Lecture 10

Total Magnification

The magnification of the microscope may be defined as in the case of the simple magnifier. Thus, the angular magnification for an image viewed at infinity is:

$$M = \frac{25}{f_{eff}} \qquad \text{..... (2-16)}$$

where f_{eff} (in cm) is the effective focal length of the two lenses, separated by a distance d, and given by:

$$\frac{1}{f_{eff}} = \frac{1}{f_o} + \frac{1}{f_e} - \frac{d}{f_e f_o} \qquad \text{..... (2-17)}$$

Substituting Eq. (2-17) into Eq. (2-16),

$$M = \frac{25(f_o + f_e - d)}{f_o f_e} \qquad \text{..... (2-18)}$$

Based on an algebraic manipulation of the thin-lens equation, however, we can show that the ratio of image to object distance s'_o/s_o, for the objective lens is:

$$\frac{s'_o}{s_o} = \frac{d - f_e - f_o}{f_o} \qquad \text{..... (2-19)}$$

where we have used the fact that $s'_o = d - f_e$ evident in the diagram. Incorporating Eq. (2-19) into Eq. (2-18),

$$M = -\left(\frac{s'_o}{s_o}\right)\left(\frac{25}{f_e}\right) \qquad \text{..... (2-20)}$$

showing that the total magnification is just the product of the linear magnification of the objective s'_o/s_o multiplied by the angular magnification of the eyepiece $(25/f_e)$ when viewing the final image at infinity. The negative sign indicates an inverted image.

Comparing Figure (2-6) with the geometry associated with Newton's equation for a thin lens, The magnification of the microscope may then be expressed, perhaps more conveniently, as:

$$M = -\left(\frac{25}{f_e}\right)\left(\frac{L}{f_o}\right) \qquad \text{..... (2-21)}$$

where L is the distance between the objective image and its second focal point, as shown in the figure.

In many microscopes, the length L is standardized at 16 cm. The focal lengths f_o and f_e are themselves effective focal lengths of multielement lenses, appropriately corrected for aberrations.

Example 5

A microscope has an objective of 3.8-cm focal length and an eyepiece of 5-cm focal length. If the distance between the lenses is 16.4 cm, find the magnification of the microscope.