Exercises for the final Exam, Physics 330, Modern Experimental Optics

Schedule: Thursday 12/06/2007, optics lab 405 Clark Hall, 9:00-11:30.

Question 1: 1P

The optical density has been measured from a reflection coefficient $R = (\frac{n-1}{n+1})^2$ by 4 different people using 4 different setups, and the following values of R were obtained with the indicated estimated error σ_R. Perform an error analysis and determine the resulting value for n and the error estimate for σ_n for each experiment. To obtain the final result for n and its error estimate, weigh each measurement according to its error. Writing formulas is sufficient here, you do not have to perform the numerical calculation.

$R(\%)$	$\sigma_R(\%)$
4	$\pm$ 0.1
9	$\pm$ 0.1
4	$\pm$ 0.1
1	$\pm$ 0.1

Question 2: 1P

A thin wedge of glass is placed in one of the arms of a Michelson interferometer in which plane waves propagate. Find an expression for the index of refraction n of the glass wedge using the number of fringes per meter N and the angle of the wedge ϕ.

Question 3: 1P

A laser beam in vacuum with irradiance of $I = 5\text{mW}/(\text{mm})^2$ is incident onto a mirror. What is the radiation pressure, i.e. the force per unit area on this mirror.

Question 4: 1P

Describe why an observer on the earth observes light from the sun that is scattered in the atmosphere as polarized. Make a sketch showing in which direction it is polarized.

Question 5: 1P

If a plane wave with wavelength λ in a medium of optical density n_1 is incident with the angle ϕ on the surface of a medium with optical density n_2, under what condition can an evanescent wave be produced? At what distance from the surface will its intensity have diminished to $1/e$ of its initial intensity?

Question 6: 1P

Underline all correct statements:

∘ All focusing lenses are convex. All focusing lenses are concave. Focusing lenses can be concave.

∘ An arrangement of focusing and defocusing lenses that focuses light coming from the right cannot defocus light coming from the left.

∘ A vertically positioned cylindrical glass rod in air focuses in the horizontal and neither focuses nor defocuses in the vertical direction. Two cylindrical glass rods can be arranged to focus a beam of light simultaneously in the horizontal and in the vertical dimension, transverse to its direction of propagation.

∘ A 4-f arrangement of lenses magnifies by a factor of 4. A 4-f arrangement of lenses magnifies by a factor of 1/4. A 4-f arrangement of lenses does not magnify. A 4-f arrangement of lenses consists of 4 lenses.

∘ An object that is located in front of a focusing lens can produce a virtual image that is also in front of the lens. An object that is located in front of a focusing lens can produce a virtual image that is behind the lens. An object that is located in front of a focusing lens always produce a real image that is behind the lens.

Question 7: 1P

Draw the shape of a glass capillary for x-rays which focuses light from a point source to an image point. Can you describe this shape with an equation? (A capillary is a narrow, empty tube of glass.)

Question 8: 1P

A laser beam has a minimum beam waist of $D_0 = 2$mm and a divergence of $\theta = 10$mrad. Its beam size changes according to $D(s) = \sqrt{D_0^2[1 + (\theta \frac{s-s_0}{D_0})^2]}$. If the beam is expanded so it has a waist of 20mm, what divergence would this beam have?

Derive the phase-space transport matrix of a Galilean beam expander and of a Keplerian beam expander.

Describe a setup to measure the astigmatism of a lens. The astigmatism coefficient A is given by the following relation between the initial trajectory in the horizontal and vertical (x_i and y_i), and the angles $\Delta x'$ and $\Delta y'$ produced by the lens,

$$\Delta x' + i\Delta y' = -\frac{1}{f}(x_i + iy_i) + A(x_i - iy_i) \tag{1}$$

where f is the focal length of the lens. How far apart are the two focal lines behind this lens when a parallel beam of light is incident.