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Department of Physics

Examination paper for TFY4195 Optics

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Examination date: Nov. 28, 2019
Examination time (from-to): 09-13
Permitted examination support material: Level C, Rottman mathematical tables.
Other information: Selected formulas are included as resources herein. Answers to two exam problems shall be scanned in.

Students will find the examination results in Studentweb. Please contact the department if you have questions about your results. The Examinations Office will not be able to answer this.

1 MC1 TFY4195 H19

A candle-light is placed 30 cm to the right of a 5 cm diameter positive lens of focal length 15 cm. Using a screen Paul is attempting to obtain an image of the burning candle. What is true about the image?

Select one alternative:

- There is a virtual, enlarged image to the right of the lens.
- There is a non-magnified, real image at the focal plane, to the left of the lens.
- There is an inverted, real, non-magnified image 30 cm to the left of the lens.
- There is no image
- There is a minimized, real image 30 cm to the left of the lens.

Maximum marks: 5

2 MC2 TFY4195 H19

An electromagnetic wave is described by the following expression:

$$\bar{E}(z,t) = E_0 \cos\left(\frac{\pi}{3}\cdot 10^7 \cdot z + 10\pi \cdot 10^{14} \cdot t\right)\cdot \hat{x} \quad [\mathrm{V/m}],$$

where the position z has the unit meter [m] and t is the time in seconds [s]. What is the propagation direction, speed and wavelength of the wave?

Select one alternative:

Slide2

Maximum marks: 5

3 MC3 TFY4195 H19

Light from a HeNe-laser (632.8 nm) passes through a prism made of glass (refractive index *n* around 1.5). The prism is placed in air. What ray-path is possible before and after the light passed the glass?

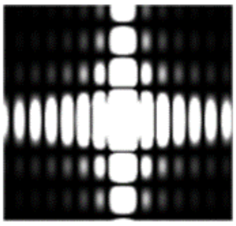
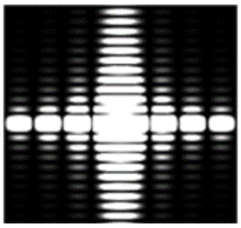
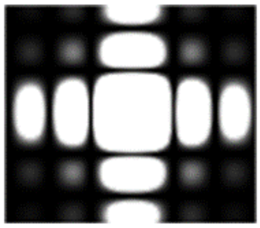
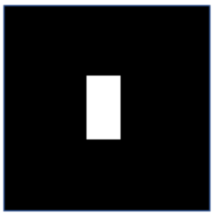
Select one alternative:

Maximum marks: 5

4 MC4 TFY4195 H19

Consider the three far-field diffraction patterns in the upper row. Which of the apertures could have made these diffraction patterns?

Please match the apertures with the diffraction pappterns:

	 3	 2	 1
 One			
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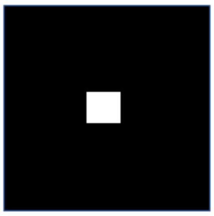
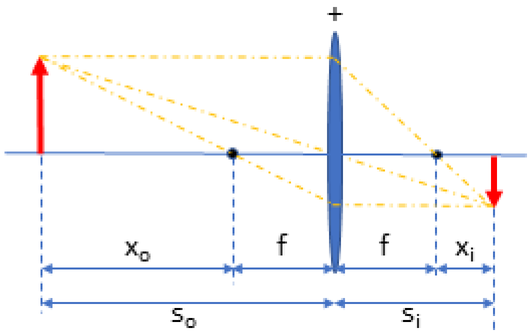
 Two			

Maximum marks: 5

5 MC5 TFY4195 H19

The object and the image formed using a positive lens of focal length f is depicted in the image below along with some distances that define their positions relative to the lens.



Which of the following equations does NOT describe their positions?

Select one alternative:

- $x_i x_o = f^2$
- $\frac{f}{x_o} = \frac{x_i}{f}$
- $\frac{f}{s_o - f} = \frac{s_i - f}{f}$
- $\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$
- $\frac{1}{x_o x_i} = f^2$

Maximum marks: 5

6 MC6 TFY4195 H19

Paul has a white light source and wants to use it in a Michelson interferometer experiment set-up using yellow light ($\lambda = 580nm$). He finds a 10 nm pass-band i.e., a filter that transmits light between 575 and 585 nm. What is the approximate coherence length of such a wavelength filtered light source?

Select one alternative:

- $l_c = 340\mu m$
- $l_c = 34\mu m$
- $l_c = 3.4mm$
- $l_c = 3.4\mu m$
- $l_c = 340nm$

Maximum marks: 5

7 MC7 TFY4195 H19

Using the yellow light source in problem MC6 ($\lambda = 580nm$), Paul also wants to test the classical double-slit experiment. As he knows about spatial coherence he puts a lens to focus the light onto a small pinhole (a thin circular aperture) which is $500\mu m$ in diameter. The light passing through the pinhole is then used for the interference experiment using a sensitive photon counting detector. The double slit is placed 50 cm from the pinhole. What is the maximum width between the slits he can examine without running into problems related to the spatial coherence?

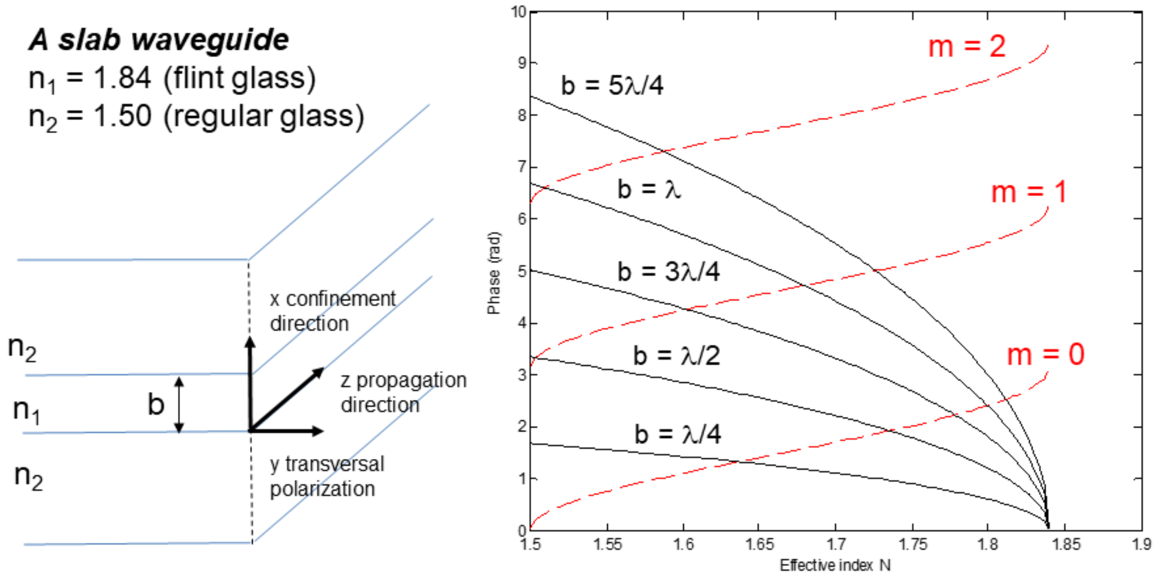
Select one alternative:

- $7mm$
- $3.5mm$
- $0.7mm$
- $35\mu m$
- $70\mu m$

Maximum marks: 5

8 MC8 TFY4195 H19

The view graph below shows the principle and essential parameters for a slab wave-guide and the calculated TE mode dispersion for several design options. If the telecommunication wavelength to be used is $1.55\mu m$ and the slab waveguide thickness is 400 nm, how many modes can the wave-guiding structure promote?



The propagating TE-mode:

$$\bar{E}(x,z,t) = \hat{y}\cdot E_0(x)\, e^{i(\beta z-\omega t)} = \hat{y}\cdot E_0(x)\, e^{i(kNz-\omega t)}$$

$$k = \frac{2\pi}{\lambda};\quad \hat{z}\ \textit{propagation direction}$$

TE Mode dispersion:

$$2\cdot\tan^{-1}\sqrt{\frac{N^2-n_2^2}{n_1^2-N^2}} + m\cdot\pi = \frac{2\pi b}{\lambda}\sqrt{n_1^2-N^2}$$

Select one alternative:

- 3
- 1
- >3
- 2
- 0

Maximum marks: 5

9 MC9 TFY4195 H19

A left-circularly polarized light-wave is impinging on a glass window of refractive index 1.60 with the incident angle 58^{o}. What can you say about the reflected light?

Select one alternative:

- No light is reflected
- All reflected light is linearly polarized.
- All light is reflected.
- The reflected light is left circularly polarized.
- The reflected light is right circularly polarized.

Maximum marks: 5

10 MC10 TFY4195 H19

A left-circularly polarized light-wave is propagating within a glass of refractive index 1.60 and hits a planar inner surface (with air on the outside). The angle of incidence is 58^{o}. What can you say about the reflected light?

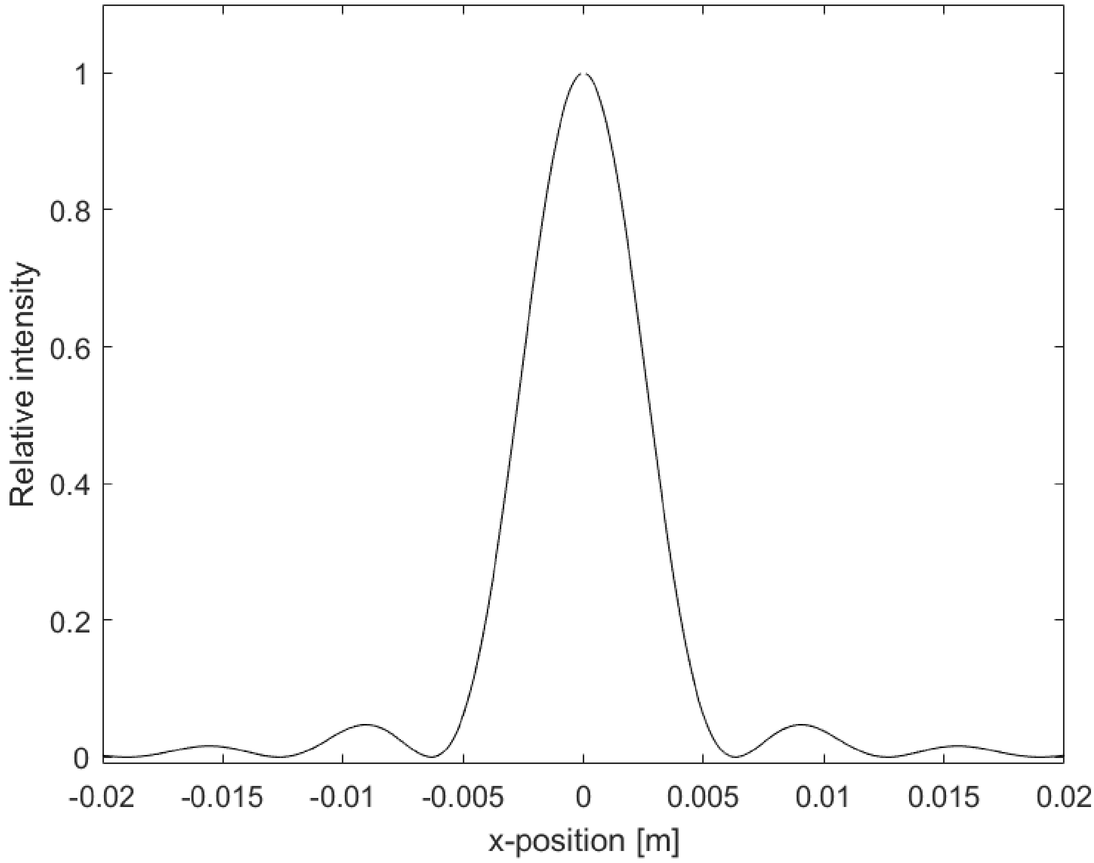
Select one alternative:

- The reflected light is left circularly polarized.
- The reflected light is right circularly polarized.
- All reflected light is linearly polarized.
- No light is reflected
- All light is reflected.

Maximum marks: 5

11 MC11 TFY4195 H19

Lars-Martin is carrying out a diffraction experiment in the Optics lab with a HeNe laser ($\lambda = 632.8nm$) using a single slit positioned with the long extension vertical. A lens of focal length 1.0 m is placed right after the slit to assure an appropriate far-field diffraction pattern. He records the intensity distribution in the horizontal direction by scanning the detector through the diffracted beam 1 m from the slit/lens and the following intensity pattern is recorded.



What is the width of the slit?

Select one alternative:

- $100\mu m$
- $632.8nm$
- $63\mu m$
- $3.1mm$
- $3.14\mu m$

Maximum marks: 5

12 MC12 TFY4195 H19

Paul continues to explore diffraction experiments with the scanning equipment described in MC11. To analyze the results, he wants to derive expressions for the intensity distribution of the diffraction patterns of multiple slits. He learned during the optics lecture that he can calculate the multiple slit diffraction by taking the Fourier transform of *N* slits represented by equally spaced Dirac delta-functions, and then multiply with the Fourier transform of the single slit, according to the convolution theorem of Fourier optics. He arrives at the following expression for the intensity distribution: $I(x) = [a \cdot \frac{\sin(2\pi f_x s)}{\sin(\pi f_x s)} \cdot \frac{\sin(\pi f_x a)}{(\pi f_x a)}]^2$ where $f_x = \frac{x}{\lambda f}$: *f* is the focal length of the lens, λ is the wavelength of the laser, *a* is the with of each single slit and finally, *s* is the separation between the slits. How many slits did he intend to analyse with this expression?

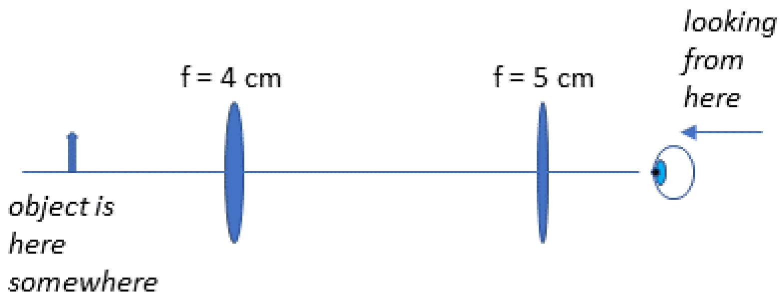
Select one alternative:

- 3
- 2
- 1
- 5
- 4

Maximum marks: 5

13 EQ1 TFY4195 H19

Victoria is preparing for the optics lab and is figuring out how to set up two (thin) lenses with 4 and 5 cm focal length to realize and test the principle of a microscope. She decides to use the short focal length as objective placed on the rail to the left, and then use the 5 cm focal length lens as eye-piece placed to the right. The object is placed to the very left as shown in the scheme below. Looking from the right she then wants to see the virtual image of the object 20 cm behind the 5 cm focal length lens as shown below, magnified 10 times.



a) Where shall the object be placed and what must be the distance between the lenses?

b) Ray-trace from the object to the image including intermediate images if apparent.

c) Is this a good design? Please comment...

Fill in your answer here

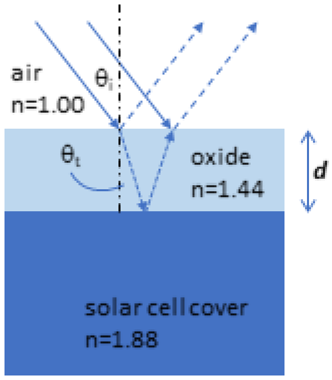
Format

Words: 0

Maximum marks: 20

14 EQ2 TFY4195 H19

Oddbjørn got a job at IFE as a technical developer and since he had an **A** in Optics his first task was to design an anti-reflective coating for a new type of solar cell cover material made from a very hard and sustainable transparent glass of high refractive index. Such a coating is made by sputtering a thin layer of SiO_2 ($n = 1.44$) on top of the cover as shown in the scheme below. As the bottom material has a relatively high refractive index only the two depicted reflections need to be considered.



a) Show that the optical path length difference of the two indicated reflected rays can be written as: $\Delta = 2d \cdot n_{oxide} \cdot \cos\theta_t$

b) What is the thinnest possible anti-reflective coating for visible light ($\lambda = 550nm$)? It is anticipated the anti-reflection coating should be operational for small incident angles (i.e. set $\theta_i = 0$).

c) Estimate and compare the reflected light intensity for the coated and non-coated surface at perpendicular incidence ($\theta_i = 0$).

State clearly any (reasonable) approximations you use.

Fill in your answer here

Format

Σ

Words: 0

Maximum marks: 20