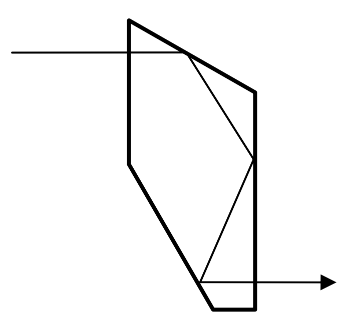
October 19, 2010 Lecture 17 Name_________________________

Closed book; closed notes. Time limit: 75 minutes.
An equation sheet is included. 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.

Distance Students: Please return the original exam only; do not scan/FAX/email an additional copy.

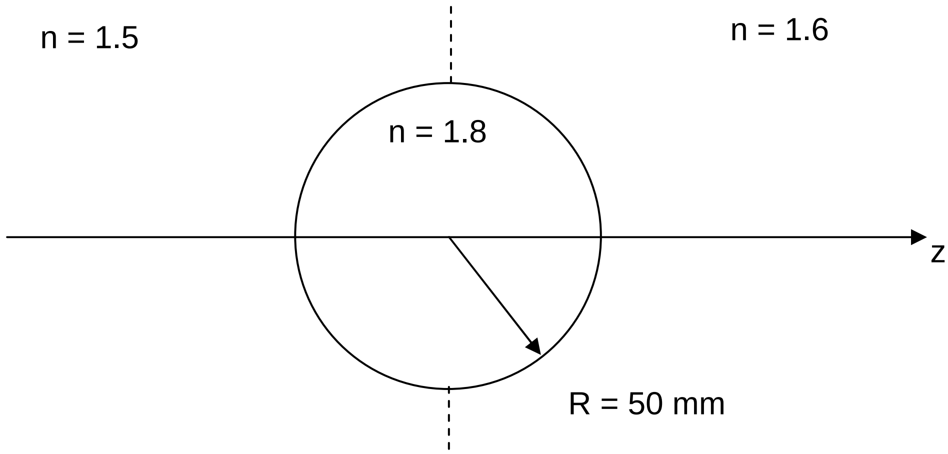
1) (10 points) Draw the tunnel diagram for this prism with the ray path shown. The tunnel diagram must be drawn to the same scale as the prism drawing.



2) (10 points) A 10 m tall tree is to be photographed with a camera that has a 25 mm focal length lens and an image sensor that is 1 x 1 cm. At approximately what object distance will the image of the tree fill the sensor? (The image size equals 1 cm.)

Object Distance ≈ _________ m

3) (20 points) A spherical ball of index 1.8 is mounted between two media with indices of refraction of 1.5 and 1.6. The radius of the ball is 50 mm.




Determine: System Power
Locations of the Principal Planes relative to the respective vertices
Front Focal Distance
Back Focal Distance
Principal Plane to Nodal Point Separation

Sketch the approximate locations of F, F', P, P', N, N' on the above figure.

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

*Continues…*

Power = ___________ $mm^{-1}$

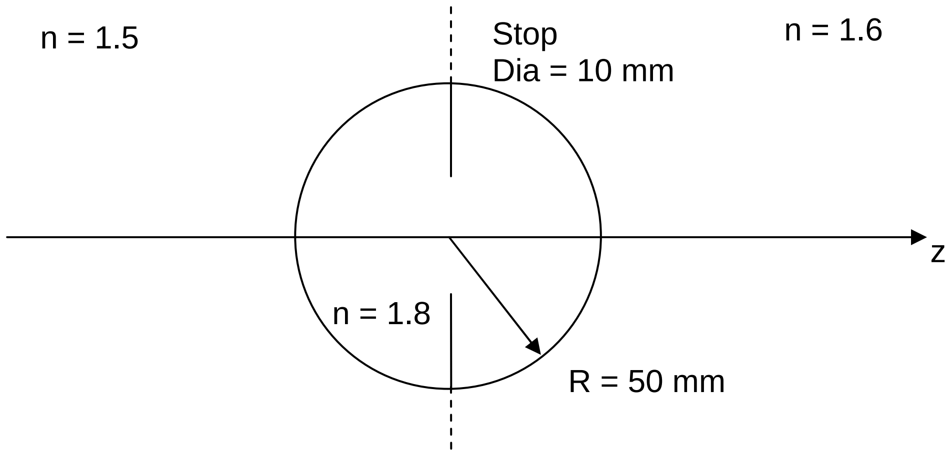
P: Located ________mm to the ________ of the front vertex.

P': Located ________mm to the ________ of the rear vertex.

FFD = ___________ mm BFD = ____________ mm

Principal Plane to Nodal Point Separation = ___________ mm

4) (15 points) A 10 mm diameter stop is now inserted at the center of the spherical ball from the last problem: A spherical ball of index 1.8 is mounted between two media with indices of refraction of 1.5 and 1.6. The radius of the ball is 50 mm.




Determine the entrance pupil and exit pupil locations and diameters.

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

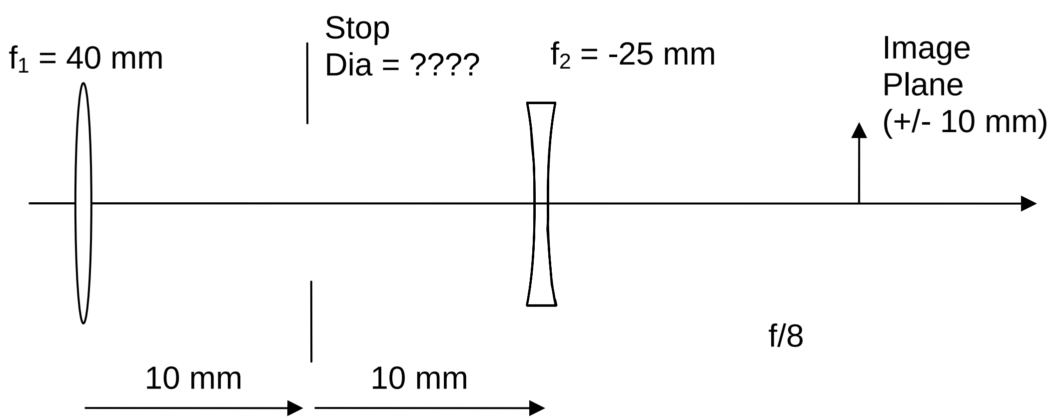
*Continues…*

EP: $D_{EP}$ = ________mm; Located ________mm to the ________ of the front surface of the sphere.

XP: $D_{XP}$ = ________mm; Located ________mm to the ________ of the rear surface of the sphere.

5) (30 points) The following diagram shows the design of a telephoto objective that is comprised of two thin lenses in air. The system stop is located between the two lenses.

The system operates at f/8.
The object is at infinity.
The maximum image size is +/- 10 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. 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 second 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| f | | | | | | | | | | | | | |
| $-\phi$ | | | | | | | | | | | | | |
| t | | | | | | | | | | | | | |
| y | | | | | | | | | | | | | |
| u | | | | | | | | | | | | | |
| y | | | | | | | | | | | | | |
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| y | | | | | | | | | | | | | |
| u | | | | | | | | | | | | | |

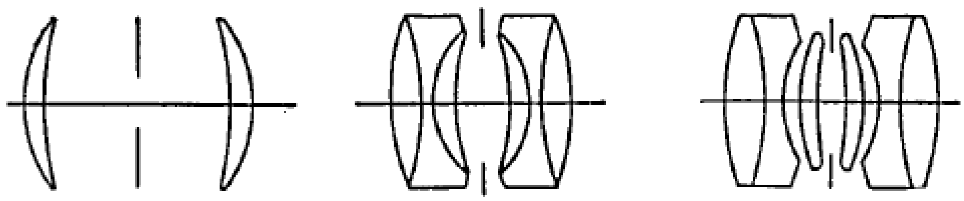
*Continues…*

Provide Method of Solution:

*Continues…*

Provide Method of Solution:

6) (20 points) An optical system is symmetric about its stop. This means that are curvatures, spacings and indices are all symmetric about the stop. To help clarify, here are a few of examples of symmetrical optical systems:



For an arbitrary symmetrical system, prove that the exit pupil of the system is coincident with the rear principal plane of the system and that the entrance pupil is coincident with the front principal plane.

Be sure to provide your proof in a logical and easy to follow manner.

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**Spare raytrace sheet**

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

# OPTI-502 Equation Sheet
# Midterm

$$\mathrm{OPL} = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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