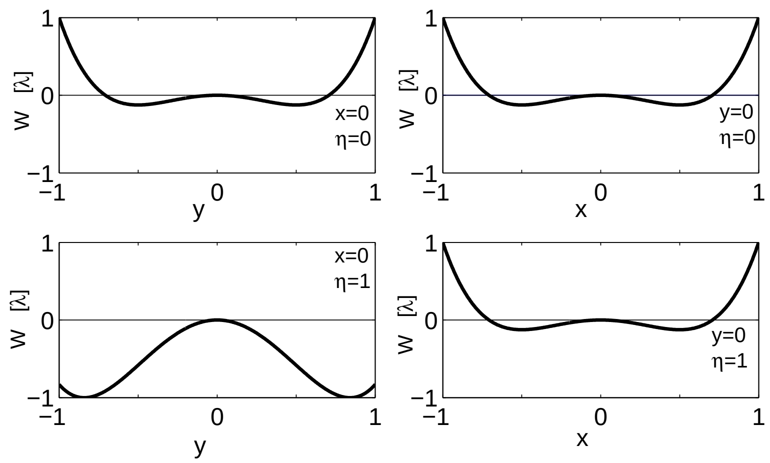
Exam SK2330 Optical Design 2011-05-27

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 phones or computers). Any other material such as books, notes, and calculators may be used.

Solutions should be well outlined and explained, and figures used when needed. Correct answers without explanations give 0p.

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

1. The wavefront aberrations of an optical system are given as a function of normalized pupil coordinates x (sagittal) and y (tangential) for a lens in monochromatic illumination (see figures below). The graphs are on-axis ($\eta = 0$) and for full image height ($\eta = 1$). The lens has an $F_\sharp$ of 7. The system has no higher-order aberrations (i.e., no aberrations higher than third order), and the object is at infinity.

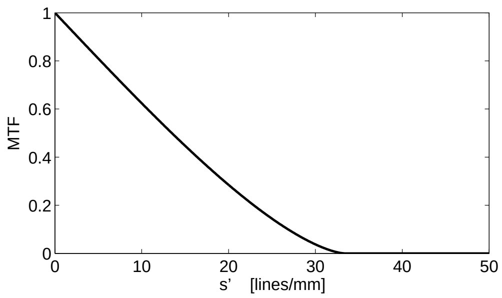


   a) Explain which aberrations may be present in this system, and which are not. Motivate your answer! (2p)
   b) Estimate the relevant wavefront aberration coefficients. (2p)

2. A positive plano-convex singlet lens of focal length f is used to image a far-away object. The lens is turned the right way, i.e., with its curved side towards the object. To further reduce the spherical aberration, the singlet lens is then replaced by two plano-convex lenses of focal length $2f$, both with their curved sides facing the object. This reduces the spherical aberration coefficient W_{040} by around 60%. The coma coefficient W_{131}, however, increases its absolute value and changes its sign. By how much does it increase? Motivate your answer. The two lenses are placed close together, and you may assume that they are thin. Assume a reasonable value for the refractive index, the same for all three lenses. (4p)

3. A cemented doublet of focal length $150\,\mathrm{mm}$ is made from BK7 ($n_d = 1.51679$, $n_C = 1.51432$, $n_F = 1.52237$) and SF11 ($n_d = 1.78470$, $n_C = 1.77597$, $n_F = 1.80643$). Find radii of curvature that make the doublet achromatic. (You may assume thin lenses, and you do not need to consider the monochromatic aberrations. There are many possible solutions, but you only need to give one.) (4p)

4. A singlet lens of focal length $200\,\mathrm{mm}$ and aperture radius $8\,\mathrm{mm}$ is used to image a small, on-axis object placed $300\,\mathrm{mm}$ before the lens. Light from a HeNe laser, at wavelength $632.8\,\mathrm{nm}$, is used. Below is an MTF curve of an optical system, as a function of image-space spatial frequency s'.



(a) Could this be the MTF of the lens described above? Motivate your answer carefully! (5p)

5. A thick meniscus lens has radii of curvature $r_1 = r_2 = 50\,\mathrm{mm}$, and a thickness of $50\,\mathrm{mm}$. It is made from BK7, with refractive index $n_d = 1.51679$.
a) Find the Seidel sum S_{IV} of the lens. (3p)
b) Find the focal length of the lens. (2p)
c) This lens has some useful properties. How can those properties be used in an optical system? On the other hand, what are the disadvantages of this lens? (2p)