Name_____

Closed book; closed notes. The time limit is 2 hours.
Equation sheets are attached and can be removed.
Spare raytrace forms are also attached.
Use the back sides if required.
Do not use any pre-stored information or programs in your calculator.
Assume thin lenses in air if not specified.
If a method of solution is specified in the problem, it must be used.
You must show your work and/or method of solution in order to receive credit or partial credit for your answer.

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

1) (10 points) The following list identifies six optical glasses by their six-digit glass code.

Identify which of these glasses is a crown (K) or a flint (F) by circling the appropriate letter.

552635	K	F
664360	K	F
589613	K	F
548458	K	F
517642	K	F
606437	K	F

Which of these two glasses should be used to produce a first-order achromatic doublet with the least excess power?

Crown Glass: _____ Flint Glass: _____

2) (20 points) During the semester, we have discussed a variety of optical systems, components and concepts. For each of the topics that is listed, provide a brief description and discuss some of the features or properties of this item. (for example, from a design perspective, what does it mean for the performance of the system or the use of the system?). Try to be practical, I am looking for concepts not equations.

Limit your answers to the space provided. Legibility does count – I need to be able to read it!

a) Field Lenses

b) Reverse Telephoto Lens

c) Right angle Roof Prism (Amici)

d) Specular Illumination System

3) (15 points) Using only 50 mm focal length thin lenses, provide the layout of a double-telecentric system with a lateral magnification of +1.0. You may use up to four of these thin lenses in your design. Provide a sketch of the system clearly indicating the spacings of the lenses and the location of the system stop.

Note: The system magnification must be POSITIVE.
The lens diameters are not required.
There are several possible designs – you need to provide only one.

4) (20 points) In a 3X Galilean telescope, the separation between the objective lens and the eye lens is 100 mm. The objective lens diameter is 30 mm and the eye lens diameter is 12 mm. The telescope is to be used with an eye that has a 4 mm diameter entrance pupil. The separation between the eye lens and the eye pupil is 15 mm. The object is at infinity.

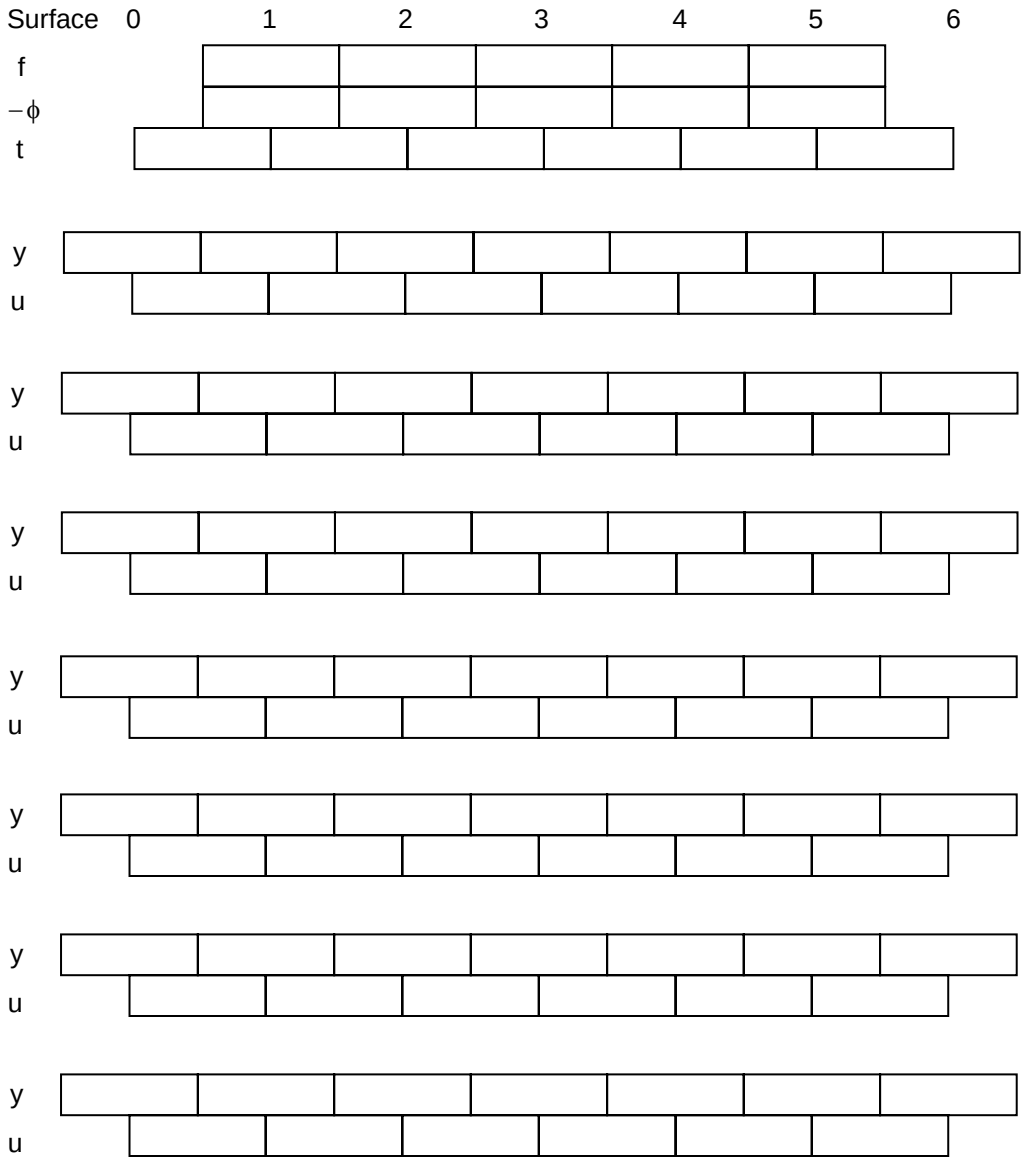
What is the unvignetted object space Field of View of this system in degrees?
Which element limits the unvignetted Field of View?

Continues…

Unvignetted Field of View = +/-_____ degrees in object space

FOV Limited by _____

Ray Trace Form Follows…


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

5) (15 points) A swimming pool has a sloped bottom (i.e. deeper on one end than the other). You notice that at noon on a sunny day, an interesting light pattern has formed on the bottom of the pool. The pattern is due to imaging of the sun by the waves on the pool surface. Especially sharp line images of the sun occur at a depth of 2 m, and the spacing of the lines is about 300 mm.

Using reasonable, simple assumptions, what can you say about the waves on the surface of the water? In particular, what are the approximate amplitude and period of the waves? State your assumptions.

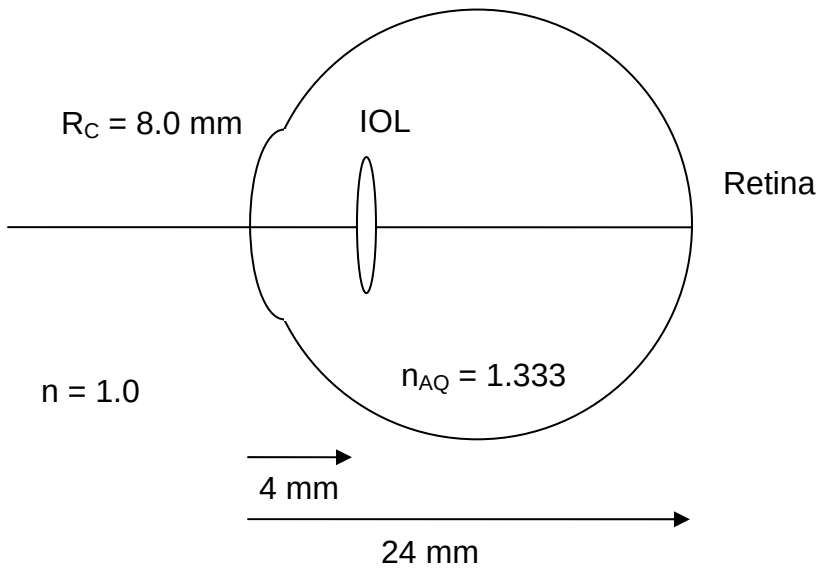
$n_{water} = 1.33$

Continues…

Wave period = _____ mm Wave peak-to-valley amplitude ≈ _____ mm

6) (20 points) In cataract surgery, the natural lens of the eye (now white and opaque) is removed and replaced by an artificial intraocular lens (IOL). The goal of this lens is to work with the cornea to focus images of distant objects on the retina. The cornea can be assumed to be a single refracting surface (R_C = 8.0 mm), and the IOL is assumed to be a thin lens. The IOL is usually made of plastic and it is immersed in the aqueous of the eye (n_{AQ} = 1.333). The IOL is located 4 mm behind the cornea, and the retina is 24 mm behind the cornea.

Both parts of this problem are to be done using Gaussian methods. No credit will be given for raytrace analysis.



a) What is the power and focal length of the IOL required to image distant objects onto the retina? This power and focal length are for the thin lens immersed in the aqueous.

Continues…

ϕ_{IOL} = _____/mm f_{IOL} = _____mm

Continues…

b) If the plastic IOL is removed from the aqueous, what are its power and focal length in air? The index of the IOL is 1.5.

$n_{IOL} = 1.5$

ϕ_{Air} = _____/mm f_{Air} = _____mm

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

$$\mathrm{OPL} = nl$$

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

$$\gamma = 2\alpha$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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