Final Exam 3 – PHYS 355 - OPTICS

Mendes, Fall 2009, Dec 09, 2009

Start time: 8:00 a.m.

End time: 10:30 am

Open textbook, classnotes, homeworks, and quizzes

Calculators allowed; no other electronic device allowed

Where it is appropriate, make sure to provide physical units to your numerical answer
1) A bi-convex lens is made from a glass of refractive index $= 1.52$ and has radii of curvature given by $|R_1| = 16 \, cm$ (for surface 1) and $|R_2| = 200 \, cm$ (for surface 2). The central thickness of the lens is 6 cm, which is too thick for the thin-lens approximation. The lens is surrounded by air.

!(image)

(5 points)
a) Calculate the effective focal length of the lens.

(5 points)
b) Calculate the back focal length of the lens.

(5 points)
c) Calculate the front focal length of the lens.

(10 points)
d) If an object is placed at 100 cm to the left of surface 1 (as indicated in the Figure), determine the position of the corresponding image with respect to surface 2?

(3 points)
e) What is the transverse magnification $m_r$ for this particular imaging configuration? Is the image magnified $|m_r| > 1$ or de-magnified $|m_r| < 1$?

(2 points)
f) Is the image upright $m_r > 0$ or inverted $m_r < 0$?
2) Consider an opaque screen with a circular aperture of radius 0.02 cm illuminated by normally incident monochromatic plane waves of wavelength $\lambda = 600 \text{ nm}$.

(5 points)

a) Calculate the angle of the first two dark rings of the Fraunhofer diffraction pattern produced by the circular aperture.

(5 points)

b) If a lens with an effective focal length of 20 cm is placed after the circular aperture, determine the radii of the first two dark rings at the back focal plane of the lens.
3) Typical microscope objectives are well designed so that their optical aberrations are reduced to a minimum. Therefore, consider here microscope objectives that are diffraction-limited in their optical resolution. What is the minimum feature size you can expect to resolve with each of the following microscope objectives using visible light ($\lambda = 550 \text{ nm}$):

(5 points)

a) 10X, N.A. = 0.25 (as conventionally described by most vendors, the first number refers to the magnification of the microscope objective; the second number refers its numerical aperture).

(5 points)

b) 40X, N.A. = 0.65
4) A beam of monochromatic light is incident from air \((n_a = 1.00)\) onto water \((n_w = 1.33)\). The optical beam impinges the water surface at an oblique angle of 53° with respect to the normal of the water surface.

(15 points)
(a) Determine the transmittance into water of s-polarized light.

(15 points)
(b) Determine the transmittance into water of p-polarized light.

(10 points)
(c) Consider that the incident beam in air has an optical intensity of 500 W/m². If the incident beam is unpolarized, we can consider that half of the optical intensity is under s-polarization and the other half is under p-polarization. Based on this, determine the total optical intensity (W/m²) of the optical beam transmitted into water?
5) This problem describes why gold looks yellowish. At 654 nm (red), the complex refractive index of gold is given by: $0.166 + j3.15$. On the other hand, at 400 nm (violet) the complex refractive index of gold is: $1.658 + j1.956$. Calculate the reflectance of a gold surface at those two wavelengths. Assume that light is incident from air at normal incidence.