SIMG-733-20092 Optics for Imaging   Final Exam

CLOSED BOOK, UNPROGRAMMED NONGRAPHING CALCULATORS OKAY
DO PROBLEM #1 (50%) AND SELECT 3 FROM #2-#6
SUBMIT ONLY THOSE PROBLEMS TO BE GRADED
Staple problem submissions IN NUMERICAL ORDER
Stamdard hint: make sketches before writing equations; label significant points on axes.

1. An imaging system consists of two identical thin lenses each with focal length $\mathbf{f}_1 = \mathbf{f}_2 = +300\,\text{mm}$ and diameter $d_1 = d_2 = 50\,\text{mm}$. The lenses are separated by $t = 150\,\text{mm}$. Between the lenses and at equal distances from each is a single iris with diameter $d_{\text{iris}} = 20\,\text{mm}$.

   (a) Determine the effective focal length of the system.

   (b) Determine the locations of the focal points $\mathbf{F}$ and $\mathbf{F}'$ and principal points $\mathbf{H}, \mathbf{H}'$ of the system, i.e., determine the distances $\overline{\mathbf{FV}}$, $\overline{\mathbf{V}'\mathbf{F}'}$, $\overline{\mathbf{HV}}$, and $\overline{\mathbf{V}'\mathbf{H}'}$

   (c) Sketch the system showing the locations of the vertices, focal points and principal points.

   (d) For an object at infinity, determine which element is the aperture stop of the system.

   (e) Determine the locations of the entrance and exit pupils of the system for an object at infinity and locate them on the sketch in part (c)

   (f) Determine the focal ratio (f/#) of the system.

   (g) If the stop is circular with diameter d_{iris} as stated, determine and sketch the the profile of the diffraction spot for wavelength $\lambda_0 = 0.5\,\mu\text{m}$

   (h) Determine the locations of the object and image such that transverse magnification of the system is $M_T = +1$.

   (i) Determine the locations of the object and image such that transverse magnification of the system is $M_T = -1$.

   (j) Determine the locations of the object and image such that transverse magnification of the system is $M_T = -\frac{1}{4}$.

   (k) If the two lenses are made of the same crown glass with $n_D = 1.5$ at $\lambda_D = 589.59\,\text{nm}$, explain what you expect to be true about the focal length of the system at the F line ($\lambda_F = 486.13\,\text{nm}$) and at the C line ($\lambda_C = 656.28\,\text{nm}$); I'm not looking for numerical values, but rather for the trend.

   (l) If the system is set up to image an object at ∞, what can you say about the depth of field?

2. The relationship of the the focal length and the object and image distances is:

$$\frac{1}{z_1} + \frac{1}{z_2} = \frac{1}{\mathbf{f}}$$

   Prove that the minimum separation between a real object and its real image is $4\mathbf{f}$.

3. An object is located at a distance $z_1 = \frac{\mathbf{f}}{2}$ from a lens with focal length $\mathbf{f} = +|\mathbf{f}|$. Locate the image and determine the transverse magnification. Draw the system including the locations of object and image.

4. A lens with $\mathbf{f} = +500\,\text{mm}$ is sawn into two pieces through a plane cutting through the optical axis (i.e., the cut is along a diameter). A point source of monochromatic light with $\lambda_0 = 500\,\text{nm}$ is placed on the optical axis at a distance $z_1 = 1000\,\text{mm}$ from the lens. The half lenses are gradually moved apart; each creates an image of the point source that are mutually coherent. The light is observed on a screen placed at a distance $z_2 = 2000\,\text{mm}$ from the lens (in the Fraunhofer diffraction region). Determine the period of interference fringes observed on the screen if the separation between the two lens halves is increased to $0.5\,\text{mm}$.

5. I am nearsighted and wear eyeglasses that are designed to change the location of the image (to put it on my retina) without changing the transverse magnification M_T of the system that includes the corrective lens and the eyelens.

   (a) At what location should the corrective lens be placed to ensure that M_T is the same with and without the corrective lens? Explain (diagrams may help)

   (b) I would like to have a corrective lens that also works when swimming. In other words, the system must have the same power if the refractive index in object space is both $n = 1.0$ and $n = 1.33$, while the refractive index in image space in both cases is $n = 1.0$. Explain how to accomplish this (again, diagram may help)

6. Light with wavelength $\lambda_0 = 500\,\text{nm}$ is incident from the left upon an opaque screen with two small holes separated by the distance d_0. Light through one hole then encounters a variable neutral-density (N-D) filter (shown on the right) that rotates about the axis in the plane of the paper (as shown) at a rate of ω_0 radians per second. Assume that the transmittance of the filter varies linearly with angle from $t = 0$ to $t = 1$ and then the cycle restarts.

   (a) Describe the amplitude and irradiance observed at the screen located a z_1 "down-stream" from the aperture plane in the Fraunhofer diffraction region. Be as quantitative as you can, but a qualitative description is necessary too.

   (b) If ω_0 is "large" so that the filter rotates many times per second, what will be seen at the observation plane by a human observer?