Optics, Spring 2024

Submit your answers as a PDF file via Google Classroom before deadline (21.03.2024 at 10.00).
If problems, contact the course assistant joonas.mustonen@helsinki.fi.

Exercise 7 (Max points 10)

1. Resolution (5p.)

a) Describe the Rayleigh criterion for the lateral resolution of a microscope.

b) What is the difference between Rayleigh criterion and Abbe's criterion?

c) Calculate the size of the smallest resolvable feature for a 50x objective at wavelength 250 nm,

350 nm, and 750 nm. Assume operation in air, and a maximum acceptance angle of 30°. What would you expect to see from a Blue-ray disc?

d) Explain the difference between optical near-field and far-field, in terms of Fraunhofer and Fresnel diffraction.

e) "Super-resolution" imaging techniques break the diffraction limit (Rayleigh criterion / Abbe limit). What are two assumptions of the Rayleigh criterion i.e., when is it valid?

Hint: One has to do with the geometry of the optical setup, the other with the constituent material properties.

2. Aberrations (3p.)

a) Explain briefly the following optical aberrations.

1. Defocus
2. Spherical aberration
3. Coma
4. Astigmatism
5. Field curvature
6. Image distortion

b) Explain the difference between approximations on geometrical optics, physical optics and Fourier optics.

c) Due to chromatic aberration, the focal length of a lens depends on wavelength. Assume that focal lengths f_1 and f_2 correspond to refractive indices n_1 and n_2, respectively. Show that if

$$n_3 = \frac{n_2 + n_1}{2}$$

corresponds to focal length:

$$f_3{}^2 \approx f_1 f_2$$

the difference in focal lengths is the following:

$$f_1 - f_2 = \frac{n_2 - n_1}{n_3 - 1} f_3$$

3. Spherical mirrors (2p.)

a) A 1 cm tall object is positioned 12 cm in front of a spherical concave mirror having a radius of curvature of 8 cm. Calculate the image location, size, orientation and type. Draw a ray diagram.

b) Repeat the calculation for a convex mirror with f = 9 cm. Draw a ray diagram.