Answer on Question #69251, Physics / Optics

Question. A concave lens of $f = 50\ cm$ is made of material of n_r for red lights is $1{,}640$ and n_b for blue light is $1{,}658$. It is then combined with a convex lens of dispersive power $0{,}0172$ to form an achromatic doublet, determination the focal length of the achromatic lens.

Given.

focal length of concave lens: $f_1 = -50\ cm = -0{,}5\ m$;

refractive index for red lights: $n_r = 1{,}640$;

refractive index for blue lights: $n_b = 1{,}658$;

dispersive power of a convex lens: $\omega_2 = 0{,}0172$.

Find.

focal length of the achromatic lens: f.

Solution.

In accordance with the conditions for achromatic doublet of two lens

$$P = P_1 + P_2;$$

$$\omega_1 P_1 + \omega_2 P_2 = 0,$$

where P – optical power of the achromatic doublet; $P_1 = \frac{1}{f_1}, P_2 = \frac{1}{f_2}$ – optical power of the first and second lens; ω_1, ω_2 – dispersive power of the first and second lens.

The expression for dispersive power of the material of the thin lens

$$\omega_1 = \frac{n_b - n_r}{n - 1}.$$

Generally, n is replaced by the mean value of n_b and n_r which is

$$n = \frac{n_b + n_r}{2}.$$

Then

$$\omega_1/f_1 + \omega_2/f_2 = 0,$$

$$\frac{\omega_1}{f_1} = -\frac{\omega_2}{f_2}, f_2 = -\frac{\omega_2}{\omega_1} f_1 = -\frac{\omega_2}{\frac{n_b - n_r}{n-1}} f_1 = -\frac{\omega_2(n-1)}{n_b - n_r} f_1 = -\frac{\omega_2\left(\frac{n_b + n_r}{2} - 1\right)}{n_b - n_r} f_1 =$$

$$= -\frac{\omega_2(n_b + n_r - 2)}{2(n_b - n_r)} f_1 = -\frac{0{,}0172(1{,}658 + 1{,}640 - 2)}{2(1{,}658 - 1{,}640)} \cdot (-0{,}5) = 0{,}62\ m.$$

The focal length of the achromatic doublet

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}; f = \frac{f_1 f_2}{f_1 + f_2} = \frac{-0{,}5 \cdot 0{,}62}{-0{,}5 + 0{,}62} = -2{,}58\ m$$

Answer: The focal length of the achromatic lens: $f = -2{,}58\ m$.