OPTI-202R  Geometrical and Instrumental Optics  John E. Greivenkamp
Midterm II  Page 1/9  Spring 2018

Name_______________________

Closed book; closed notes. Time limit: 50 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.
As usual, only the magnitude of a magnification or magnifying power may be given.
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. No credit if it can’t be read/followed.
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.

1) (15 points) An infinity-corrected microscope is constructed out of an objective lens
f_{OBJ}, a tube lens f_{TUBE}, and an eye lens or eyepiece f_{EYE}. In terms of these three focal
lengths, what is the visual magnification of this microscope?

\[ m_V = \]
2) (20 points) A 5 mm diameter extended source is used to project a spot of light onto a distant wall. A 500 mm focal length lens with a diameter of 100 mm is to be used.

The source is placed at the front focal point of the lens to “collimate” it. What is the projected spot size on a wall 100 m away?

Note: Compute the maximum extent of the projected spot. Do not determine the irradiance profile of the spot. This is a geometrical optics problem – do not consider diffraction or aberrations.

Spot Dia at 100 m = ______mm
3) (20 points) Design a doubly telecentric system using two thin lenses (in air). The overall object-to-image distance is required to be 200 mm, and the image size is one third the object size. The object and image must both be real.

Determine the focal lengths, the lens separation, a pair of conjugate object and image positions, and the stop location. Provide a neat sketch the system showing these distances.

Continues ...
f1 = _____ mm  f2 = _____ mm  t = _____ mm

Stop Location: _______________________________________________________

Object: _____ mm to the ___ of the first lens

Image: _____ mm to the ___ of the second lens
4) (20 points) You are using a camera with a 20 mm focal length lens to take a picture on large-format solid state detector (total image size is 23.7 mm x 15.6 mm). The long dimension of the detector is oriented horizontally. You are photographing a house against a very distant mountain backdrop, and the distance to the house is 15 m. The camera is focused on the house. The house is 10 m wide and has a peaked roof that is 8 m high. Assume that the lens is a thin lens with the stop at the lens.

a) How far behind the lens must the detector be located? How big is the image of the house on the detector? Sketch the image formed on the detector (as seen through the back of the sensor).

Lens-detector separation = ________ mm

Image size: ______mm x ______ mm

Detector

8 m

10 m

15.6 mm

23.7 mm
b) The pixels on the sensor are 7 μm square. If this is the limiting image blur in the system (produces acceptable image quality), what is the fastest f/# lens that can be used so that the distant mountains are also considered to be in focus along with the house? Remember that the camera is focused on the house.

\[ f/# = \frac{f}{}\]  

c) With this f/#, what is the closest object that will be considered to be in focus?

The closest in-focus object is _______ m from the camera.
5) (25 points) Design an object-space telecentric imaging system consisting of a 100 mm focal length thin lens and a stop. The object is 300 mm to the left of the lens. The system images a 20 mm diameter object onto a 10 mm square detector.

The system operates at a working f-number of 4 ($f/#_W = 4$ or NA = 0.125) and is unvignetted for this object.

Provide the diameter of the lens, the stop diameter, and the required spacings. Provide a neat sketch of the system showing these distances.
Lens Diameter = __________ mm

Stop Diameter = __________ mm

Stop Location: __________ mm to the _________ of the Lens

Image Location: __________ mm to the _________ of the Lens
Spare Raytrace Sheets:

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OPTI-202R Equation Sheet – Midterm II

OPL = nl

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

\( \gamma = 2\alpha \)

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

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

\[ \frac{n'}{z'} = \frac{n}{z} + \phi \]

\[ f_E = \frac{1}{\phi} = \frac{-f_F}{n} = \frac{f_R'}{n'} \]

\[ m = \frac{z'/n'}{z/n} = \frac{\omega}{\omega'} \]

\[ m = \frac{f_{F2}}{f_{R1}} = -\frac{f_2}{f_1} \]

\[ \bar{m} = \frac{n'}{n} \]

\[ \frac{\Delta z'/n'}{\Delta z/n} = m_1m_2 \]

\[ m_N = \frac{n}{n'} \]

\[ P'N' = PN = f_F + f_R' \]

\( \tau = \frac{t}{n} \)

\( \omega = nu \)

\( \phi = \phi_1 + \phi_2 - \phi_1\phi_2\tau \)

\( \delta' = \frac{d'}{n'} = -\frac{\phi_1}{\phi} \)

\( BFD = d' + f_R' \)

\( \delta = \frac{d}{n} = \frac{\phi_2}{\phi} \tau \)

\( FFD = d + f_F \)

\( \omega' = \omega - y\phi \)

\( n'u' = nu - y\phi \)

\( y' = y + \omega'\tau' \)

\( y' = y + u't' \)

\( f/\# = \frac{f_E}{D_{EP}} \)

\( NA \equiv n|\sin U| \approx n|u| \)

\( f/\#_w = \frac{1}{2NA} \approx \frac{1}{2n|u|} \approx (1 - m)f/\# \)

\( I = H = \mathcal{K} = n\bar{u} - n\bar{u} \)

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

\[ MP = \frac{10\text{in}}{f} = \frac{250\text{mm}}{f} \]

\[ MP = \frac{1}{m} \]

\( MP = m_RMP_K \)

\[ m_v = m_{OBJ}MP_{EYE} \]
\[ a \geq |y| + |\bar{y}| \quad \text{Un} \]

\[ a = |\bar{y}| \quad \text{and} \quad a \geq |y| \quad \text{Half} \]

\[ a \leq |\bar{y}| - |y| \quad \text{and} \quad a \geq |y| \quad \text{Full} \]

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DOF = ±B'f/#_w

\[ L_H' = -\frac{fD}{B'} \quad L_{\text{NEAR}} = \frac{L_H}{2} \]