Optics Laboratory

Magnifying Glasses and Microscopes

1. OBJECTIVES

- Determine the visual magnification of a magnifying glass.
- Design and assemble a didactic microscope.
- Estimate and measure the visual magnification of the didactic microscope.

2. THEORY

2.1 The eye

The human eye is a positive optical system (cornea plus lens) with a variable focal length, which forms images at the retina. In this practice, the imaging properties of an eye with only two different focal lengths is going to be analyzed with the aid of two lenses that can be exchanged. A screen at a fixed distance behind the lenses is going to play the role of the retina. One of the lenses simulates the observation of remote objects (**unaccommodated eye condition**), while the other one does for proximal objects (accommodated eye condition or **maximum accommodation**). The closest observation point of an eye is called the near point, a_0.

2.2 Visual magnification

The visual magnification is the ratio between the size of the image of an object produced by an optical instrument, y'_{with}, and the size of the image of the same object when observed with the naked eye, y'_{without} (see Fig. 1). This quantity is also related to angular magnification, in terms of the corresponding angles ω_{with} and $\omega_{\mathrm{without}}$ under which the eye sees the object with and without an instrument. More specifically, this relation is given as

$$M = \frac{y'_{\mathrm{with}}}{y'_{\mathrm{without}}} = \frac{\tan\omega_{\mathrm{with}}}{\tan\omega_{\mathrm{without}}}, \qquad (1)$$

In the case of magnifying glasses and microscopes, the observation without instrument is always assumed to be in conditions of maximum accommodation (i.e., object in the near point) regardless of the accommodation considered with the instrument.

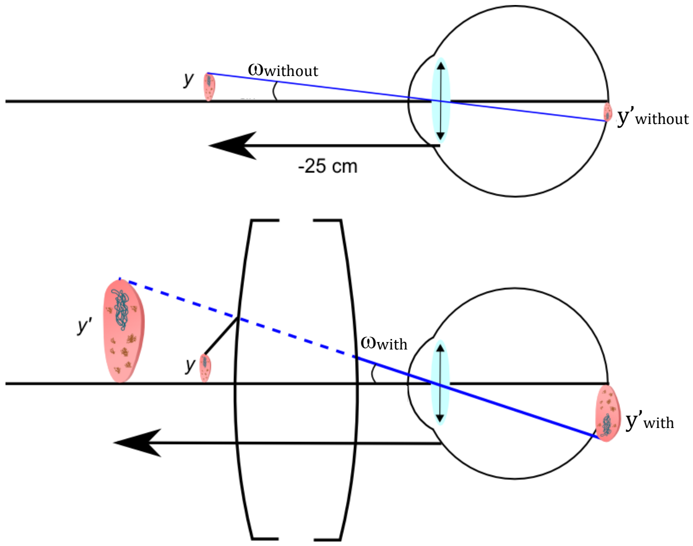


Figure 1: Visual magnification: comparison of the vision of an object with and without an optical instrument.

2.2.1 Visual magnification without accommodation

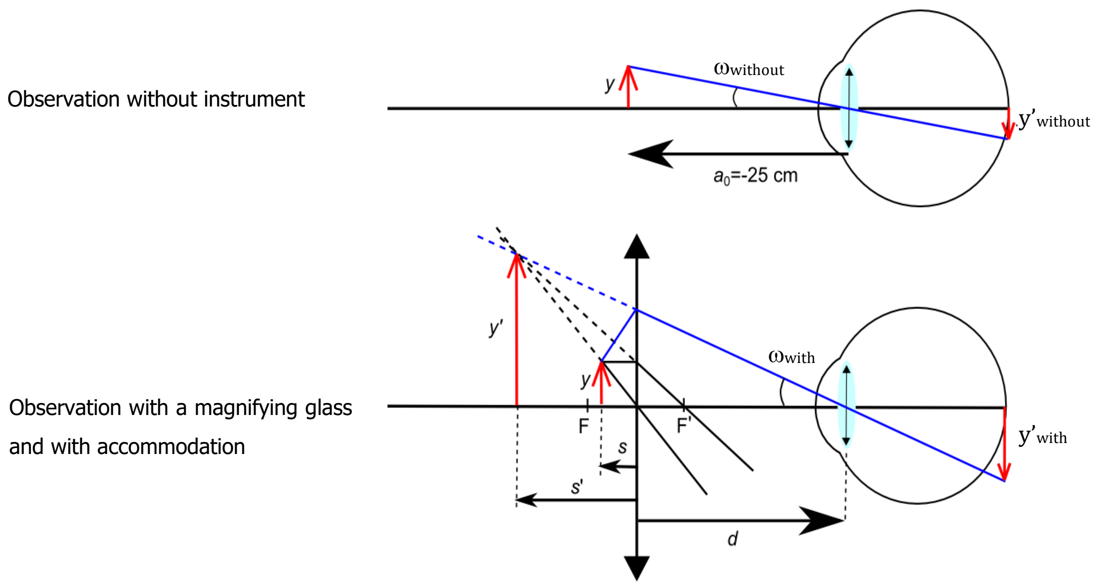
Usually, when observing with an optical instrument, the object is placed at the object focal plane of the instrument, thus, with unaccommodated eye conditions. In this case, the visual magnification can be obtained from

$$M = -\frac{a_0}{f'} \tag{2}$$

where f' is the image focal length of the optical instrument and a_0 the eye near point.

2.3 Magnifying glasses

Typically, when we inspect an object, the eye works under maximum accommodation conditions, positioning the object at the near point [see Fig. 2(a)]. To perceive details, we may consider a magnifying glass, which is just a positive lens that allows us to observe a larger image of the object. This is possible by accommodating the object between the magnifying glass and its object focal point, which generates an enlarged and direct virtual image of the object [see Fig. 2(b)]. This image, when observed with the eye without accommodation, translates into an also larger image (of such an image) on the retina with respect to the observation without the magnifying glass.



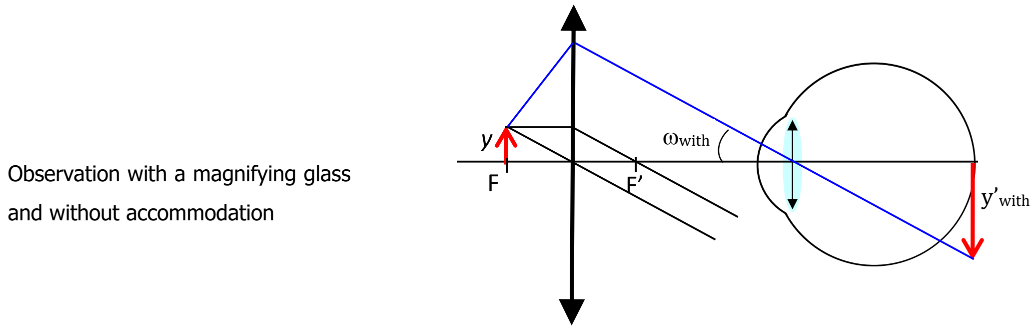


Figure 2. Visual magnification produced by a magnifying glass.

2.4 Microscopes

The microscope is a short focal optical system formed by two positive lenses. It is based on the working principle of the magnifying glass but enhancing its magnification power. To do so, the first lens, namely the objective, produces an inverted real image beyond its image focal point of an object placed somewhere between the object focal point and twice this distance. This image is slightly larger than the object, regardless of the objective focal length, and its position is at the object focal point of the second lens, namely the eyepiece or ocular. The eyepiece will act as a magnifying glass, taking the previous image as object and producing a larger image at infinite, as shown in Fig. 3. According to Eq. (2), to determine the visual magnification, we need the focal length of the microscope. The focal length of h microscope is given by

$$f' = -\frac{f'_{\mathrm{o}} f'_{\mathrm{e}}}{t}, \tag{3}$$

with f'_{o} and f'_{e} the image focal lengths of the objective and the eyepiece, respectively, and t is the so-called optical length of the microscope, which is the distance from the objective image focal point to the ocular object focal point. Observing without accommodation, the visual magnification can be obtained from Eq. (2) and (3)

$$M = \frac{a_0 L}{f'_{\mathrm{o}} f'_{\mathrm{e}}}, \tag{4}$$

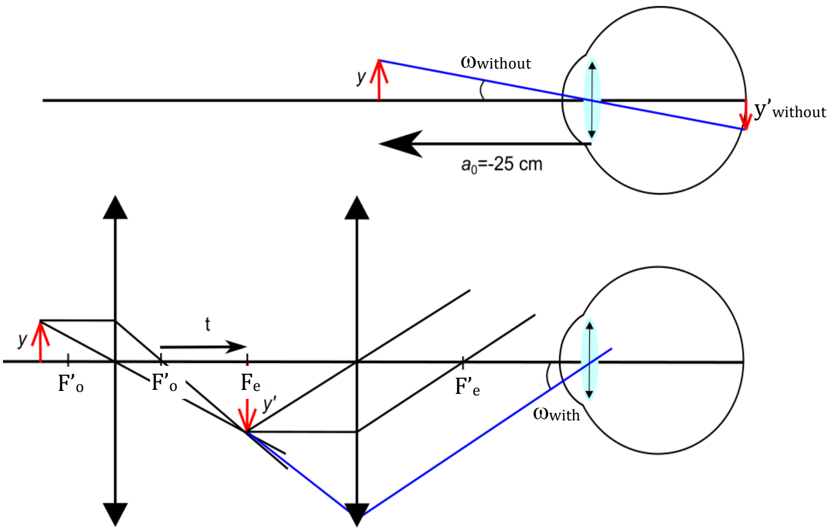


Figure 3. Visual magnification produced by a microscope.

4. BIBLIOGRAPHY

[1] A. Ghatak, *Optics* (McGraw-Hill, 6th Ed., 2017).

[2] F. L. Pedrotti, L. M. Pedrotti and L. S. Pedrotti, *Introduction to Optics* (Pearson Int'l Edition, 2006).

[3] J. F. James, *An Introduction to Practical Laboratory Optics* (Cambridge University Press, 2014).

QUESTIONNAIRE

- **In this practice, uncertainties are optional.**
- **For an easier identification of the answers, please, specify in a visible place the number of the question responded (unless you have included explicitly the question).**

The eye

1. Indicate which lens simulates maximum accommodation and which one no accommodation.
2. Determine theoretically and experimentally the near point of the simulated eye. Theoretically means taking as data the size of the eye and the focal length of maximum accommodation.

The magnifying glass

3. Determine the value of the two lenses available with the aid of the autocollimation method (see practice manual "Thin Lenses"). Annotate the value of their focal lengths. Choose one of them, properly justifying your choice, to play the role of a magnifying glass.
4. Experimentally determine the unaccommodated visual magnification of the selected magnifying glass. Indicate the measurements taken for this purpose.
5. Determine theoretically the unaccommodated visual magnification and compare this value with the one obtained in point 4.

The microscope

6. Use the two lenses now to build a microscope. Write down which lens is going to play the role of the objective and which one the eyepiece, properly justifying the choice. Indicate the value of their focal lengths as well as the distance between objective and eyepiece that you have used in the experiment. From these values, determine the optical length t and focal length of your microscope, and write it down.
7. As before, choose a reference element from the slide and determine experimentally the value of the unaccommodated visual magnification. Using the values of the of the near point of the eye, the focal lengths of the lenses and the optical length of your microscope, determine the theoretical value of the visual magnification produced by your microscope and compare it with the experimental value.

Additional comments

8. If you have observed or thought about something else that has not been previously considered in any of the above points, you can add it here.