NTNU
Norwegian University of Science and Technology

Department of Physics

Examination paper for TFY4195 Optics

Academic contact during examination: Prof. Emil J. Samuelsen
Phone: 4824 4832

Examination date: Dec 20, 2016
Examination time (from-to): 09.00 – 13.00
Permitted examination support material: Level C, Specified printed and hand-written support material is allowed: K. Rottmann, 'Matematisk formelsamling'; S. Barnett & T. M. Cronin, 'Mathematical Formulae'; O. Øgrim & B. E. Lian, 'Størrelser og enheter I fysikk og teknikk'. English dictionary. A specific basic calculator is allowed (empty memory).

Other information: The exam was prepared by Prof Mikael Lindgren in collaboration with Prof Emil J. Samuelsen.

Language: English (answer in Norwegian allowed)
Number of pages (front page excluded): 2
Number of pages enclosed: 3 pages (formulas)

Informasjon om trykking av eksamensoppgave
Originalen er:
1-sidig X **2-sidig** ☐
sort/hvit X **farger** ☐
skal ha flervalgskjema ☐

Checked by:

Date Signature

Problem 1: Light as an electromagnetic wave. The electric field component of an electromagnetic light-wave propagating in vacuum can be described by the following expression:

$$\bar{E}(x,y,z,t)=\frac{1}{\sqrt{10}}(\hat{x}-3\hat{y})\cos\left(1,26\cdot10^{7}z-3,77\cdot10^{15}t\right)\left[\frac{V}{m}\right]$$

The position coordinate has unit [m], the time unit [s].

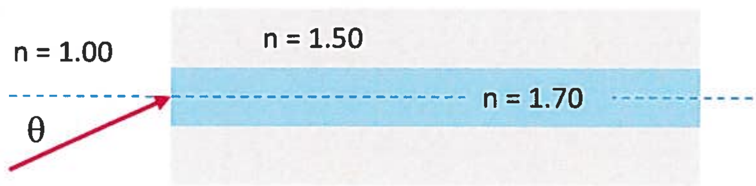
a) Determine the: propagation direction, wavelength and frequency.
b) Give an expression for the associated magnetic field.
c) Write an expression for the corresponding Jones vector describing the polarization state.
d) Assume that the light passes a so-called 'quarter-wave plate' with the slow axis horizontal ($\hat{x}$). Determine the resulting Jones vector and sketch the corresponding polarization ellipse.

Problem 2: Thin lenses and imaging. Monica found two lenses with no labels and she needs to determine their focal lengths. She has access to a rail with two lens holders, a movable screen and a fixed object 15 cm in front of the first lens holder. She first inserts lens 1 in the closest holder and obtains an inverted magnified (x2) image 30 cm behind the lens. Secondly she inserts the 2nd lens in holder #2, placed 20 cm behind the first lens. Now she obtains again a magnified (x4) inverted image, this time 20 cm behind the 2nd lens.

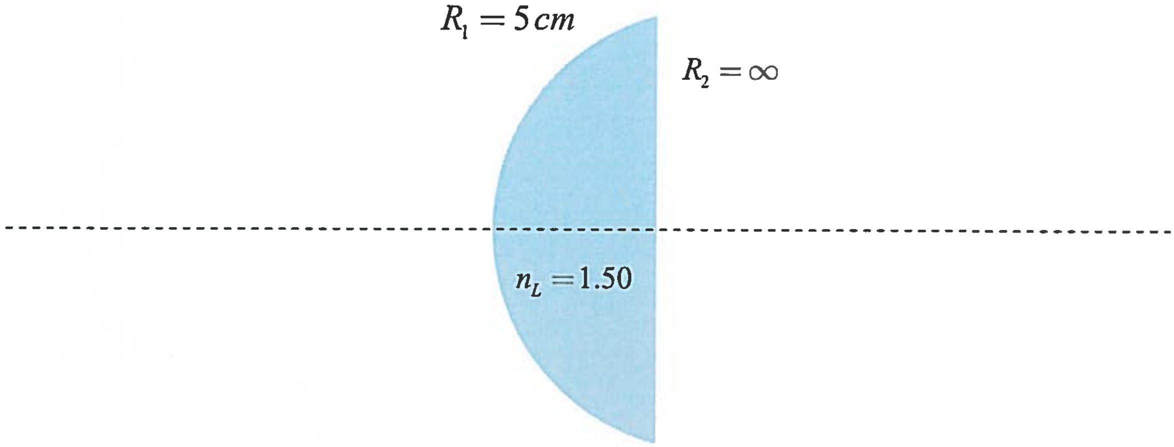
a) What are the focal lengths of the lenses?
b) Verify by drawing the ray-tracing of the set-up with both lenses.

Problem 3: Snell's law and reflections. Cleo wants to introduce a thin beam of linearly polarized laserlight into a multimode fiber. The fiber is of step-index type, and has core refractive index 1,70 and the index of the cladding is 1,50.

a) At the start of the fiber, what is the range of incident angles possible to excite wave guiding modes in the fiber?
b) What angle of incidence should be used in order to maximize the optical power launched into the fiber?



Problem 4: Optical systems and ray tracing.
a) By using the ray-transfer matrix, determine the cardinal points ($F_1;F_2;H_1;H_2;N_1;N_2$) for a hemispherical glass lens as shown below. The thickness of the lens is 2,0 cm.



b) You want to use it as a magnifying glass. Determine where (on the left side) to place an object in order to obtain a magnified (virtual) image approximately 25 cm from the lens? What will be the magnification?
c) Ray-trace the position of the image, indicate where the viewer shall be placed.

Problem 5: Coherence and diffraction. A mercury lamp gives out a broad wide spectrum with several distinct narrow lines. The green line (λ = 546,1 nm) is separated out using a filter, resulting in a spectral line-width of δλ = 0,050 nm, according to the technical specifications.

a) Ole wants to check the corresponding coherence length using the Michelson spectrometer in the optics lab. How shall he set-up and carry out the experiment, and what should he expect? (Hint: For longitudinal coherence the following formula applies: $l_c = c \cdot \tau_c$, coherence time is related to the spectral width $\tau_c = 1/\Delta f$.)

Ole wants to carry out a diffraction experiment and focusses the filtered green light of the mercury lamp onto a thin pinhole. At an appropriate distance behind the pinhole he places a construction with two slits of width 10 μm and separation 40 μm. He intends to record the diffraction pattern at a distance 1,0 m behind the aperture.

b) Is the distance 1,0 m 'safe' in order to observe the far field diffraction pattern (Fraunhofer diffraction)? Motivate your answer.
c) Sketch the diffraction pattern and specifically the positions and magnitude of maxima in the central diffraction lobe.