NTNU – Trondheim
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Department of Physics

Examination paper for Optics TFY4195

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Permitted examination support material: Level C, specified printed and handwritten references allowed. Scientific calculator according to NTNU regulations. Physics and mathematics tables e.g., Matematisk formelsamling (Rottmann), Fysikaliske størrelser (Øgrim), BETA Mathematics Handbook (Råde; Westergren), Fysiske størrelser og enheter (Angell; Lian) **.**

Other information: The examination problems were reviewed by Prof Emeritus Emil J. Samuelsen and Prof Morten Kildemo during translation to *bokmål* and *nynorsk*.

Language: English

Number of pages: 3

Number of pages enclosed: 4 (formulae)

Checked by:

Date Signature

Problem 1: Circularly polarized light from air (*n* = 1.00) is incident onto a glass surface with refractive index 1.54. The angle of incidence is 57.0^{o}

a) How much of the total power/irradiance is transmitted into the glass side?
b) What is the polarization of the reflected light?
c) Show that the sum of the reflected and transmitted power/irradiance is equal to the incident power/irradiance.
d) If the angle of incidence is 0^{o}, perpendicular to the glass surface, how much light intensity is reflected?

Problem 2: There is a bowl, just as the one outside cantina in *Realfagbygget*, filled with a liquid with refractive index 4/3, close to that of water. The bowl diameter is 50 cm and the glass walls can be neglected, i.e., the liquid can be regarded as being in air (n = 1).

a) The paraxial approximation applies, compute the ray-transfer matrix for the optical system (suppose it to be spherically symmetric).
b) Determine the principal planes as well as the focal points.
c) The system is used to focus an image of the sun onto a curved metal screen, creating patterns reflecting the variation of sun over time and sun position. Why is the metal screen curved, what is the curvature radius and where should it be located with reference to the bowl.

Problem 3: i) Show that the number of bright fringes seen under the central diffraction peak in a double-slit experiment is given by 2(a/b) – 1, where *b* is slit width and *a* is slit separation. ii) if 15 bright fringes are seen in the central diffraction peak when the slit width is 0.30 mm, what is the slit separation?

Problem 4: For a slab waveguide the dispersion relation for the TE (transverse electric) mode can be written: $\frac{2\pi b}{\lambda}\sqrt{n_1^2 - N^2} - 2\cdot\tan^{-1}\sqrt{\frac{N^2 - n_2^2}{n_1^2 - N^2}} = m\cdot\pi$, where b is the slab thickness, n_1 the refractive index of the guide layer, n_2 of the two surrounding cladding layers, λ the wavelength of the light, and N the mode 'propagation index'.

a) How many TE modes are there if n_1 = 1.6, b = 1.2 μm, n_2=1.48 and λ = 632 nm.
b) Sketch the approximate electric field distribution for the lowest TE mode (0'th mode) and the two associated magnetic field distributions. Assume z is propagation direction and the x –axis is perpendicular to the flat slab geometry.
c) Sketch the approximate 3 field distributions for the next lowest TM mode (1st mode), both magnetic and electric.

Problem 5: An object measuring 2 cm tall (from optic axis) is standing 14 cm from a positive thin lens with focal length 6 cm. There is an aperture stop, size 2 cm, placed 4 cm in front of the lens (i.e., between the object and the lens).

a) Determine image position, magnification and size.
b) Find position of entrance pupil (EnP) and exit pupil (ExP).
c) Raytrace to scale (1:1 should do on A4 paper) to show imaging condition.
d) Include positions and size of EnP and Exp.
e) Sketch the chief ray and the two marginal (extreme) rays through the optical system from the top of the object to its conjugate image point.

Problem 6: The coherence length l_t of a wave is the spatial length of coherence of its pulse (or duration τ_0): $l_t = c\cdot\tau_0$. Also, the bandwidth of the wave pulse can be taken as the inverse of its duration: $\Delta\nu = \frac{1}{\tau_0}$

a) From these assumptions, find an expression that related the spectral width $\Delta\lambda$ to the coherence length.
b) Michelson found that the cadmium red line 643.8 nm is useful in his famous interferometer since a difference in path-length of 30 cm could be used. Calculate the wavelength spread of the cadmium line source and its coherence time (τ_0).