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ME297
Homework 1
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1) Dispersion and Abbe Number

A. Question: What kind of Abbe V number offers large dispersion?
   Answer: There is an inverse relationship between dispersion and Abbe V number; a small Abbe V number (i.e.~20), offers large dispersion.
B. Question: What is the sign of the Abbe V number for a glass with
   a. Negative dispersion?
   b. Positive dispersion?
   c. No dispersion?
   Answer: For visibly transparent glass, the Abbe V number sign is positive in all cases.
C. Question: Find 3 glasses from a catalogue (mention the source) with
   a. Negative dispersion
   b. Positive dispersion
   c. Minimum dispersion
   Answer: An example of a Negative Dispersion Glass is Hoya TAF4, (n_e=1.79195, ν_e=47.26, $\Delta P_{g,F}$ = -0.0090). An example of Positive Dispersion Glass is Hoya NBFD15 (n_e=1.79512, ν_e=33.03, $\Delta P_{g,F}$ =0.0000). An example of Minimum dispersion Glass is Hoya ADC1 (n_e=1.61526, ν_e=61.88, $\Delta P_{g,F}$ = 0.0088).
D. Question: What can we way about dispersion of a glass in IR range based on its Abbe V number?
   Answer: The Abbe V number is based upon behavior in the visible region and so we cannot say anything about its IR behavior based on the Abbe V number.

2) Rules of Thumb

1	**Name for Rule:**	**Airy Disc**
	The Rule of Thumb:	$\Theta d = 2.44 * \lambda / D$
	When is this used?	Determining angular size of central diffraction blur circle. Application is point sources imaged by optical system with circular aperture used for comparison of geometric blur to diffraction limited blur size.
	Limitations:	Monochromatic incoherent light, sharp edge apertures much larger than wavelength, unobscured systems, point source illumination with dark background.
2	**Name for Rule:**	**Rayleigh Criterion**
	The Rule of Thumb:	$\Theta r = 1.22 * \lambda / D$
	When is this used?	Determining angular extent of the minimum resolvable detail for diffraction limited system. Application is angular separation of point sources imaged by optical system with circular aperture.
	Limitations:	Monochromatic incoherent light, sharp edge apertures much larger than wavelength, unobscured systems, point source illumination with dark background.
3	**Name for Rule:**	**Wedge Deviation**
	The Rule of Thumb:	$\Theta d = (n-1) * A$
	When is this used?	Small angle approximation used to describe axis deviation due to plane parallel wedge.
	Limitations:	Rays close to the axis and small field angles.

3) A camera focused between 3 meters & infinity

A point and shoot camera company claims their digital camera can take sharp images of the objects located between 1m and infinity. The pixel size is 3micrometers x 3 micrometers size, the lens aperture is 5mm diameter and the lens focal length is 10mm.

a) Evaluate validity of the claim numerically for green light.

Answer:

1st study:

F/# = 10/5 = 2

CoC = 3*10E-6 meters (Assume Blur limited to Pixel Size)

F = 10*10E-3 meters

Hyperfocal Distance: H=(f^2)/(F/#*CoC) + f = 16.68 meters

Assume **fixed focus** at Hyperfocal distance, then Depth of Field Maximized:

Nearpoint = H/2 = 8.34 meters

Farpoint = infinity

Conclusion1: assuming a fixed focus, the camera is not pixel limited, and the lens geometric blur is bigger than a pixel.

2nd study:

Assume fixed focus at Hyperfocal distance of 2meters giving the Nearpoint of 1 meter and farpoint of infinity. CoC = (f^2)/(F/#*H) = 25micrometers Blur Circle corresponding to the large depth of field claim.

Diffraction Blur at 0.5micrometers: B = 2.44*lambda*F/# = 2.44 micrometers.

Conclusion 2: Assuming a fixed focus at 2m, the camera is more than 10 times worse than the diffraction limit. The claim of sharp images seems false.

b) What happens when you consider red (750nm) and blue (450nm)light? For which wavelength is the focus the best?

Answer: It is difficult to determine the color correction of the camera, only that the geometric blur circle is very large and is likely a combination of many different aberrations. If the camera was diffraction limited, the shortest wavelength of its spectral pass-band would diffract the least and give potential for a better focus having a smaller blur circle.

c) What if the diameter of the lens is 2.5mm focal length working at F/5?

Answer:

f = 2.5*10E-3 meters

F/# = 5

lambda = 0.5micrometers

Diffraction Blur B = 2.44*lambda*F/# = 6.1micrometers = CoC

H =(f^2)/(F/#*CoC) + f= 0.2025 meters

Nearpoint = H/2 = 0.1013meters

Farpoint = infinity

Conclusion: The claim seems consistent with well corrected optics.

d) What if the diameter is 10mm and the focal length is 10mm?
   Answer:
   f = 10*10E-3 meters
   F/# = 10/10 = 1
   lambda = 0.5micrometers
   Diffraction Blur B = 2.44*lambda*F/# = 1.2 micrometers
   CoC = pixel size = 3 micrometers.
   H =(f^2)/(F/#*CoC) + f = 33.34 meters
   Nearpoint = H/2 = 16.67meters
   Farpoint = infinity
   Conclusion: The claim seems inconsistent with well corrected optics.

e) Organize your findings as a function of f# which is f/D and wavelength in the form of an easy rule to remember.
   Answer:
   Diffraction Limited Hyperfocal Distance:
   H = ((f^2)/(F/#*2.44*lambda*F/#)) + 1 = ((f^2)/((F/#^2)*2.44*lambda)) + f
   Nearpoint = H/2
   Farpoint = infinity