TRICK OF THE TRADE

How to Quickly Estimate the Focal Length of a Diverging Lens

To quickly estimate the focal length of a *converging* lens, we form a real image of a distant object. Thus a child with a magnifying glass imaging the Sun to burn a hole in a piece of paper can be viewed as "measuring" the focal length (distance from magnifying glass to paper) of the glass.

For a *diverging* lens, however, a quick estimate is not so easy because a diverging lens forms no real image. Suggested methods for making such a measurement most often require additional elements with known properties.[1] But for the hands-on physicist who wants to estimate the eyeglass prescription of a nearsighted friend over dinner, there is a quicker, simpler technique.

Diverging lenses do not form real images of an object, but the virtual images formed can be seen and focused by the eye. As shown in the ray tracing of Fig. 1, if an object is placed a distance equivalent to (the magnitude of) the focal length of the lens, the magnification of the virtual image will be one-half. To implement the technique (and perhaps before you perform your dinner-table demonstration), hold the lens in front of an object for which you can easily see when the magnification is one-half (a nice pattern for this is shown in Fig. 2). Adjust the lens-object distance until the magnification is one-half. It is best to draw long object lines so the viewer can simultaneously look at the image through the lens and the object outside it. With a bit of practice, soon the virtual image and the original object can both be seen and you can easily determine when the magnification is one-half.

If the focal length is greater than a few tens of centimeters, this will involve two people, one to hold and move the lens and another to look for the magnification of one-half. This is because the person looking for the magnification needs to be "far away" ($d >> |f|$), compared with the focal length, to avoid a differential magnification of object and image by the eye. If you are estimating your nearsighted friend's eyeglass prescription, you can usually come to within 0.5 diopters, where a diopter is the inverse of the focal length (in meters).

You can explain the technique by using the "thin-lens equations." If f, o, and i are focal length (a negative number for a diverging lens), object distance, and image distance, respectively, then

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}.$$

Now if the object is placed at the magnitude of the focal length from the lens, then

$$\frac{1}{f} = \frac{1}{-f} + \frac{1}{i}$$ and therefore $i = f/2$.

But the magnification $M = -i/o = -(f/2)/(-f) = ½$. In practice this technique affords a reasonable estimate of common eyeglass prescriptions for nearsighted persons, i.e., a lens with a focal length between –10 cm and –1 to –2 meters.

Reference

1. Hemanshu Roy, "A new method for measuring the focal length of a diverging lens," *Am J. Phys.* **40**, 1869–1870 (1972).

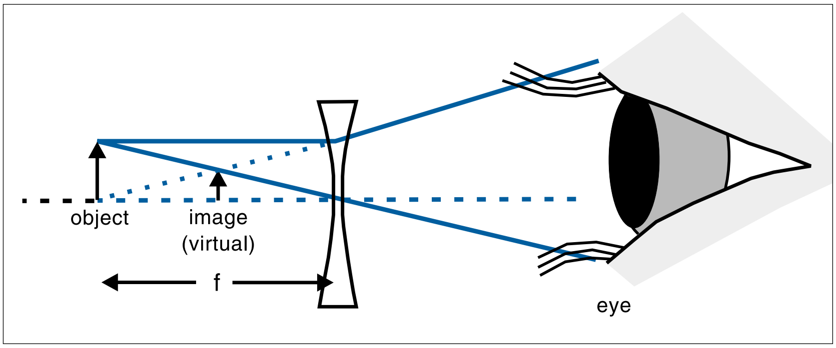

Fig. 1. Ray tracing of estimation technique.

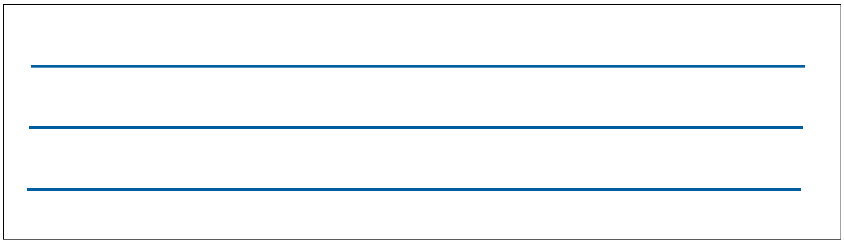

Fig. 2. Test pattern for estimation technique.

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