University of Calgary
Winter semester 2008

PHYS 471: Optics

Final examination

April 24, 2007, 12.00–15.00 (3 hours)

Open books. Try all problems. Calculators permitted.
All answers must be given in both symbolic and numeric forms.

Total points: 100.

Problem 1. (15 pts) Make an order-of-magnitude estimate of the mean electric field amplitude in a laser pulse containing one photon. The geometric radius is $w = 1$ mm, pulse duration $\tau = 10^{-12}$ s, wavelength $\lambda = 1$ μm.

Problem 2. (20 pts) We observe interference of beams of powers P and $100P$ obtained from the same laser.

a) Find the visibility in the case of perfect mode matching.

b) Find the visibility if the beams are polarized linearly at angle $\theta = 60°$ with respect to each other.

Problem 3. (10 pts) Calcite is a birefringent material with $n_o = 1.65$, $n_e = 1.49$. Light is propagating through a calcite prism as shown in the figure. Find the range of angles α such that one of the polarizations (horizontal or vertical?) will experience total internal reflection at the back surface of the prism, and the other will be partially transmitted.

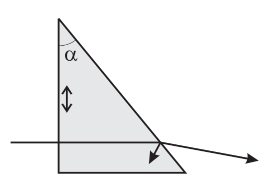

Figure 1: diagram for Problem 3. The double arrow is the crystal's optic axis.

Problem 4. (15 pts) A laser beam with a $1/e^2$ radius of $w = 1$ mm propagates through a long horizontal slit of width $a = 0.1$ mm. Write an expression for the two-dimensional Fraunhofer diffraction pattern intensity $I(x, y)$ on a screen located $L = 10$ m away. Neglect the overall coefficient.

Problem 5. (10 pts) Two-slit interference of light is observed. Behind the slits there are two identical cuvettes filled with air. When the pressure of air in one of the cuvettes is varied, the interference fringes displace. A displacement by one-half of the fringe period occurs when the pressure difference is $\Delta p_1 = 1$ Pascal. Estimate the pressure difference Δp at which the fringes will disappear completely if the laser source has a relative spectral width of $\Delta\omega/\omega = 10^{-5}$, ω being the central frequency.

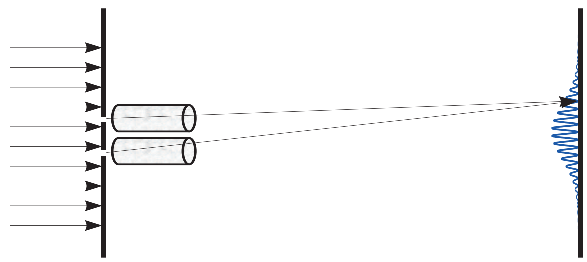

Figure 2: diagram for Problem 5.

Problem 6. (30 pts) Consider a photocamera whose lens has a focal length $f = 0.05$ m and an aperture $a = 0.01$ m. The camera is aligned to produce a geometrically perfect image of a point object located at $s = 1$ m on the film.

a) Find the distance s' between the lens and the film. **Hint:** Because s' is close to f, it is easier to find the small quantity $s' - f$. You can restrict the calculation to the first nonvanishing order.

b) The image will in fact have a finite width d due to diffraction. Estimate this width assuming a reasonable wavelength λ.

c) In order to estimate the depth of field of the camera, consider another point object located at distance $l > s$ from the lens. Because the camera is not focused on this object, its geometric image will be smeared. Using geometric considerations, find the size b of the smear as a function of l and other parameters of the system (approximate if necessary). If l is not too high, b does not exceed d, so the image of the second object will be as clear as the image of the first, even though it is geometrically not in focus. The corresponding range of values of l is the camera's depth of field.

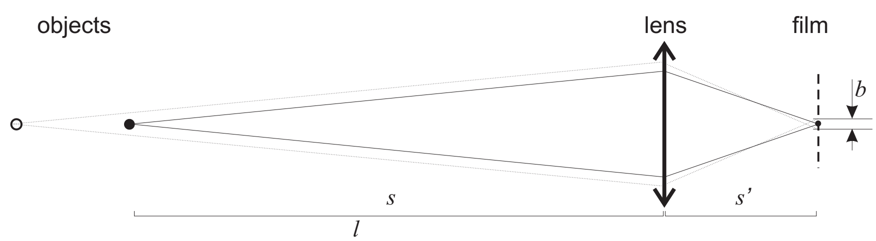

Figure 3: diagram for Problem 6.