Chromatic Aberration:

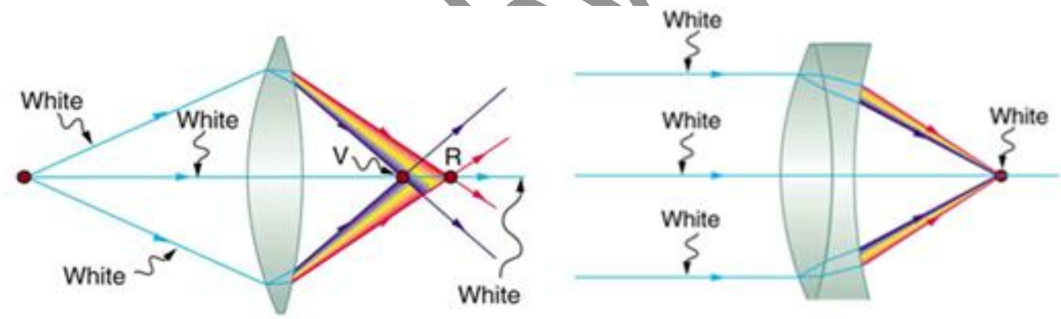
a) Cause for Chromatic Aberration:

This aberration occurs for the dispersive power of the lens. Since lens has prismatic action and prism has its own 'dispersive power', so lens has also its dispersive power.

Let us see what we mean about the dispersive power of a lens.

Since lens is composed of several prismatic portions then the dispersive power of lens will be identical to that of the prism as the light refracting through the lens will suffer the refraction of the localized prism at that region of incidence on the lens. Hence the dispersive power of the lens will be

$$\omega_L = \frac{(\mu_v-\mu_r)}{(\mu_y-1)} = \frac{(\mu_v-1)-(\mu_r-1)}{(\mu_y-1)} = \frac{(\mu_v-1)\left(\frac{1}{r_1}+\frac{1}{r_2}\right)-(\mu_r-1)\left(\frac{1}{r_1}+\frac{1}{r_2}\right)}{(\mu_y-1)\left(\frac{1}{r_1}+\frac{1}{r_2}\right)}$$

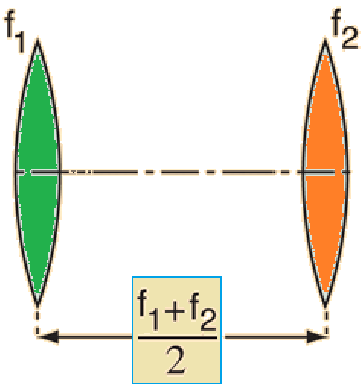


Hence we get $\omega_L = \frac{\frac{1}{f_v}-\frac{1}{f_r}}{\frac{1}{f_y}} = \frac{f_y(f_r-f_v)}{f_r f_v}$. But since the yellow colour is the average colour of the spectrum of white light we should have for $AM \approx GM \Longrightarrow f_y = \frac{f_r+f_v}{2} = \sqrt{f_r f_v} \Longrightarrow f_y^2 = f_r f_v$ So we get $\omega_L = \frac{f_y(f_r-f_v)}{f_r f_v} = \frac{f_y(f_r-f_v)}{f_y^2} = \frac{(f_r-f_v)}{f_y} = \frac{\Delta f}{f}$. This is dispersive power of the lens.

For such dispersive power of the lens, when image formation occurs through white light, all of its seven distinct visible colors will be focused at seven several focal points after refracting through the lens and will participate in image formation separately. Thus seven several images with different magnifications will occur and they will then overlap on the same screen. Finally confusion in clear image formation will occur and it is Chromatic aberration for image formation by the lens.

b) Removal of Chromatic Aberration:

There are several ways to remove the effect of Chromatic aberration, but the best way is the use of the combination of two convex or converging lenses where the combination has zero dispersive power as a whole. Such combination is called 'Achromatic Doublet' which may be contact doublet or separated doublet.



As we have mentioned earlier that It is the combination of two lenses such that the dispersive power of the combination will be zero, the white light passing through this combination will remain still white without giving any spectrum. Hence for this achromatic doublet the dispersive power of the equivalent lens of the combination will be zero. Now by considering the dispersive power of the component lens same we have for achromatic separated doublet

$$\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1f_2}\Rightarrow-\frac{\Delta f}{f^2}=-\frac{\Delta f_1}{f_1^2}-\frac{\Delta f_2}{f_2^2}+\frac{d}{f_1f_2}\left(\frac{(f_1\Delta f_2+f_2\Delta f_1)}{f_1f_2}\right)$$

$$\Rightarrow\frac{\Delta f/f}{f}=\frac{\Delta f_1/f_1}{f_1}-\frac{\Delta f_2/f_2}{f_2}+\frac{d}{f_1f_2}\left(\frac{\Delta f_1}{f_1}+\frac{\Delta f_2}{f_2}\right)$$

Hence for $\omega=\frac{\Delta f}{f}=0$ and $\omega_1=\omega_2=\omega=\frac{\Delta f_1}{f_1}=\frac{\Delta f_2}{f_2}$,

We get $\frac{\omega}{f_1}+\frac{\omega}{f_2}-\frac{d}{f_1f_2}(\omega+\omega)=0\Rightarrow d=\frac{f_1+f_2}{2}$. This is the condition of achorism of the separated doublet.

On the other hand for achromatic contact doublet $d=0$ and then in that case $\frac{1}{f_1}+\frac{1}{f_2}=0$. Thus in this case the focal length of two component lens must be of opposite sign and actually the combination of one convex and one concave lens in contact is used as an achromatic contact doublet.