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PHYS 1120 Discussion 10. Compound Optics

1. **Microscope**

A simple microscope contains an objective lens with focal length f_1, which creates a magnified real image of the object at an image distance of L from the lens. This image is viewed through an ocular lens, which enables the operator to see the image comfortable with high magnification. For the microscope to act as a microscope, L is much larger than f_1. From that, we know that the object distance d_o is only slightly larger than f_1. For now, we will approximate that $d_o = f_1$.

A. Find the size h_1 of this magnified real image in terms of L, f_1, and h_o, the height of the object.

To view the real image comfortably at high magnification, the viewer looks through an ocular lens with focal length f_2. The ocular lens is placed so that the real image from the objective lens is at the focal plane of the ocular lens. With this real image as the object of the ocular lens, the ocular lens produces a virtual image at an image distance of infinity.

B. The angular size α_2 of the image as viewed by the operator is $\alpha_2 = h_1/f_2$. Express this in terms of L, f_1, f_2, and h_o.

The magnification provided by the microscope is $M = \alpha_2/\alpha_1$, where α_2 is the final angular size as viewed by the operator and α_1 is the angular size of the object as seen by the operator without the aid of the microscope. This would be $\alpha_1 = h_0/N$, where N is the *near point*, the closest distance at which the operator's eyes can focus.

C. Express the magnification given by this microscope in terms of f_1, f_2, L, and N.

2. **Telescope**

A simple refracting telescope, like a microscope, contains two lenses: an objective lens, which receives light from a distant object, and an ocular lens, which the operator looks through. The distant object is effectively at an object distance of $d_o = \infty$, so the object height is not a meaningful quantity. Instead, we consider α_1, its angular size as viewed by an observer. (For example, the angular size of the Moon in the sky is about ½ degree.)

A. Consider an objective lens with focal length f_1. When the object is at an object distance $d_o = \infty$, where is the image? (What is the image distance?)

B. What is the height h_1 of the image? Recall that the angular size of an object and its image are the same, when viewed from the location of the lens. (For the purposes of these calculations, the "angular size" is the tangent of the angle in question.)

To view the real image comfortably at high magnification, the viewer looks through an ocular lens with focal length f_2. The ocular lens is placed so that the real image from the objective lens is at the focal plane of the ocular lens. With this real image as the object of the ocular lens, the ocular lens produces a virtual image at an image distance of infinity.

C. The angular size α_2 of the image as viewed by the operator is $\alpha_2 = h_1/f_2$. Express this in terms of α_1, f_1, and f_2.

D. Find the magnification M of this telescope, $M = \alpha_2/\alpha_1$.

E. If the operator looks through the telescope in reverse, what is the magnification?

3. **Corrective lens for myopia**

In the eye, the image distance must always be *D*, the diameter of the eyeball, for an image to be in focus. To focus on objects at different distances from the eye, the viewer must adjust the lens's focal length *f*.

In myopia ("nearsightedness"), the greatest distance at which an object can be in focus is the "near point" *N*.

A. If D = 25 millimeters and N = 1 meter, what is the focal length of the lens?

To correct myopia, a corrective lens is placed in front of the eye. When viewing an object an infinite distance away, the corrective lens produces an image at the eye's near point. Then, the lens of the eye produces an image of that image that falls on the retina of the eye.

B. The image made by the corrective lens is at a distance *N* in front of the eye. Is the *image distance* of this image $-N$ or $+N$?

C. What is the focal length of the corrective lens?

D. Is the corrective lens a converging lens, or a diverging lens?

4. **Corrective lens for hyperopia**

In hyperopia ("farsightedness"), the eye cannot focus on nearby objects. Let us consider a case of hyperopia in which the focal length of the eye's lens is $D(1+a)$, where a is a small dimensionless number. This means that a distant object, such as a star, produces an image at a distance of $D(1+a)$, *beyond* the retina of the eye.

To correct hyperopia, a corrective lens is placed in front of the eye. The corrective lens produces an image which is the object of the eye's lens. The corrective lens's image is at a distance such that the eye's lens produces an image of it at the retina.

A. Where is the image produced by the corrective lens located?

B. Is this image in front of the lens (same side of the corrective lens as the object) or behind the lens?

C. Is this image distance (with respect to the corrective lens) positive or negative?

D. What is the focal length of the corrective lens?

E. Is the corrective lens a converging lens, or a diverging lens?

F. Here, we considered a corrective lens to allow the viewer to focus on a distant object. To allow the viewer to focus on a nearby object, should the focal length of the corrective lens be longer or shorter?