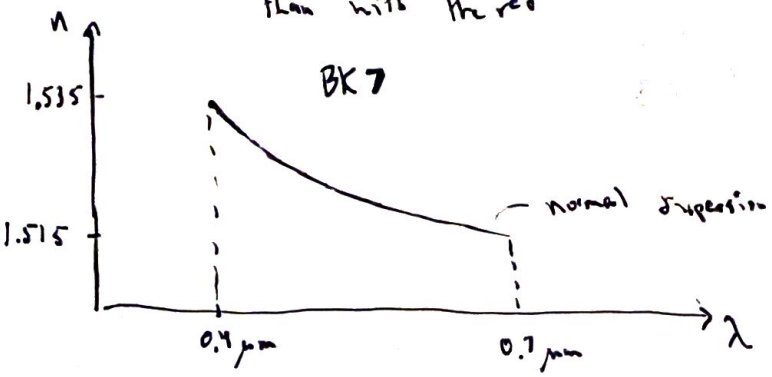
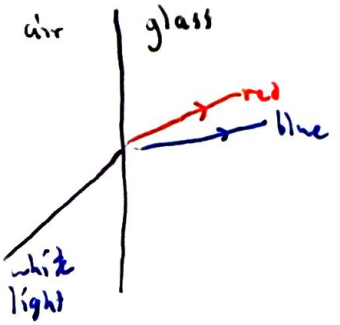
## Week 3

Chapter 3: optical instrumentation

Dispersion, $n(\lambda)$

in general $n$ will be larger with the blue than with the red



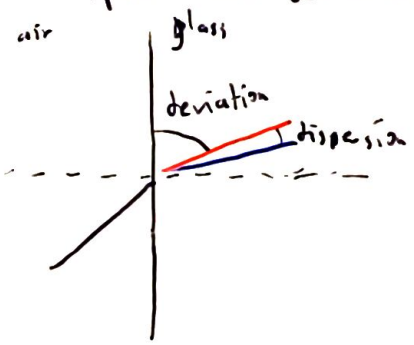




Cauchy relationship: $n(\lambda) = A + \frac{B}{\lambda^2}$ for BK7, $A \approx 1.505$ $B \approx 0.0042\ \mu m^2$

then dispersion

$$\frac{dn}{d\lambda} = -\frac{2B}{\lambda^3}$$

distinguish dispersion and deviation




We specify the glass dispersion by the Abbé number

Hydrogen: 486 nm - F line

Sodium: 589 nm - D line

Hydrogen: 656 nm - C line

Define the dispersive power $\Delta = \frac{n_F - n_C}{n_d - 1}$

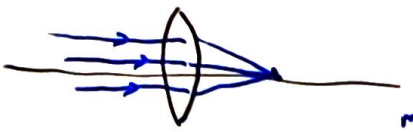
$\Delta_{\text{crown glass}} \approx \frac{1}{65} \Rightarrow$ 65 Abbé num.

$\Delta_{\text{flint glass}} = \frac{1}{30} \Rightarrow$ 30 Abbé numb

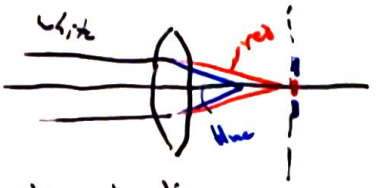
the Abbé number is $\frac{1}{\Delta}$

the smaller the Abbé number, the more dispersive the glass

Some comments on lenses



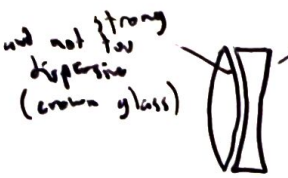
but when there are multiple colors



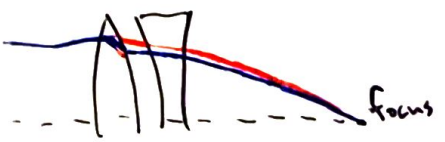

chromatic aberration

this is not a problem with mirrors → use reflecting system for imaging

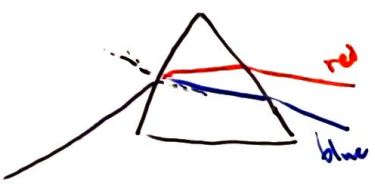
Can make a partial correction using an achromat



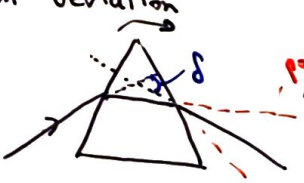

(stronger – shorter focal length)




prism and prism spectrometer




minimum deviation



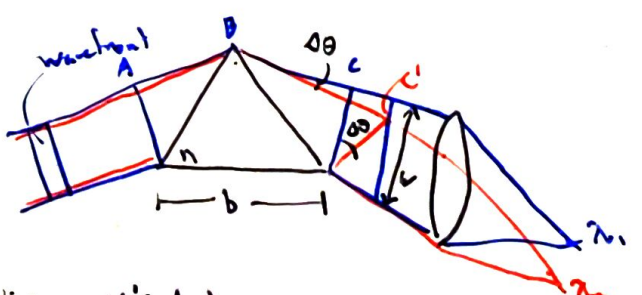

upon rotating you'd see that there is

As we rotate the prism we see that there is one position of minimum deviation

this occurs when input and output angle are the same


$$n = \frac{\sin\left(\frac{A+\delta}{2}\right)}{\sin\left(A/2\right)}$$

prism chromatic resolution




$$\frac{AB}{v_{light}} + \frac{BC}{v_{light}} = \frac{b}{v_{light}/n}$$

$$AB + BC = nb$$

$$AB + BC' = (n + \Delta n)\, b$$

distance $CC' = \Delta n\, b$

the smallest angle that can be resolved by the lens is

$$\Delta\theta = \frac{\lambda}{w}$$

this $\theta = \frac{\lambda}{w}$ comes from the wave picture of light (from diffraction)

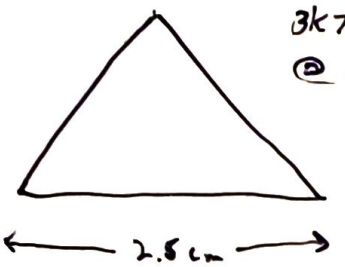
so $CC' = w\Delta\theta = \Delta n b$

$w\frac{\lambda}{w} = \Delta n b \Rightarrow \lambda = \Delta n b$

Resolution: $\frac{\lambda}{\Delta\lambda} = b\frac{\Delta n}{\Delta\lambda}$

$R = b\frac{dn}{d\lambda}$

Example




BK7 glass @ 589 nm

$n(\lambda) = A + B/\lambda^2$

$\frac{dn}{d\lambda} = -\frac{2B}{\lambda^3} = \frac{2 \cdot 0.0042}{(589\,nm)^2} = 0.041\,\mu m^{-1}$

$R = 1025$ (from eq)

so $\Delta\lambda = \frac{\lambda}{R} \simeq 0.6\,nm$

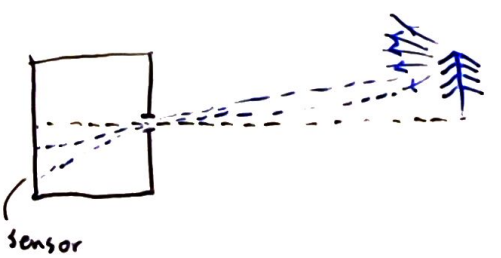
typically, prism is about ~R=1000

Camera

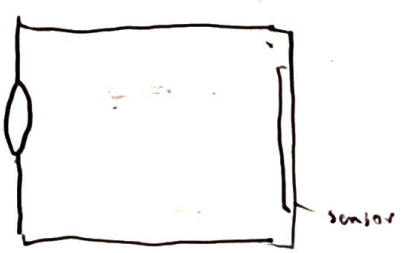
pinhole camera

infinite depth of field

not very efficient with light




how do improve the camera? use a lens




big aperture

limited depth of field