Homework 9

Angular magnification. Simple magnifiers. Eyepieces.

The simple magnifier is a convex lens used to read small print. It is often called a *reading glass*. We already know that a simple magnifier creates a magnified virtual image of the object. Virtual images viewed with optical instruments may be at great distances, sometimes even "at infinity" when the rays entering the eye are parallel. In this case it is difficult to analyze lateral magnification, since it also approaches the infinity and is not very useful. The concept of "*angular magnification*" is much more useful in such cases. Angular magnification is the ratio of angle, subtended by the image, created by the magnifier, to the angle, subtended by the object examined by the unaided eye. Angular magnification is a measure of the size of the image formed at the retina.

The operation principle of the simple magnifier is shown in Figure 1.

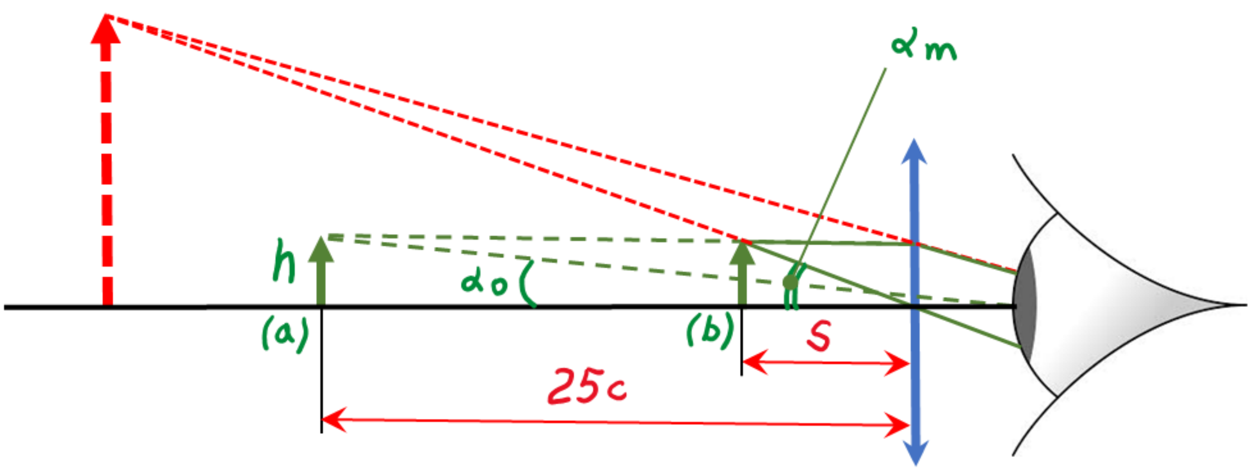

Figure 1. Operation of a simple magnifier.

First, a small object with a lateral size h is examined by the unaided eye. It is assumed to be held at the *near point* of the normal eye – nearest position of distinct vision – 25cm from the eye (position (a) in Figure 1). If we put the object farther away from the eye, we will see it "smaller", if the distance is less than 25 cm, we may experience difficulty in "focusing". So, the distance of 25 cm is commonly accepted as the distance for the most comfortable viewing of small objects with the unaided eye. At this position the object subtends an angle α_0 at the eye (Figure 1).

Second, we "magnify" the object: we move the object to the closer position (b) and insert the simple magnifier (for example a convex lens) between the object and the eye. In this position the object is close to the focal distance f of the lens and the lens forms a virtual larger image subtending a larger angle α_m at the eye. We will consider the angles as small, to their tangents are approximately equal to the angles themselves ("paraxial" approximation). So we have:

$$\frac{\alpha_m}{\alpha_0} = \frac{h/s}{h/25} = \frac{25}{s} \qquad (1)$$

If the image is very far away (at infinity), then $s \approx f$, and angular magnification $\boldsymbol{M}$ is:

$$M = \frac{25}{f} \qquad (2)$$

At the other extreme, the virtual image is close to the near point of the eye, then the distance to the image $s_i \approx -25cm$. "Minus" sign is used since the image is virtual. Then, from the thin lens equation we have:

$$s = \frac{25f}{25+f} \qquad (3)$$

and the angular magnification is

$$M = \frac{25}{f} + 1 \qquad (4)$$

The actual angular magnification depends then on the particular viewer, who will move the simple magnifier until the virtual image is seen comfortably. If the focal distance of the magnifier lens is small, then there is no much difference between expressions (2) and (4) and expression 2 is often used. Typically, simple magnifiers have magnification range from 2x to 10x. Higher magnification is reachable, but requires special lenses,

When magnifiers are used to aid the eye in viewing images formed by prior component of the optical system, they are called *oculars* or *eyepieces*. The image which is formed by this prior component (for example by the microscope objective) serves as ther object that is viewed by the eyepiece, whose angular magnification contributes to the total magnification of the instrument.

Problems.

1. A reading glass has a focal distance of 2.5cm find its maximum angular magnification.

2. A convex lens produces a real image which is 2 times larger than the object. Find the focal distance of the lens if the distance between the lens and the image is 24cm. Make a picture.

3. An object is placed 25cm before the front focal point of a concave lens. The image is produced 36cm behind the rear focal point. Find the focal distance of the lens. Make a picture.

4. A concave mirror is filled with water. The radius of curvature is 40cm; the refractive index of water is 4/3. Find the focal distance of this optical system.