

SIMG-303-20033      IN-CLASS FINAL EXAM

Do all problems – point totals are given. Staple problems together and submit *in numerical order*.

1. (40%) An imaging system is constructed of two identical thin lenses  $L_1$  and  $L_2$  with  $f_1 = f_2 = -50$  mm. The lenses are separated by  $t = +100$  mm and everything is 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 the position and transverse magnification of the image of an object located at the point  $\mathbf{O}$  such that with  $\overline{\mathbf{OV}} = +50$  mm.
  - (e) 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”.
  - (f) OPTIONAL BONUS: Evaluate the effective focal length of the system if the lens with the focal length you derived in part (e) is placed between  $L_1$  and  $L_2$  a distance  $\ell$  “behind” the first lens and a distance  $t - \ell = 100$  mm “in front” of the second lens. Your expression for  $f_{eff}$  will be a function of  $\ell$ .
  
2. (20%) We derived an expression for the sum of two oscillations with the same amplitude and different oscillation frequencies:

$$\cos[\omega_0 t] + \cos[\omega_1 t] = 2 \cdot \cos[\omega_{\text{mod}} t] \cdot \cos[\omega_{\text{avg}} t]$$

Extend this concept to consider the sum of two three-dimensional nondispersive TRAVELING plane waves that have unit amplitude. The first wave travels in the direction specified by:

$$\underline{\mathbf{k}}_1 = \begin{bmatrix} (k_x)_1 \\ (k_y)_1 \\ (k_z)_1 \end{bmatrix}, \text{ where } |\underline{\mathbf{k}}_1| = \sqrt{(k_x)_1^2 + (k_y)_1^2 + (k_z)_1^2} = \frac{2\pi}{\lambda_1}$$

where  $(k_x)_1, (k_y)_1, (k_z)_1$  are respectively the  $x, y,$  and  $z$  components of the first wave vector. The second plane wave travels in the direction (NOTE INDICES)

$$\underline{\mathbf{k}}_2 = \begin{bmatrix} (k_x)_2 \\ (k_y)_2 \\ (k_z)_2 \end{bmatrix} = \begin{bmatrix} -(k_x)_1 \\ -(k_y)_1 \\ (k_z)_1 \end{bmatrix}, \text{ where } |\underline{\mathbf{k}}_2| = \frac{2\pi}{\lambda_2}$$

- (a) If  $\lambda_1 = \lambda_2$ , find an expression for the amplitude AND the irradiance (intensity) of the resulting electric field viewed at some distance down the  $z$  axis towards  $z = +\infty$ .
- (b) Describe the QUALITATIVE difference that will result if  $\lambda_1 \neq \lambda_2$ .
- (c) OPTIONAL BONUS: Find the QUANTITATIVE expression for the sum of the two traveling waves in part (b).

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3. (15%) Explain the conditions that must exist for a negative lens to create a real image. Repeat for a positive lens that creates a virtual image. Illustrate with sketches.
  
4. (15%) A linearly polarized plane wave travels down the  $z$  axis and its electric field is directed along the  $x$  axis of the coordinate system. Describe TWO different ways for creating elliptically polarized light from this wave. You may use any of the optical components that we considered in class and/or lab, but specify any critical parameters (e.g., angles of linear polarizers relative to the axes, etc.). Use sketches to illustrate your answer.
  
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 this quarter and describe its relevance to imaging. Obviously the phenomena already included in the problems above are excluded for your choice. For example, you could consider the phenomenon of diffraction and its effect on an imaging system. Your score will reflect the suitability of both the question and of the answer.