ACHROMATISM

M. SATYA VANI
LECTURER IN PHYSICS

ACHROMATISM

Elimination of Chromatic Aberration is known as **Achromatism.**

When two or more lenses are combined together in such a way , then the combination is free from Chromatic Aberration . Then the combination is Achromatic Chromatic .

⇒ Chromatic Aberration is eliminated by the following methods

- By an Achromatic Doublet (different materials)
- By the lenses of same material separated by a distance .

ACHROMATIC DOUBLET

Elimination of Chromatic aberration using Achromatic doublet

Def : **It is the combination of two lenses in contact with each other which produces no Chromatic Aberration .**

It consists of two lenses ,a convex lense of crown glass of small focal length and Concave length of flint glass of large focal length placed in contact . An achromatic doublet shows no colours come to focus at one point. It means all colours have same focal length. The focal length of an Achromatic Doublet is independent of Refractive index.

Consider two lenses of focal lengths f1 and f2 and dispersive powers $\omega 1$ and $\omega 2$. If f is the combined focal lengths of the system, $1/f = 1/f1 + 1/f2 \quad \because d=0$

Differentiating ,

$$\Rightarrow \quad d(1/f) = d(1/f1) + d(1/f2)$$

$$\Rightarrow \quad -1/f^2 \; df = -1/f^2{}_1 \; df1 + -1/f^2{}_2 \; df2$$

$$\Rightarrow \quad -1/f^2 \; df = (-df1/f1) . 1/f1 + (-df2/f2) . 1/f2$$

For no chromatic aberration , df=0 $\because$ f is constant i.e focal length of the combination is the same for all colours. (f=constant) $\Rightarrow$ (-df1/f1) . 1/f1 + (-df2/f2) . 1/f2 = 0

$$\Rightarrow \quad \omega 1/f1 + \omega 2/f2 = 0 \qquad \because \quad \omega 1 = (-df1/f1) \; ; \quad \omega 2 = (-df2/f2)$$

$$\Rightarrow \quad \underline{\boldsymbol{\omega 1 / \omega 2 = -f1/ f2}}$$

ω1 & ω2 are +ve , f1 & f2 must have opposite sign i.e one lense is convex and other should be concave .

Achromatic Combination Of Two Lenses Separated By A Distance

Let us consider two convex lenses of focal lengths f_1 and f_2 separated by a suitable distance x. As the material of two lenses is the same, hence their dispersive power is the same. Now, we will derive the condition for achromatism for these two lenses. If F is the combined focal length of two lenses, then

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2} \qquad \ldots(1)$$

Now, the change in $\frac{1}{F}$ as the refractive index changes can be obtained by differentiating eq. (1), *i.e.*,

$$d\left(\frac{1}{F}\right) = d\left(\frac{1}{f_1}\right) + d\left(\frac{1}{f_2}\right) - d\left(\frac{x}{f_1 f_2}\right)$$

$$= d\left(\frac{1}{f_1}\right) + d\left(\frac{1}{f_2}\right) - \frac{x}{f_2}\, d\left(\frac{1}{f_1}\right) - \frac{x}{f_1}\, d\left(\frac{1}{f_2}\right) \qquad \ldots(2)$$

As proved in the previous article

$$d\left(\frac{1}{f_1}\right)=\frac{\omega_1}{f_1} \quad \text{and} \quad d\left(\frac{1}{f_2}\right)=\frac{\omega_2}{f_2}, \text{ hence}$$

$$d\left(\frac{1}{F}\right)=\frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}-\frac{x}{f_2}\times\frac{\omega_1}{f_1}-\frac{x_1}{f_1}\times\frac{\omega_2}{f_2} \qquad \ldots(3)$$

For an achromatic combination, the focal length F or $\frac{1}{F}$ should not change with colour, *i.e.*,

$d\left(\frac{1}{F}\right)=0$

$$\therefore \quad 0=\frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}-\frac{x\,\omega_1}{f_1\,f_2}-\frac{x\,\omega_2}{f_1\,f_2}$$

or
$$\frac{\omega_1}{f_1}+\frac{\omega_2}{f_2}=\frac{x\,\omega_1}{f_1\,f_2}+\frac{x\,\omega_2}{f_1\,f_2}$$

or
$$\frac{\omega_1\,f_2+\omega_2\,f_1}{f_1\,f_2}=\frac{x\,(\omega_1+\omega_2)}{f_1\,f_2}$$

or
$$x=\frac{\omega_1\,f_2+\omega_2\,f_1}{\omega_1+\omega_2}. \qquad \ldots(4)$$

When the two lenses are made of the same material, *i.e.*, $\omega_1=\omega_2=\omega$ (say), then

$$x=\frac{\omega f_2+\omega f_1}{\omega+\omega}=\frac{\omega f_2+\omega f_1}{2\omega}$$

or
$$x=\frac{f_1+f_2}{2}. \qquad \ldots(5)$$

Thus, the separation between the two lenses must be equal to the mean of focal lengths of the two lenses.