1. Bright fringes occur when $a \sin \theta = m \lambda$

or when

$$y = \frac{m \lambda s}{a}$$

When red light with $\lambda_0 = 780 \text{ nm}$ in the first order fringe overlaps with violet in the second order fringe we have

$$y = \frac{\lambda_0 s}{a} = \frac{2 \lambda s}{a}$$

Therefore, $\lambda = \frac{\lambda_0}{2} = 390 \text{ nm}$.
2. The Fresnel biprism is equivalent to a double slit experiment with slit spacing given by

\[ \theta_s = d(n-1) \alpha \]

In this case, the geometry looks like this:

![Diagram of Fresnel biprism](image)

where \( \Theta_s = \Theta_i - (n-1)\alpha = \Theta_i' + (n-1)\alpha \)

Bright fringes occur when \( a \sin \Theta_i = m\lambda \) or \( a \Theta_i = m\lambda \)

when \( \Theta_i \ll 1 \).

Hence, \( \frac{1}{2}a(\Theta_i + \Theta_i') = a \Theta_s = m\lambda \)

and bright fringes will be located at \( y = d \Theta_s = \frac{d m \lambda}{a} \)

But \( \alpha = 2d(n-1)\alpha \) so \( y = \frac{m \lambda}{2(n-1)\alpha} \)

and \( \alpha = \frac{\lambda}{2(n-1)y} = \frac{500 \text{ nm}}{2(1.5-1)(0.5 \text{ mm})} = 0.001 \)

\[ \alpha = 0.06^\circ \]
3. Resolving power for a prism is

\[ R = \frac{2}{\Delta \lambda} = \frac{B \Delta n}{\Delta \lambda} \]

where \( B \) is the base length.

(a) For quartz,

\[ \text{http://www.instant-analysis.com/Principles/refraction.htm} \]

For wavelengths between approximately 430 nm and 550 nm, the first derivative is

\[ \frac{dn}{d\lambda} = \frac{1.473 - 1.450}{300\text{nm} - 770\text{nm}} = \frac{-0.000049}{470\text{nm}} \]

When \( B = 10 \text{ cm} \), \( R = \left(10 \times 10^{-2} \text{ m}\right) \left(0.000049 \times 10^9 \text{ m}^{-1}\right) = 4900 \)
(b) For a Fabry-Perot interferometer,

\[ R = \frac{2\pi}{\lambda} = \frac{2nfd}{\lambda_0} \]

Typical values are \( R = 50 \), \( nfd = 1 \text{ cm} \).

Then, \( R = \frac{50 \cdot 2 \cdot 10^{-1} \text{ m}}{500 \times 10^{-9} \text{ m}} = 2 \times 10^6 \)

(c) The sodium doublet consists of two spectral lines with a mean wavelength of

\[ \lambda = \frac{1}{2} (588.9950 \text{ nm} + 589.5924 \text{ nm}) \]

\[ = 589.2937 \text{ nm} \]

and a spacing of \( \Delta \lambda = 589.5924 - 588.9950 \]

\[ = 0.5974 \text{ nm} \]

The minimum resolvable wavelength difference with the prism is

\[ (\Delta \lambda)_{\text{min}} = \frac{\lambda}{R} = \frac{589.3 \text{ nm}}{4900} \]

The minimum resolvable wavelength difference with the Fabry-Perot interferometer is

\[ (\Delta \lambda_{\text{min}}) = \frac{\lambda}{R} = \frac{589.3 \text{ nm}}{2 \times 10^6} \]

The doublet would be resolvable with the Fabry-Perot interferometer but would be barely resolvable with the prism.