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Measuring the diameter of your blind spot

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Optics is a component of three introductory physics courses my university offers: the third course of a three-semester calculus-based sequence for physics and engineering students, the second course of a two-semester algebra-based sequence for biology students, and a conceptual course for students planning to teach at the elementary school level. In all of these courses, I devote some time to the eye, discussing standard topics such as its structure, image formation, and defects in vision and how they can be corrected with lenses. To complement this discussion, I have designed a simple experiment that allows students to work together in small groups, take data, and then make a calculation to roughly determine the diameter of their "blind spot." The level of the calculation is altered to suit the mathematical level of the students.

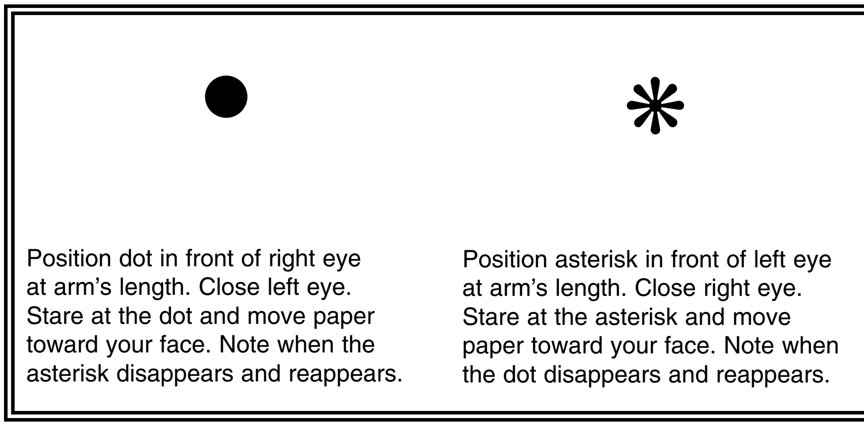

Fig. 1. One version of figure commonly used to demonstrate presence of blind spot.

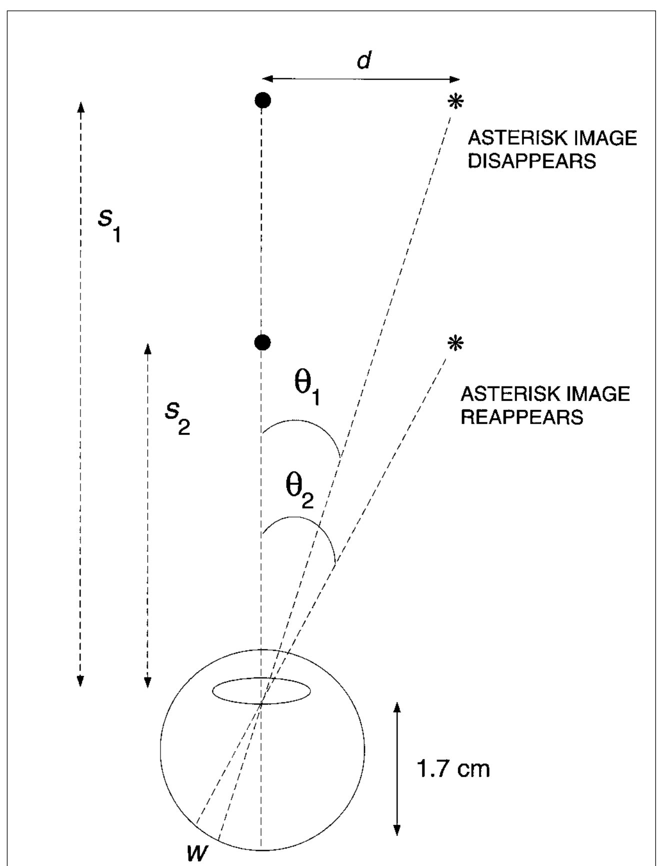

Fig. 2. Geometry involved for estimating (for the right eye) the diameter of blind spot.

Procedure

First, I pass out sheets of paper similar to Fig. 1 and ask the students to follow the directions given. (Surprisingly, the majority of our classes have not seen this "dot-asterisk" diagram and its effectiveness in illustrating the presence of the blind spot.) Discovery of the blind spot commonly produces a "whoa!" from various parts of the classroom.[1]

After everyone has observed the effect, the students organize themselves into groups of threes and I give each group a meterstick. We now think through together how a rough estimate of the diameter of the blind spot might be found, using the dot-asterisk diagram and the meterstick. In general, students come up with the right procedure, but are unsure of the geometry. The next step then is to consider the geometry used. Here, the procedure may differ somewhat for different courses. The calculation may be assigned as homework or could be illustrated on the blackboard. For students with very limited background in trigonometry, it might be more appropriate to just mention the concepts used and provide a simplified formula for the calculation.

Figure 2 is one sketch I have used to describe the geometry of the system. The distance between the dot and the asterisk is represented by d. When the student doing the experiment first observes the disappearance of the image of the asterisk (using her right eye), she indicates to a second student in the group to make a measurement of s_1, the distance between the sheet and her eye. During this time, the second student has been holding the meterstick horizontally close to the head of the first student and parallel to her line of sight. The second student makes the measurement and tells the third student in the group, who records the value. A second measurement is made and recorded when the image of the asterisk reappears (this is s_2 in the figure). So when the sheet is between s_1 and s_2, the light ray from the asterisk entering the eye falls on the blind spot. Students take turns performing the experiment until everyone has found personal values for s_1 and s_2.

Calculations

As shown in Fig. 2, the angle between the optical axis and the light ray from the asterisk entering the eye when its image first disappears is designated by θ_1; the corresponding angle when the image reappears is θ_2. In terms of d, s_1 and s_2, we have $\theta_1 = \tan^{-1}(d/s_1)$ and $\theta_2 = \tan^{-1}(d/s_2)$. The width of the blind spot, w, is given by $w \approx r(\theta_2 - \theta_1)$, where r is the distance between the retina and the optical center of the cornea-crystalline lens combination.

For d = 12 cm, the averages (found for a group of about 12 students) for s_1 and s_2 were about 45 cm and 34 cm respectively. If a value[2] of 1.7 cm is used for r, the average calculated diameter of the blind spot for that group of students is

$$w \approx (1.7 \text{ cm})[\tan^{-1}(12 \text{ cm}/34 \text{ cm}) - \tan^{-1}(12 \text{ cm}/45 \text{ cm})] = 0.14 \text{ cm}$$

which is a reasonable value[3] considering the simple approach used.

If time permits, it is useful to follow the experiment with questions on the location of the blind spot on the retina, the effect of corrective lenses on the measurements, the effect of changing the separation between the dot and the asterisk on the measurements (for example, was there any experimental advantage to making d = 12 cm rather than a smaller value, say, 4.0 cm?), and any approximations or assumptions that were made to simplify the experiment. Often the students come up with interesting questions, which make for stimulating discussion and interaction.

References

1. For another classroom demonstration with the blind spot effect, see A. DePino, "The disappearing student," *Phys. Teach.* **36**, 491 (Nov. 1998).
2. Eugene Hecht, *Physics* (Brooks/Cole, California, 1994), p. 910.
3. Vincent P. Coletta, *College Physics* (Mosby, Missouri, 1995), Fig. 25-1.