SIMG-733 Optics-20092 Midterm Exam

CLOSED BOOK, NO calculators
Standard hint: make sketches before writing equations; label axes.
SELECT ANY FIVE (5) PROBLEMS (equal weight though not equal difficulty)
Staple problem submissions IN NUMERICAL ORDER (lest you risk my wrath – or is it "wrisk my rath?")

1. In the homework, you demonstrated that the cascade of propagation of light from a 2-D function $f[x,y]$ over the distance z_1 in the Fresnel region, followed by second propagation over the distance z_2 in the Fresnel region yields the same result as a propagation of light from $f[x,y]$over the distance $z_1 + z_2$. Consider the 1-D case, i.e., consider propagation of light from the 1-D function $f[x]$ over the distances z_1 and z_2. Is this propagation equivalent to that over the distance $z_1 + z_2$? Explain.

2. Images of objects at different distances from the optic are created by a lens with a certain focal length $\mathbf{f}_1 = 50\,\text{mm}$ and aperture diameter $d_1 = 35\,\text{mm}$. The lens is used in monochromatic light with wavelength $\lambda_0 = 0.5\,\mu\text{m}$. The lens is used to image an object with "depth", i.e., its distance from the lens ranges from $(z_1)_{\text{far}}$ to $(z_1)_{\text{near}}$. Alternatively, you could consider several objects in the field of view at distances in this interval.

   (a) Explain the concept of "depth of field" for this lens, use diagrams.

   (b) Explain the effect of "stopping down" the lens (reducing the diameter of the aperture while maintaining the image distance).

   (c) Describe the effect of stopping down the lens on the "quality" of images obtained of an object at the distance z_1 that exactly satisfies the imaging equation for a fixed focal length $\mathbf{f}$ and fixed image distance z_2; in other words, what are the relative "qualities" of the images before and after stopping down the lens.

3. Determine the forms of the Fraunhofer diffraction patterns for an aperture function consisting of transparent circular holes is similar to that for the "complementary aperture," i.e., replace the transparent holes with opaque circular spots and opaque background with a transparent background.

4. Construct an aperture function $p[x,y]$ that, if acting on coherent (monochromatic) light will produce an output amplitude $g[x,y]$ of the form:

$$g[x,y] \cong \frac{\partial}{\partial x} f[x,y]$$

   Describe how a practical such aperture may be constructed from glass, etc., and also describe any limitations in the success of the result.

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5. Light with wavelength λ_0 propagates from a point source located on axis at a very large distance "to the left" of the plane $z = 0$, i.e., at some coordinate $z \ll 0$. The wavefronts from the source observed at the origin are appropriatedly modeled as plane waves; assume that the amplitude of the sinusoidal oscillations is 1. The "aperture" at the plane $z = 0$ is a square with side dimension of 25 mm. Within the square, the aperture function consists of alternating transmitting and opaque regions with equal widths of $10\,\mu$m. The light transmitted through the aperture then traverses a large distance z_2 to the observation plane in the Fraunhofer region.

   (a) Write down an equation for and sketch $t[x, y]$; label relevant quantities.

   (b) Derive the expression for the amplitude pattern observed at the distance z_2 from the aperture. Include relevant numerical factors in the expression. You need not sketch this, but it may help to do so.

   (c) Evaluate AND SKETCH the irradiance pattern at the same location.

   (d) Describe in words AND SKETCH the irradiance pattern that would be observed if the point source radiates the same amplitude at different wavelengths λ spanning the entire visible spectrum.

6. An object $f[x, y]$ is illuminated by a monochromatic plane wave with wavelength λ_0. *Immediately after* the object is a lens with focal length $\mathbf{f}$ whose diameter is sufficiently large so that all light transmitted through the object passes through the lens; in other words, the lens is in contact with the object. The light propagates a distance $z_2 = \mathbf{f}$, where it encounters an identical lens with focal length $\mathbf{f}$. The observation plane immediately follows (is in contact with) the lens.

   (a) Sketch the system.

   (b) Determine the amplitude and irradiance patterns at the observation plane in terms of the parameters of the system and $f[x, y]$.

7. Consider two monochromatic point sources emit radiation with wavelength λ_0 and the same phase. The sources are separated by distance d_0 along the y-axis. Light emitted by from one of the sources immediately passes through a pane of glass with refractive index n_0, thickness ℓ_0, and plane-parallel sides. The thickness is such that to the light emerging from the glass is exactly out of phase relative to the light from the other source. Light from both sources then propagates a distance z_2 to the observation plane.

   (a) Determine the thickness ℓ_0 of the glass and comment on the practicality of using glass to induce the phase delay.

   (b) Determine the irradiance pattern observed if the distance z_2 is in the Fresnel diffraction region.

   (c) Determine the irradiance pattern observed if the distance z_2 is in the Fraunhofer diffraction region.

   (d) (OPTIONAL BONUS) Describe how you can create a "practical" pane of glass that induces an appropriate phase delay in the light from one source.