

SIMG-303 TAKE-HOME FINAL EXAM  
DUE THURSDAY 20 MAY 2004 AT 9:30 AM in ROOM 08-2300 (Gosnell  
Building)

Open Book: you may use any sources (written or electronic), but you may NOT get help from any persons (or other carbon-based life forms, directly OR indirectly) except the instructor. Do not discuss the form, content, or degree of difficulty of the questions with anyone else (in class or not) until after the test is due.

Do all problems – point values are listed with the problem.

Staple problems together and submit *in numerical order*.

1. (30%) An imaging system is constructed of two identical thin lenses  $L_1$  and  $L_2$  with  $f_1 = f_2 = -100$  mm and diameters of 25 mm. The lenses are separated by  $t = +200$  mm and all are in air.
  - (a) Sketch the system.
  - (b) Determine the equivalent (effective) focal length of the system.
  - (c) Find the focal and principal points of the system and locate them on the sketch of part (a).
  - (d) Determine which lens is the “aperture stop” of the system and explain your reasoning.
  - (e) Locate the entrance and exit pupils of the system and find their sizes.
  - (f) USE THE DISTANCES TO THE PRINCIPAL POINTS to find the image of an object located at the point  $\mathbf{O}$  such that with  $\overline{\mathbf{OV}} = 100$  mm. Also find the transverse magnification of this image.
  - (g) USE THE “BRUTE-FORCE” METHOD (find the images created by each lens in sequence) to determine the location of the image of an object located at the point with  $\overline{\mathbf{OV}} = 100$  mm; also find the transverse magnification of the image. These answers should confirm those of the previous question.
  - (h) Determine the longitudinal magnifications of the image of the object with  $\overline{\mathbf{OV}} = 100$  mm
  - (i) Now add a third thin lens to the system that is placed in the center of the system (i.e., midway between the first two lenses) with focal length  $f_3$ . Determine the focal length  $f_3$  that creates a three-lens telescope and find its angular magnification.
  - (j) Find the focal length  $f_3$  (between  $L_1$  and  $L_2$ ) such that the focal length of the optical system is  $f_{eff} = f_3$
  - (k) (OPTIONAL BONUS) Find the focal length of the third lens (between  $L_1$  and  $L_2$ ) that generates an optical system where the two focal points coincide.
  - (l) (OPTIONAL BONUS) Find the focal length of the third lens (between  $L_1$  and  $L_2$ ) that generates an optical system where the two principal points coincide.

MORE→→→

2. (20%) For ONE of your eyes:

- (a) Use a ruler to find the APPROXIMATE distance to the closest point where you see a “clearly focused” image (this is called the “near point” of the eye). The generally accepted distance between the eye and the near point is 10 in = 254 mm, but use your own measurement in the following sections.
- (b) Determine the approximate angle that a Lincoln penny would subtend at this distance for your eye and compare it to the angular subtense for a Lincoln penny viewed at the “standard” distance for the near point. Is your eye better or less suited than the “standard” eye for performing work that requires vision of fine detail?
- (c) You are now to add an additional thin lens with focal length  $f$  that will be held between the eye and the penny to create an image of the penny at the near point of your eye. Determine the location of the lens and of the penny that produces such an image and find its transverse magnification.

3. (20%) During the term, we have seen several examples of the “superposition” of sinusoidal waves with different spatial or temporal periods. For example, we showed that:

$$\begin{aligned}\cos[\omega_0 t] + \cos[\omega_1 t] &= 2 \cos\left[\frac{\omega_0 + \omega_1}{2}t\right] \cos\left[\frac{\omega_0 - \omega_1}{2}t\right] \\ &\equiv 2 \cos[\omega_{avg}t] \cos[\omega_{mod}t]\end{aligned}$$

and extended this result to three dimensional waves to evaluate the pattern that results from two apertures via:

$$\cos[\underline{\mathbf{k}}_0 \bullet \underline{\mathbf{r}} - \omega_0 t] + \cos[\underline{\mathbf{k}}_1 \bullet \underline{\mathbf{r}} - \omega_1 t] = 2 \cos[\underline{\mathbf{k}}_{avg} \bullet \underline{\mathbf{r}} - \omega_{avg} t] \cdot \cos[\underline{\mathbf{k}}_{mod} \bullet \underline{\mathbf{r}} - \omega_{mod} t]$$

where the scalar product of two vectors is defined:

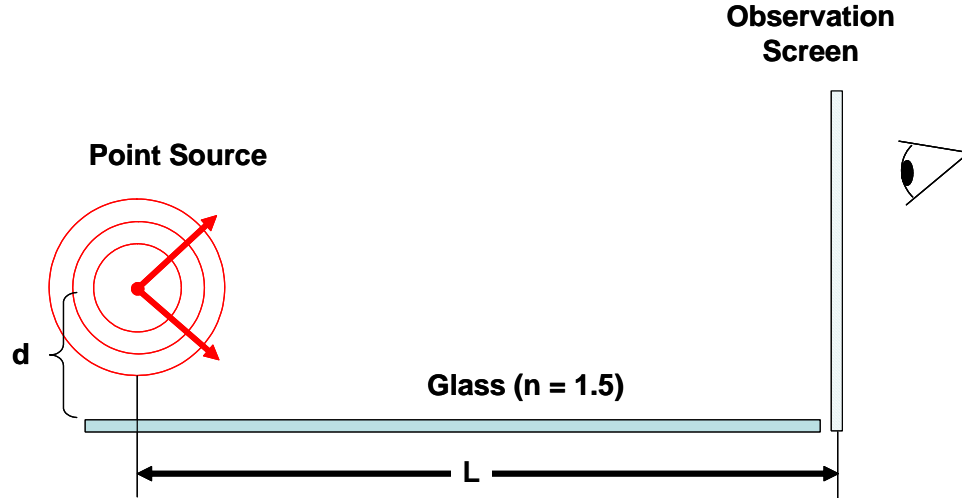
$$\underline{\mathbf{k}} \bullet \underline{\mathbf{r}} = \begin{bmatrix} k_x \\ k_y \\ k_z \end{bmatrix} \bullet \begin{bmatrix} x \\ y \\ z \end{bmatrix} = k_x x + k_y y + k_z z$$

and the length of the vector  $\underline{\mathbf{k}} = \sqrt{k_x^2 + k_y^2 + k_z^2}$ . In all of the the following, assume that  $(k_x)_0 = (k_x)_1 = 0$ .

- (a) Find an expression for and sketch the output amplitude and irradiance (intensity) if  $(k_y)_0 = -(k_y)_1$  and  $(k_z)_0 = (k_z)_1$ .
- (b) Find an expression for and sketch the output amplitude and irradiance (intensity) if  $(k_y)_0 = -(k_y)_1$  and  $(k_z)_0 = (k_z)_1$  AND if the relative phase of the two light sources is  $\pi$  radians.
- (c) Find an expression for and sketch the output amplitude and irradiance (intensity) if  $(k_y)_0 = (k_y)_1 = 0$  and  $(k_z)_0 = -(k_z)_1$ .
- (d) Find an expression for and sketch the output amplitude and irradiance (intensity) if  $(k_y)_0 = -(k_y)_1$  and  $|\underline{\mathbf{k}}_0| \neq |\underline{\mathbf{k}}_1|$ .

MORE→→→

4. (20%) Consider the system shown below that consists of a point source of light with wavelength  $\lambda_0 = 632.8 \text{ nm}$  that is located a distance  $d$  above the reflecting surface of a sheet of glass with  $n = 1.5$ . The observation screen has a diffusing surface that allows the eye to view the pattern of light from the source. The distance  $L$  from the point source to the observation screen is “large”.



- (a) Describe what the eye sees if the observation screen is removed and the eye is focused on the point source.
- (b) Describe and sketch what the eye sees on the observation screen. Be as quantitative as possible.
- (c) What happens to the observed light if the “height”  $d$  of the source above the mirror is varied (increased or decreased).
5. (10%) Sometimes exams don’t cover the aspects of the subject that you studied most carefully or in which you have the greatest interest. For that reason, I offer this “free” question; write your own problem or describe an optical system, effect, or theorem of your choice that we studied and describe its relevance to imaging (excluding those already included in the problems above). For example, you could consider the phenomenon of diffraction and its effect on an imaging system. You will be judged on both the suitability and caliber of the question and of the answer.