Physics 5CL Prelab

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Collaborators

I worked wth **Andrew Binder** and **Aren Martinian** to complete this prelab.i

Problem 1

In Experiment 1, you will be asked to produce an image with magnification of (roughly) $M = -1$.

a) Given a lens with focal length f, what must d_o and d_i be to accomplish this?

Solution: The magnification is $M = -1$, so using equation 2b:

$$M = -1 = -\frac{d_i}{d_o} \implies d_i = d_o$$

The following three parts are a brief derivation of the angular magnification formula Eq. 4. Consider an eyepiece with a focal length f_{EP}. If an object is placed slightly less than one focal length away from the eyepiece then the image is a virtual image formed far in front of the lens. You may assume that the angular width made by this virtual image is the same as its angular size as perceived by the eye because the eyepiece is meant to placed very close to the eye.

b) Find the angular width θ_{NP} of an object of height h as seen by the eye when the object is placed in front of the eye at the person's near point distance d_{NP}. You may use the small-angle approximation.

Solution: By the small angle approximation we have $\theta_{NP} \approx \tan\theta_{NP} = \frac{h}{d_{NP}}$.

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c) Find the angular width of the object θ_{EP} as seen by teh eye when placed one focal length in front of the eyepiece lens. Assume the eye is placed near the lens. You may use the small-angle approximation. *Hint: Use one of the principal rays for lenses to relate the angular width of the object to the angular width of the image.*

Solution:

The image is virtual, and forms behind the object. However, since this is true, θ_{EP} is a part of two different triangles: that of the image as well as that of the object. Thus:

$$\theta_{EP} \approx \tan\theta_{EP} = \frac{h}{f_{EP}}$$

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d) Use the previous two results to recover Eq. 4

Solution: The magnification is defined as $m = \frac{\theta_{EP}}{\theta_{NP}}$. Thus:

$$m = \frac{\frac{h}{f_{EP}}}{\frac{h}{d_{NP}}} = \frac{d_{NP}}{f_{EP}}$$

Problem 2

Consider a microscope with a converging objective lens of focal length f_{OB} and a converging lens of focal length f_{EP}. The two lenses are separated by a distance $f_{OB} + s + f_{EP}$.

a) At what object distance (for the objective lens) will the image from the objective lens form a distance f_{EP} before the *eyepiece* lens?

Solution: The image forms at a distance $f_{OB} + s$ from the objeectie lens:

$$\begin{aligned} \frac{1}{f_{OB}} &= \frac{1}{d_o} + \frac{1}{f_{OB} + s} \\ \frac{1}{d_o} &= \frac{1}{f_{OB}} - \frac{1}{f_{OB} + s} \\ &= \frac{s}{f_{OB}(f_{OB} + s)} \\ \therefore d_o &= \frac{f_{OB}(f_{OB} + s)}{s} \end{aligned}$$

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b) What is the linear magnification of the original object by the objective lens?

Solution: We use the magnification equation:

$$\begin{aligned} m &= -\frac{d_i}{d_o} = \frac{f_{OB} + s}{\frac{f_{OB}(f_{OB}+s)}{s}} \\ &= -\frac{s}{f_{OB}} \end{aligned}$$

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c) [*Optional*] Show that the angular magnification by this microscope is given by Eq.5 *Solution:* We know that $M \equiv m_{EP} m_{OB}$, and we have m_{EP} from the previous question:

$$M = -\frac{s}{f_{OB}} \cdot \frac{d_{NP}}{f_{EP}} = -\frac{s d_{NP}}{f_{OB} f_{EP}}$$
