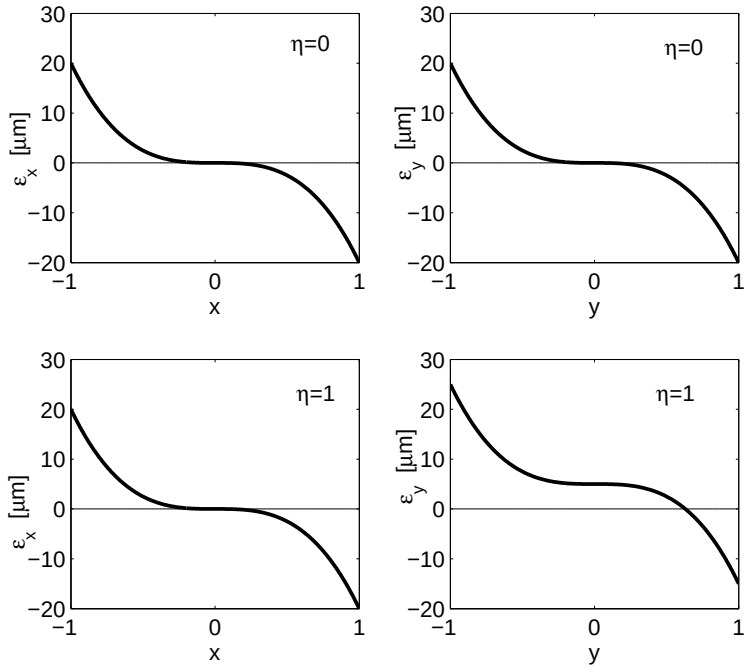
Exam SK2330 Optical Design 2010-05-25

No devices that allow for communication with the outside world, or that would permit installation of commercial optical design software, are permitted (i.e., no computers). Any other material such as books, notes, and calculators may be used.

Grading: 0–8p F, 9–11p Fx, 12–14p D, 15–18p C, 19–21p B, 22–24p A

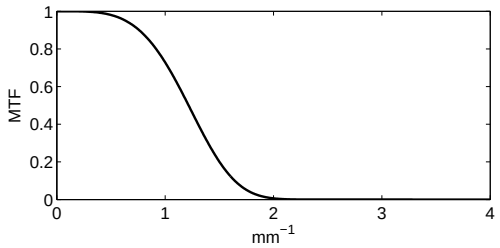
1. You wish to manufacture a cemented achromatic doublet of focal length 100 mm from the two glasses BK6 (n=1.53113, V=62.15) and SF2 (n=1.64768, V=33.85). A friend of yours suggests the two designs given below. Before starting the manufacture process, you check both designs carefully. Which one will you choose? Explain your choice! (Answer without explanation gives 0p even if correct.) (4p)
   Design A: BK7 placed first, radii of curvature $r_1 = 41.5$ mm, $r_2 = -41.5$ mm, and $r_3 = \inf$ (last surface flat).
   Design B: BK7 placed first, radii of curvature $r_1 = 51.2$ mm, $r_2 = -45.8$ mm, and $r_3 = -297.4$ mm.

2. The transverse ray aberrations ϵ_x (sagittal) and ϵ_y (tangential) of a lens in monochromatic illumination are given in the figure below as functions of normalized pupil coordinates x and y. The graphs are on-axis ($\eta = 0$) and for full image height ($\eta = 1$). The lens has focal length 200 mm and aperture radius 10 mm. The system has only third-order aberrations, and the object is at infinity.



   a) Explain which aberrations are present in this system, and which are not. Motivate your answer! (2p)
   b) Calculate the relevant wavefront aberration coefficients. (2p)

3. a) Stella wants to use a diffraction-limited lens of focal length 100 mm to image two sinusoidal gratings. The aperture radius is 10 mm and the distance from lens to image is 1.5 m. The two gratings have spatial frequencies 50 lines/mm and 15 lines/mm, respectively. Assuming the object contrast is 1, what will the image contrast for each of the gratings be? (4p)
   b) Stella cannot find a diffraction-limited lens, but settles instead for a plano-convex lens turned the right way. The MTF of this lens is given in the figure below. What will the image contrast be? Is this lens suitable for imaging the two gratings? (2p)



4. A thin lens of refractive index 1.6, focal length 50 mm and aperture radius 5 mm is used to image an object placed 100 mm before the lens.
   a) Determine the radii of curvature of this lens, if it should have zero coma. (2p)
   b) Calculate the spot size radius if an on-axis point is imaged. (2p)

5. A lens system consists of two lenses, the first of focal length 200 mm, the second of focal length 100 mm and placed 100 mm after the first. The system is used to image an object at infinity with a half-angle of 10°. The stop is at the first lens and has a 10 mm radius.
   a) Calculate the positions of the principal and focal planes of the system. Find the effective focal length of the system. Sketch the system and mark the principal plane positions. (2p)
   b) Given that each lens separately is free from longitudinal chromatic aberration, spherical aberration and coma (can be achieved e.g. by using doublet lenses), find the curvatures of the sagittal and tangential image planes. You may treat the lenses as thin, with refractive index 1.5. (2p)
   c) Suggest improvements to this system, and explain how they would improve the optical performance. (2p)