200X Microscope – Finite Tube Length

Design a 200X optical microscope with a 20X objective and a 10X eyepiece. The optical tube length is 200 mm. The optical tube length is the distance from the rear focal point of the objective to the front focal point of the eyepiece or the intermediate image plane. Assume a simple eyepiece.

a) Provide the focal lengths and spacings of the two lenses. Determine the working distance.

b) If the diameter of the objective lens is 6.0 mm and the diameter of the eyelens is 5.0 mm, what is the unvignetted field of view (in mm) of the microscope? The objective lens is the system stop.

Solution:

Tube Length = 200 mm
Objective : 20X
Eyepiece : 10X

a) Eyepiece: \[ f_{\text{EYE}} = \frac{MP}{10} = \frac{250\text{mm}}{10} = 25\text{mm} \]

![Diagram showing the microscope setup with focal lengths and spacings labeled.]

Objective:

\[ m = -20 = \frac{z'}{z} \]

\[ z' = f_{\text{OBJ}} + \text{Tube Length} = f_{\text{OBJ}} + 200\text{mm} \]
\[ z = \frac{z'}{-20} = \frac{f_{OBJ} + 200mm}{-20} \]

\[ \frac{1}{z'} = \frac{1}{z} + \frac{1}{f_{OBJ}} \]

\[ \frac{1}{f_{OBJ} + 200mm} = \frac{-20}{f_{OBJ} + 200mm} + \frac{1}{f_{OBJ}} \]

\[ f_{OBJ} = 10mm \]

\[ WD = z = -10.5mm \quad L = f_{OBJ} + \text{Tube Length} + f_{EYE} \]

\[ L = 235mm \]

Note: Can also be done by recognizing the the Tube Length is a Newtonian image distance:

\[ z_F' = \text{Tube Length} = 200mm \quad m = -20 = -\frac{z_F'}{f_{OBJ}} \quad f_{OBJ} = 10mm \]

b) Field of View

\[ D_{OBJ} = 6.0mm \quad D_{EYE} = 5.0mm. \]

Since the objective is the stop, vignetting will occur at the eye lens, Determine \( y_{EYE} \) and \( \bar{y}_{EYE} \) as a function of objective height.
\( \bar{u} = -h / 10.5mm \quad \bar{y}_{EYE} = \bar{u} L = 235mm \quad \bar{u} = -\frac{235mm \cdot h}{10.5mm} = -22.38h \)

\[ u' = -\frac{D_{OBJ} / 2}{f_{OBJ} + \text{Tube Length}} = -\frac{3.0mm}{210mm} = -0.0143 \]

\[ y_{EYE} = u f_{EYE} = -0.0143 \times 25mm = -0.357mm \]

For no vignetting:

\[ D_{EYE} = 5.0mm \]

\[ a_{EYE} = \frac{D_{EYE}}{2} = |y_{EYE}| + |\bar{y}_{EYE}| = 2.5mm \]

\[ 0.357mm + 22.38h = 2.5mm \]

\[ h = HFOV = 0.096mm \]

\[ FOV = 0.192mm = \pm 0.096mm \]