Name_____

Closed book; closed notes. Equation sheets are attached and can be removed.
Use the back sides if required. The time limit is 2 hours.
Calculators are permitted, but do not use any pre-stored information or programs.
Note any assumptions you make in solving the problems.
Show your work. Present it in a neat and logical fashion.

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

1) (20 points) Design a slide projector using a projection-condenser (specular) illumination system for the following conditions:

Slide:	25 mm x 25 mm
Screen:	2 m x 2 m
Projection Lens to Screen Distance:	4 m
Filament:	8 mm diameter (circular)
Condenser Lens:	f/0.8

To simplify the problem, assume that the condenser lens is a thin lens in contact with the slide. No source mirror is to be used in this system.

Provide the element locations, focal lengths and diameters. Sketch your system.

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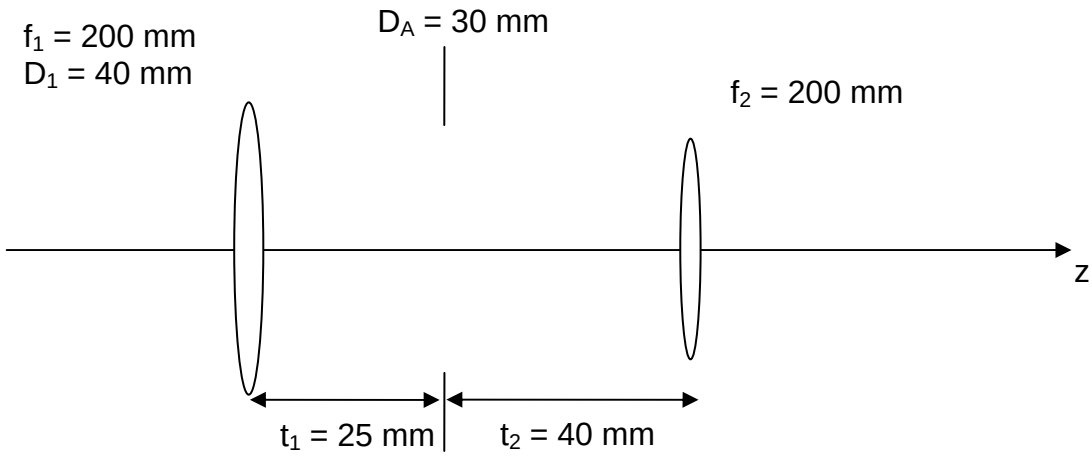
System Layout Sketch

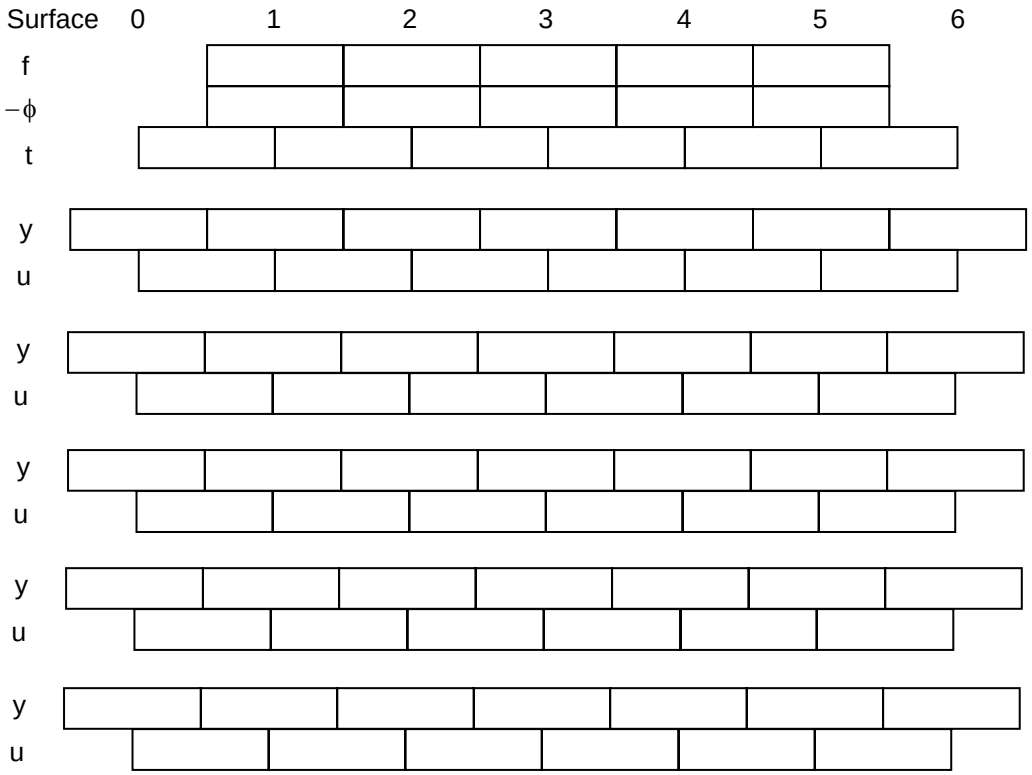
2) (20 points) The following imaging system consists of two thin lenses and an aperture. The spacings and the focal lengths of the lenses are specified. The diameter of the first lens and the aperture are also given.



a) For an object at infinity, use a paraxial raytrace to determine if the first lens or the aperture serves as the System Aperture Stop.

b) Determine the required diameter of the second lens so that the system is unvignetted for an object FOV of +/- 5°.

Raytrace sheet follows…


Surface
0
1
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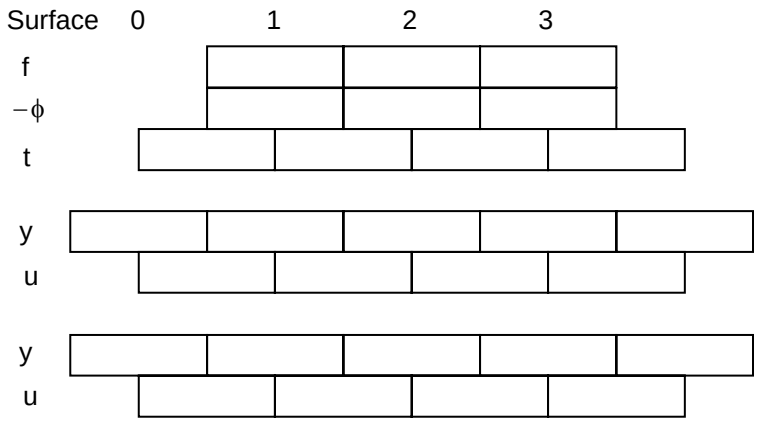
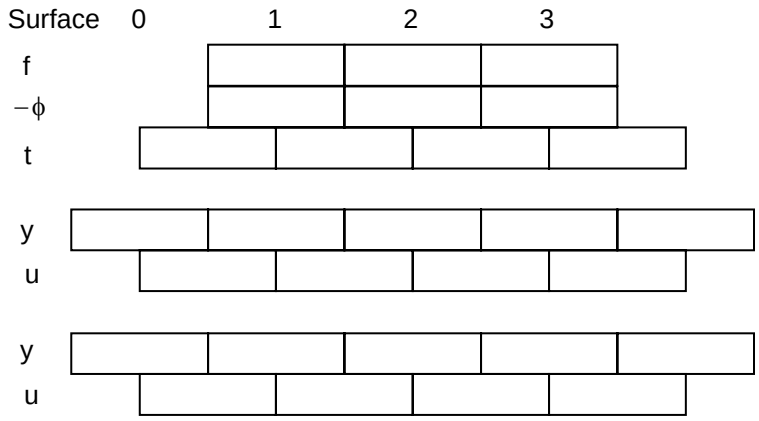
3) (20 points) A magnifier that is marked 10X is used to examine an object. The magnifier lens has a diameter of 10 mm, and the magnifier is used with a relaxed eye. This implies that the eye is focused at infinity, and that the virtual image produced by the magnifier is also at infinity.

a) The magnifier is first used as an eye loupe. The separation between the magnifier lens and the eye is 25 mm. What is the diameter of the half-vignetted field of view (object size in mm) seen through the magnifier? Assume that the eye has a pupil diameter of 4 mm.

Continues…



b) The magnifier is now used as a magnifying glass by increasing the separation between the magnifier lens and the eye to 250 mm. What is the diameter of the half-vignetted field of view (object size in mm) seen through the magnifier? Once again, assume that the eye has a pupil diameter of 4 mm.



Continues…

c) What do these results imply about the way a magnifier is best used?

4) (20 points) A biconvex thick lens in air has the following prescription and is used with a distant object:

R1 = 250 mm	$n_F = 1.828$
R2 = -500 mm	$n_d = 1.805$
t = 50 mm	$n_C = 1.796$

Use Gaussian reduction to determine the longitudinal chromatic focus shift of the lens.

5) (10 points) A doubly telecentric system is constructed out of two thin lenses. The spacing between the lenses is 250 mm , and the magnitude of the magnification |m| is 1/4.

a) Sketch the layout of the system. Show the required spacings and focal lengths.

b) A 12 mm high object is located 100 mm to the left of the first lens of this system. Determine the location and size of the image. Do not use a raytrace for this problem.

6) (10 points) Provide relationships for each of the following. The relationships should be in terms of focal lengths, object/image distances, etc.

Magnification of a focal imaging system:

Magnification of an afocal imaging system:

Magnifying power of a telescope:

Magnifying power of a magnifier:

Visual magnification of a microscope:

Spare raytrace forms:

Surface	0	1	2	3	4	5	6
C							
t							
n							
$-\phi$							
t/n							
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

$$\mathrm{OPL} = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$f/\# \equiv \frac{f_E}{D_{EP}} \qquad f/\#_W \approx (1-m)\, f/\#$$

$$\mathrm{NA} = n\left|\sin U\right| = \frac{1}{2\, f/\#_W}$$

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

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

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

$$\mathrm{MP} = \frac{1}{m}$$

$$m_V = m_{OBJ}\mathrm{MP}_{EYE}$$

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

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

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

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

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

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

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

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

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

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

$$D \approx f/\# \text{ in } \mu m$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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