EXAMINATION SUBJECTS

Optics I – Foundations and Applications (FYSS375)

Date: Friday, 05.11.2010, 12:00 a.m. – 16:00 p.m.

Requirement: each of the 5 subjects (problems) has to be solved on a separate set of pages.

1: Theoretical part – General questions (10.0p)

Answer the following questions and formulate your answer as precise as possible:

a) What is the difference between a natural phenomenon and a physical phenomenon? **(0.5p)**

b) What is the relation between an observer and an interaction? **(0.5p)**

c) What is the difference between the concept of field in classical mechanics and the concept of field in the theory of relativity? **(0.5p)**

d) What is the difference between visual photometry and physical photometry? **(0.5p)**

e) Write down the eikonal equation and explain it. How is it obtained, *i.e.*, through what approximations and assumptions, and why is it important in optics? **(1.0p)**

f) What is the difference between a plane wave and a monochromatic plane wave? (define both of them, explain the differences and why we can make these approximations) **(1.0p)**

g) Explain the notion of *degree of polarization* and the quantities that appear in the formula. Why is is necessary to introduce such a notion? **(1.0p)**

h) Define the phenomena of interference. **(1.0p)**

i) Explain the notions of $\mathcal{P}-$state, $\mathcal{R}-$state, $\mathcal{L}-$state of polarization and also the reason why the last two are important in the quantum description of light.**(1.0p)**

j) What are the ranges of applicability of Fraunhofer and Fresnel diffraction theories for an aperture of $0.5mm$ and a wavelength $\lambda = 550nm$? **(1.0p)**

k) Explain the notions of *normal dispersion* and *anomalous dispersion*. What are the conditions for which anomalous dispersion can be observed in experiments? **(1.0p)**

l) In the context of optics of crystals (or optics of solids), define and explain the notion of *optic axis*. **(1.0p)**

2: Theoretical part – Own choice (15.0p)

Treat *in extenso*[1] the theoretical subject that is your $\mathbf{3}^{rd}$ choice in the e-mail sent to the assistant or the lecturer before the exam.

[1] *in extenso* - in full, at length

3: Exercise part – Transformations of the electromagnetic field (10.0p / 5.0p per question)

Consider a transformation in the x-direction of two reference frames S and S' with $\mathbf{V}$ being the relative velocity of the two coordinate frames.
a) Using the Lorentz coordinate transformations, show that the form of the wave equation for electromagnetic waves

$$\frac{\partial^2 E(x,t)}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 E(x,t)}{\partial t^2} = 0$$

is the same in both reference frames.
b) Why does this imply that the speed of light is the same in both systems?

4: Exercise part – Interference (10.0p / 5.0p per question)

A white piece of paper is placed in the way of *monochromatic light* with wavelength λ. An interference pattern

$$I(x) = I_0\left(1 + \cos\left(\frac{2\pi x}{\Lambda}\right)\right)$$

is observed on the paper, where I_0 = constant (units of optical intensity) Λ = constant (units of distance) and x is a distance coordinate measured on the paper.
a) Describe, quantitatively, two fields that could have led to the same observations on the paper.
b) Describe an experimental way by which one can determine which one of the two other proposed fields is illuminating the observation screen.

5: Exercise part – Polarization (15.0p)

An elliptically polarized light beam given by

$$\mathbf{E}(z,t) = \hat{\mathbf{i}}E_0\sin(kz - \omega t) + \hat{\mathbf{j}}E_0\sin(kz - \omega t + \pi/4)$$

passes normally through an ideal linear polarizer whose transmission axis is tilted at 45 degrees in the xy-plane. Write an expression for the emerging beam (irradiance) and describe its state of polarization.

Hint: To find the transmitted component of $\mathbf{E}$, you may find useful to form a unit vector along the transmission axis of the polarizer, *i.e.*,

$$\hat{\mathbf{a}} = \frac{1}{\sqrt{2}}(\hat{\mathbf{i}} + \hat{\mathbf{j}})$$

Total: 60 points