



Norwegian University of
Science and Technology

Department of Physics

Examination paper for TFY4195 Optics

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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 ☒ **2-sidig** ☐

sort/hvit ☒ **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:

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

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

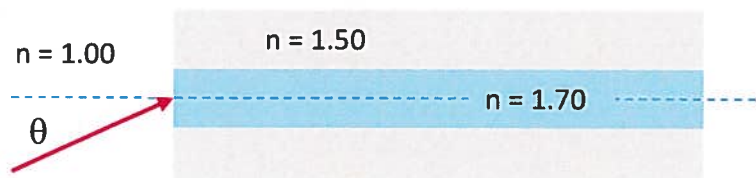
- Determine the: propagation direction, wavelength and frequency.
- Give an expression for the associated magnetic field.
- Write an expression for the corresponding Jones vector describing the polarization state.
- Assume that the light passes a so-called 'quarter-wave plate' with the slow axis horizontal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

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

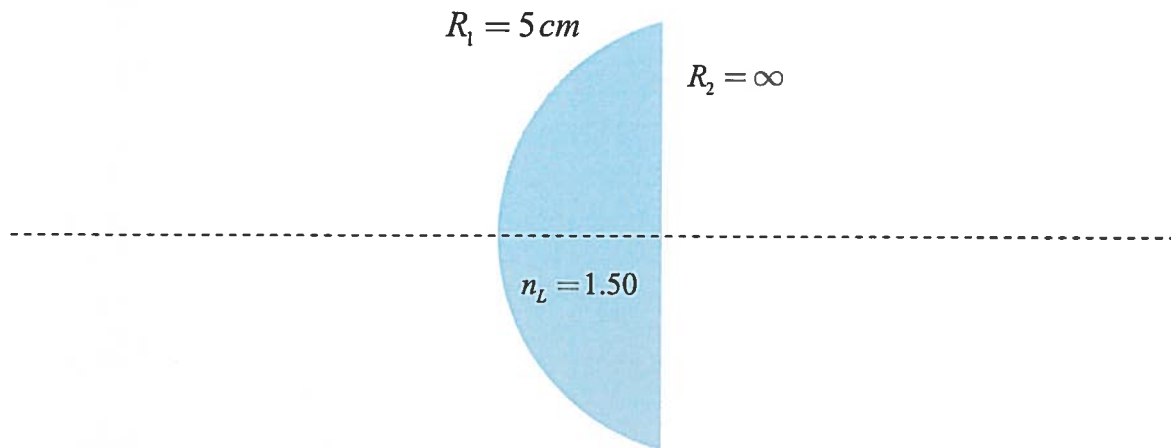
Problem 3: Snell's law and reflections. Cleo wants to introduce a thin beam of linearly polarized laserlight into a multimode fiber. The fiber is of step-index type, and has core refractive index 1,70 and the index of the cladding is 1,50.

- At the start of the fiber, what is the range of incident angles possible to excite wave guiding modes in the fiber?
- 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 ($\lambda = 546,1 \text{ nm}$) is separated out using a filter, resulting in a spectral line-width of $\delta\lambda = 0,050 \text{ nm}$, 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 $10 \mu\text{m}$ and separation $40 \mu\text{m}$. 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.