Ray Optics 21 december 2007
N.Westbrook duration: 3h (9h-12h)
Documents and calculator authorized

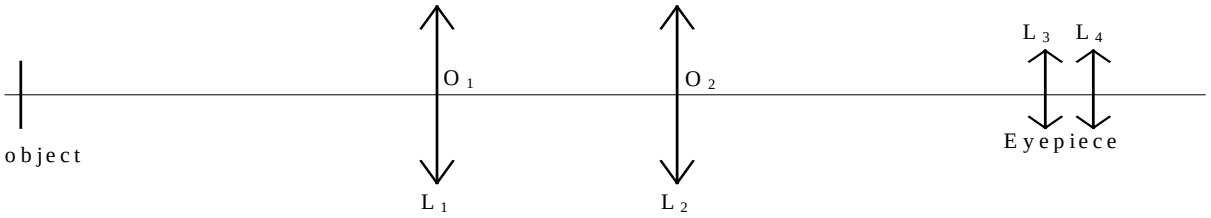
RAY OPTICS EXAM

Measuring microscope with a long front focal length and variable power

I- Study of the measuring microscope :

The microscope is composed of :
- an objective consisting of two thin lenses L_1 and L_2 with focal lengths $f'_1 = 200$ mm and $f'_2 = 160$ mm;
- a Huyghens-type eyepiece (3,2,1) with a focal length $f'_{ey} = 12{,}5$ mm.

The distance between L_1 and L_2 is equal to 60 mm.
The object is located at the first focal point of the lens L_1. The observer is emmetropic and does not accommodate.



1- Calculate the transverse magnification of the objective (L_1+L_2), the power of the eyepiece and the power of the whole microscope.

2- Determine the cardinal points (F_{ey} , $H_{ey,}$ $F'_{ey,}$ H'_{ey}) of the eyepiece and make a drawing of the eyepiece (use as a convenient scale 2cm= distance between the two lenses). Represent a bundle of rays through the eyepiece originating from its first focal point F_{ey}.
Calculate the focal lengths of each lens L_3 and L_4.

The lens L_2 is the aperture stop (pupil) of the microscope. Its diameter is equal to 20 mm.

3- Determine the position and diameter of the exit pupil. Determine the position and diameter of the entrance pupil, and the numerical aperture in the object space. Determine the depth of field (ie longitudinal uncertainty) in the object space if we assume we are only limited by diffraction (λ=0.5µm). Compare it with the depth of field due to the accommodation of the observer (near point at 250mm). Should we reduce the accommodation? How?

We want a bright field of view with a diameter of 10mm in the object space, and we want L_1 to limit this bright field.

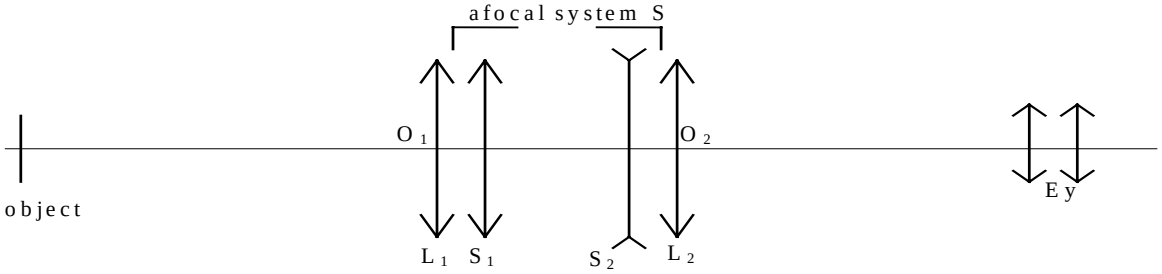
4- Calculate the diameter of the lens L_1 to fulfill this condition. Calculate the bright field of view in the intermediate space and in the image space.

5- Make a drawing **with scale ½ along the axis and scale 4 in the transverse direction** of the system. Draw the path through the microscope of a bundle of rays from an object point A on axis with the largest possible aperture. Draw a bundle of rays from a point B on the edge of the bright field of view, with the largest aperture. Choose a diameter of 10mm for both lenses of the eyepiece.

6- Determine the minimum diameter of each lens of the eyepiece so that they do not affect the bright field of view.

II- Additional system to obtain different powers for the microscope :

We insert between the two lenses L_1 and L_2, an afocal system S.



This afocal system S consists of a converging lens S_1, and a diverging lens S_2. The distance between S_1 and S_2 is equal to 40 mm ($0_1S_1 = 0_2S_2$= 10 mm). The system S can be inserted in the direction shown on the figure above (position 1), it can be removed (position 2), or it can be put in the reverse direction (position 3: the positions of S_1 and S_2 are interchanged). We thus obtain, depending on the position chosen, three different powers for the whole intrument (L_1+ S_1+ S_2+L_2+eyepiece).

1- Calculate the focal length of the lenses S_1 and S_2 so that the total power of the microscope doubles when we switch from position 3 to position 2, and doubles again when we switch from position 2 to position 1.

The aperture stop is still the lens L_2 with diameter 20mm. For the three positions, we want the same diameter of the bright field of view **in the image space**, equal to what we calculated in question 4, and we want to suppress all vignetting.

2- Determine the position and diameter of a field stop that will fulfill the above condition.

3- Calculate, for each position of S, the corresponding bright field of view in the object space. Make a drawing to scale for each of the three positions, of a bundle of rays on the edge of the bright field. Draw only the subsystem (L_1, S_1, S_2, L_2) and choose the scales ½ along the axis and **2 in the transverse direction**.

Determine the minimum diameters for the lenses S_1, S_2 and L_1 so that they do not affect the bright field of view in **any** of the three positions.