\frac{dv}{dx} + v\frac{du}{dx}$$

$$\frac{d}{dx}e^{u} = e^{u}\frac{du}{dx}$$

$$\frac{d}{dx}\left(\frac{u}{v}\right) = \frac{1}{v}\frac{du}{dx} - \frac{u}{v^2}\frac{dv}{dx}$$

$$\frac{d}{dx}\left(u^{n}\right) = nu^{n-1}\frac{du}{dx}$$

$$\frac{d}{dx}\sin u = \cos u\frac{du}{dx}$$

3) (10 points) As shown below, a concave refracting surface separates an index of refraction of 1.8 from an index of 1.5. The magnitude of the radius of curvature of the surface is 25 mm. A 10 mm high object is 200 mm to the left of the surface.

Where is the image and how big is it?
NOTE: Only Gaussian methods may be used for this problem.

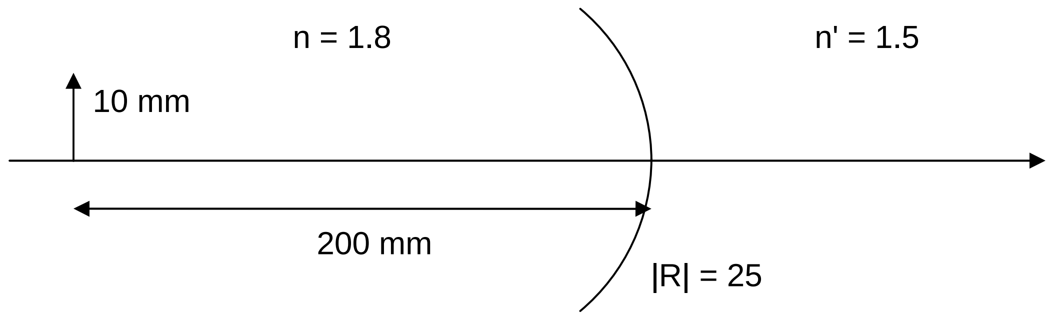


Image size is ________ mm and it is located ________ mm to the _________ of the surface.

4) (20 points) A 5 mm high object is 250 mm to the left of the front vertex of a thick lens in air. The lens specifications are:

R1 = 75 mm	R2 = -50 mm
t = 12 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.

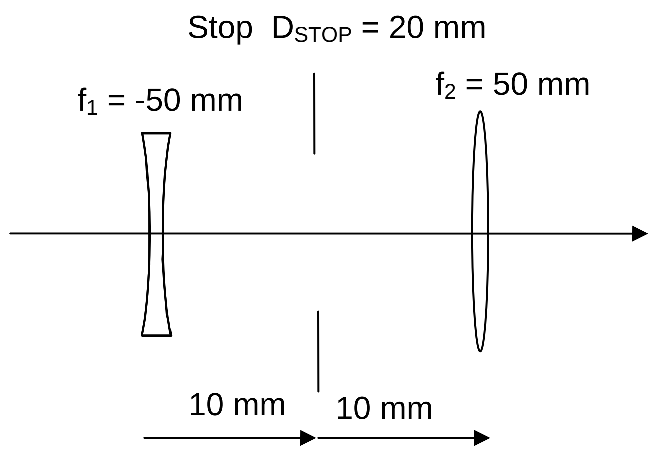
NOTE: Only Gaussian methods may be used for this problem.

Continues…

Focal length = _______ mm

Image size = _______ mm Located _______ mm to the ______ of the rear vertex.

5) (20 points) A 20 mm diameter stop is located between two thin lenses in air as show.



Determine the system focal length and the system back focal distance.
Determine the entrance pupil and exit pupil locations and diameters. The entrance pupil is to be located relative to the first lens, and the exit pupil is to be located relative to the second lens.

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

Continues…

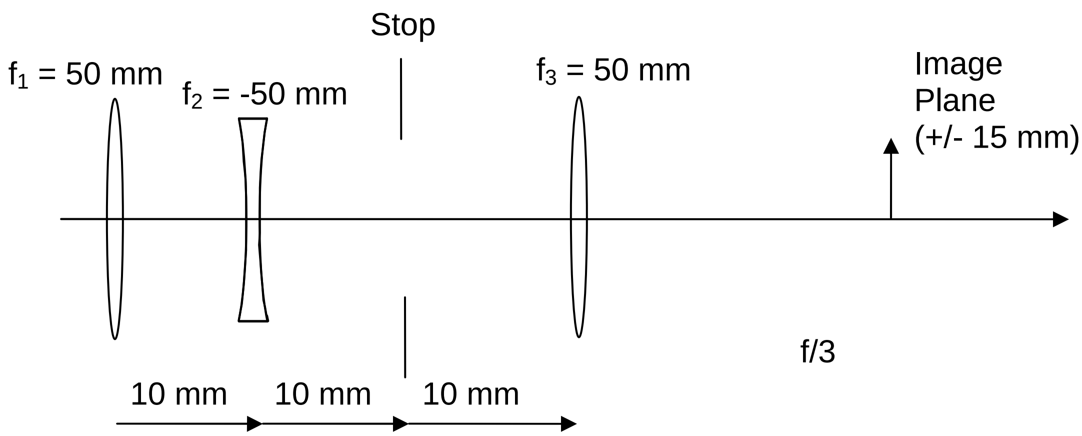
Focal length = __________ mm Back Focal Distance = ________ mm

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

XP: D_{XP} = ________ mm; Located ________ mm to the ________ of the second lens.

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

The system operates at f/3. 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 field of view must be determined from the chief ray. 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

FOV = +/- _______ deg in object space

Surface	0	1	2	3	4	5	6	7
f								
$-\phi$								
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 sheet

Surface	0	1	2	3	4	5	6	7
f								
-ϕ								
t								
y								
u								
y								
u								
y								
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OPTI-502 Equation Sheet
Midterm

$$OPL = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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