VS203B Problem Set: Chromatic and Monochromatic Aberrations

1) Design an achromatic doublet that has a power of -10 D using ophthalmic crown glass (refractive efficiency = 58.6) and polycarbonate (refractive efficiency = 30.0).

2) In a reduced eye made up of water, the indices of refraction of the F, D and C lines are as follows: F: 1.337; D: 1.333; C: 1.331. If a 60 D (nominal power: expressed at D-line wavelength) reduced eye is properly focused for the D-line, what is the size, in micrometers, of the C-line (red) blur and the F-line (blue) blurs on the retina if the pupil size is:
   a) 8 mm
   b) 2 mm
   Use this result to explain why the colored halos around light are more visible at night than in the daytime.

3) A special type of intraocular implant, called the multifocal IOL, uses monochromatic aberrations to provide a longer depth of focus. A longer depth of focus is desired since the eye cannot accommodate with an IOL (i.e. its focus is restricted to a single focal plane). By adding positive spherical aberration to a lens the premise is that the margins of the lens would be used for near vision and the paraxial region of the lens would be used for distant vision. If the intraocular lens implant has 3 D of positive spherical aberration and its power is such that the eye is paraxially focused on infinity, at what distance would the marginal regions of the eye be focused.

4) One way to define longitudinal spherical aberration in a lens is with the following formula:

$$f' = f_o' - c \cdot r^2$$

   where f' is the secondary focal point, f_o' is the paraxial focal point, r is the radius of the lens and c is a constant. The units are in mm. The formula demonstrates that the focal power is increasing toward the margins of the lens. If the lens has a diameter of 10 mm, the paraxial focal point is 100 mm and the constant c is 2,
   what type of spherical aberration is present?
   what is the longitudinal spherical aberration of the lens in mm?
   what is the longitudinal spherical aberration in D?
   what is the transverse spherical aberration of this lens (measured at the paraxial focal plane)?

5) To make the calculations for object and image formation simpler, Gauss adopted the first order approximation for the sin function (NOTE: for this approximation, you must use units of radians for the angle)

$$\sin\theta = \theta$$

   and Seidel adopted a third order approximation:

$$\sin\theta = \theta - \frac{\theta^3}{3!}$$

   Calculate the percentage difference between the actual sin function and each of these two approximations for angles from 0 to 80 degrees in 5 degree steps (I recommend using Excel or another spreadsheet for this)
   Identify the approximate angle beyond which the Gauss approximation is incorrect by more than 2%.
   Identify the approximate angle beyond which the Seidel approximation is off by more than 2%.
   Note: to calculate the percentage difference, use the formula:

$$\text{difference (\%)} = 100 \times \frac{\text{ExactValue - ApproximateValue}}{\text{ExactValue}}$$

6) Take a high power positive trial lens from your lens kit and estimate the angle that an incident light ray, parallel to the optical axis and entering the margin of the lens, would make from the normal to the surface. Is Gauss' approximation a fair approximation for these lenses? (i.e. does the lens makers formula work for these lenses?)

7) Johannes Kepler is a myope who prefers to sit at the back of the class. By the end of the year, his myopia progressed from -5 to -5.5 D. He had no time or money to purchase new glasses, so he decided to increase his lens power by tilting his lenses. What angle does he need to tilt the lens to get enough spherical equivalent to correct his increasing myopia. How much astigmatism does he have through the tilted lenses? (assume the glasses have an index of refraction of 1.5)

Answers

1. -20.49D and 10.49D (you need to specify types for each power)
2. a) 36 and 76.3 microns b) 9 and 19 microns
3. 33.33cm
4. a) positive b) 50mm c) +10D d) 5mm
5. 19.71deg and 67.65deg
6. 30 deg
7. 19.84deg and -0.6D