SIMG-712-90 MIDTERM Exam Open Book

Due M 1/31/2005, 4 PM EST (unless other agreement)

Select 5 of 6

1. A lens system is composed of two thin lenses separated by a variable distance t. The prescriptions for the surfaces of the two lenses are:

$$L_1 : n = 1.5,\ R_1 = +500\,\text{mm},\ R_2 = +200\,\text{mm}$$

$$L_2 : n = 1.6,\ R_1 = -100\,\text{mm},\ R_2 = -200\,\text{mm}$$

   (a) Find the focal lengths of the two thin lenses.

   (b) Find the focal length of the system formed from these two lenses in contact.

   (c) Characterize the image (i.e., tell me everything you can about it) of an object created by the system of the two lenses in contact. The object is 20 mm tall and 2 mm "deep" (dimension along the direction of the optical axis). If the depth "midpoint" of the object is **O**, then the object distance is $\overline{\mathbf{OV}} = 250\,\text{mm}$.

   (d) Find the separations t_n such that the power of the resulting lens systems are (1) $\varphi = +\frac{1}{2}$ diopters, (2) $\varphi = 0$ diopters, and (3) $\varphi = -\frac{1}{2}$ diopters.

   (e) Sketch the systems for each of the separations, showing the path traveled by a ray entering the system parallel to the optical axis (i.e., from an object an infinite distance away).

2. A reflective sphere (imagine a ball bearing) of diameter $d = 50\,\text{mm}$ acts as a spherical mirror that can be used to image objects.

   (a) Determine the focal length of the imaging "system" composed of this sphere.

   (b) Sketch the "system," including the location of the *image-space* focal and principal points (no need to do the object-space focal and principal points, but you may if you wish).

   (c) Determine the location of the input object that produces a paraxial image at the center of the sphere.

   (d) Determine the location of the input object that produces a paraxial image at the vertex of the mirror.

   (e) Determine the transverse magnification for the object-image combination in part (d).

   (f) Sketch the object, system, and image in the configuration in part (d).

3. A mercury thermometer is constructed from a cylindrical glass tube ($n = 1.5$). The outer diameter is twice as large as the inner diameter of the tube. The outer diameter is small (a few mm) and *much* smaller than the viewing distance; this means that the rays reaching the eye are approximately parallel. Determine the apparent diameter of the mercury column (i.e., the diameter of the inner wall of the glass tube) relative to the apparent outside diameter. HINT: sketch the entire "system" first.

4. Following is the prescription for a real multielement lens system with seven surfaces.

   (a) Calculate the vertex-to-vertex matrix for the system.
   (b) Locate and determine the magnification of an image of an object located 1000 mm in "front" of the front vertex (so that $\overline{\mathbf{OV}} = 1000\,\text{mm}$).
   (c) Locate the cardinal points
   (d) Locate the entrance and exit pupils (HINT: pupils are images of the stop!)
   (e) Draw the system to scale showing provisional marginal and chief rays (the chief ray should go through the center of the stop!)
   (f) (OPTIONAL, Extra Credit). If the lens system is known to have an f/number of 4 and the full field of view is 28°, determine the actual marginal and chief rays for this system if the object is at ∞

Surface↓	**Radius**	n'	t'
1	26.16 mm	1.6739	4.92 mm
2	1201.92 mm	1.0000	3.99 mm
3	−83.46 mm	1.6481	1.04 mm
4	25.67 mm	1.0000	5.53 mm
5	stop	1.0000	5.40 mm
6	302.57 mm	1.6515	2.57 mm
7	−54.79 mm	1.0000	-

5. The index of refraction of a hypothetical material is found to vary in proportion to the reciprocal of the vacuum wavelength λ_0. Determine the modulation ("group") velocity in terms of the average ("phase") velocity at a given wavelength. Does the material exhibit normal or anomalous dispersion?

6. In a diffraction experiment, a pinhole ("point") source with $\lambda = 600\,\text{nm}$ is used. The distance from this source to a diffracting aperture is 10 m and the aperture is a circular hole of diameter 1 mm. The light diffracted from the circular aperture is observed on a screen located at a variable distance from the aperture. We know that the observed diffraction falls into the category of "Fraunhofer" if the distance from the aperture to the screen is "large" and "Fresnel" if the distance is "small".

   (a) Make a case for a distance from the aperture to the screen that roughly divides between the two classes of diffraction. Note that there is no one "correct" answer; it's your argument that matters.
   (b) Sketch an approximation of the pattern observed if the distance from the aperture to the screen is 2 m. Information from the courses on Linear Mathematics may be helpful..
   (c) Consider that there are two identical point sources separated by a distance d at the source plane and the pattern is observed at the same distance of 2 m in part (b). Determine the value of d such that the two sources just be "resolved" at the observation plane.