University of Calgary
Winter semester 2007

PHYS 471: Optics

Final examination

April 23, 2007, 15.30–18.30 (3 hours)

Open books. Answer all questions. Calculators permitted.

Total points: 100.

Problem 1. (15 pts) In a conventional microscope, two convex lenses with focal lengths $f_1 = 10$ mm (objective) and $f_2 = 50$ mm (eyepiece) are separated by a distance of $L = 100$ mm. The object of size $d = 0.1$ mm is located $d = 12$ mm in front of the objective.

a) Draw a ray diagram (you can use this sheet).

b) Determine the position and size of the intermediate and final images.

Figure 1: diagram for Problem 1.

Problem 2. (10 pts) A horizontally polarized laser beam passes through a half-wave plate and enters a polarizing beam splitter cube (which transmits horizontal polarization and reflects vertical). Find the transmitted and reflected intensities as a function of the angle between the wave plate's optical axis and the horizontal.

Problem 3. (15 pts) A horizontally polarized laser beam passes through a $\lambda/4$ waveplate with its slow axis oriented at $45°$ to horizontal. The beam then undergoes normal reflection at a mirror and propagates back through the same waveplate. Write the Jones vectors and provide a verbal description of the field

- before the waveplate;
- after the first passage through the waveplate;
- after the reflection;

- after the second passage through the waveplate.

Note: there is no penalty for confusing the left and right circular polarizations as long as your answers are consistent with each other.

Problem 4. (10 pts) A policeman stops a driver for running a red light. The driver argues that because of the Doppler effect, the red light appeared green. Estimate the speeding fine the driver will have to pay if it is \$100 for every 10 km/h above the speed limit.

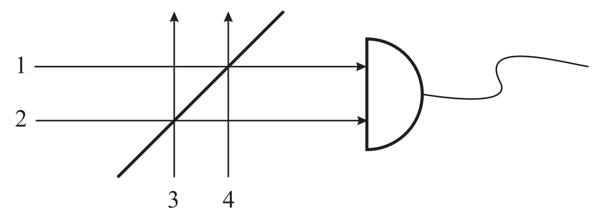

Figure 2: diagram for Problem 5.

Problem 5. (15 pts) Two pairs of laser beams interfere on a symmetric beam splitter as shown in Fig. 2. The power of beam 1 is 1 mW, beam 2: 2 mW, beam 3: 3 mW, beam 4: 4 mW. The optical phases of the beams in each pair are the same, but the phase difference between the pairs is varied. All four beams have the same wavelength. Find the visibility of the interference pattern observed with the photodiode.

Note: the visibility in this context is $V = (i_{\min} - i_{\max})/(i_{\min} + i_{\max})$, where i is the photocurrent proportional to the total optical power incident on the diode.

Problem 6. (10 pts) The objective lens of a digital camera has a focal length of $f = 1$ cm and a relative aperture (ratio of the focal length and the diameter) $A = 8$. The size of the CCD pixel array is $a \times b = 1 \times 0.75$ cm^2. In order to improve the resolution, we try to increase the number of pixels while reducing the size of an individual pixel. Estimate the optimum pixel size such that further reduction will not help improve the resolution. How many megapixels does this correspond to? What is the angular resolution of this camera?

Problem 7. (25 pts) A gain medium of gain coefficient γ and length L is inserted into a lossless linear Fabry-Perot cavity whose mirrors have amplitude reflectivity r. The cavity operates below the oscillation threshold; the saturation is negligible ($I_S \to \infty$).

a) Calculate the transmission line shape, finesse, FWHM line width and the minimum/maximum transmission coefficients.

b) Calculate the threshold gain γ_{th} for this cavity.

c) What happens to the answers of part (a) if $\gamma = \gamma_{th}$?