ABSTRACT
A physical eye model made of a water balloon and a convex lens is described. It can be used to model how an image is formed in the eye as well as shortsightedness and farsightedness. The model is unique in featuring a fluid-filled “eyeball” with “intraocular pressure,” making it a useful tool for teaching about accommodation and glaucoma. Instructional ideas for the model are suggested.

Key Words: eye; eye model; interocular pressure; physical models; glaucoma.

Introduction
Physical models facilitate learning by making abstract ideas visible (Rapp & Kurby, 2008), which is particularly important for kinesthetic learners (Fleming, 2001). A variety of physical eye models are used to teach about the anatomy and functionality of the human eye. These models are either commercially manufactured or self-made. All have their respective strengths and limitations. Some models only show the anatomical features, while others function as eyes—models that “see.” A commonly used eye model is a large round flask filled with fluorescent dyed water, which makes the light path visible when a light source is shone into the flask via a convex lens attached on the outside of the flask (Institute of Physics, 2019). Convex lenses of different refractive power can be used to model accommodation, shortsightedness, and farsightedness. Pulley et al. (1968) described four self-made eye models made of a ping-pong ball, globe, papier-mache, and rubber ball. All these models work by allowing light to pass through a hole and a convex lens to form an image at the back of the eyeball. The globe eye model even has a sliding lens for accommodation, which, however, is different from the human eye, in which accommodation is a result of changes in the convexity of the lens. Colicchia et al. (2008) made a lens with adjustable convexity by injecting water into a plastic disk.

Water Balloon Eye Model
A functional eye model made of a water balloon and a convex lens is described here (Figure 1). It is easily made with inexpensive materials. A convex lens is placed inside the water balloon in such a way that it is being pushed by the pressure of the water (vitreous humor) to seal off the hole (pupil). This model is unique in having a water-filled eyeball that simulates the role of vitreous humor in producing intraocular pressure. Besides, the water-filled eyeball more accurately depicts the refraction of light across the lens than other models, since light is less refracted moving from the lens to fluid than to air.

Making the Water Balloon Eye Model
(1) Insert a convex lens (~6 cm focal length) into a 10-inch balloon (Figure 2A).
(2) In the sink, fill the balloon with water until it is ~12 cm in length. Twist the neck of the balloon and turn the balloon upside down. The lens will sink to the bottom over the neck. In the sink, untwist the neck. The lens will be pressed against the neck, sealing off the mouth (Figure 2B).
(3) Cut off the balloon’s neck to make a hole (pupil) above the center of the lens (Figure 2C).
(4) Stick a paper “iris” around the hole, about half the diameter of the water balloon (Figure 2D).
(5) At the back of the balloon, at the center, draw a circle ~2 cm in diameter to represent the yellow spot. A few centimeters lateral to the yellow spot, draw a dark spot to represent the blind spot.

Instructional Ideas
To show how an image is formed in the eye, shine an LED flashlight at the pupil (Figure 3) and an image is formed at the back...
of the balloon (Figure 4). If a letter “F” is written on the lens of the flashlight, an upside-down, left-and-right reversed image can be seen. The object distance depends on the refractive power of the convex lens; most often the lens used is not strong enough to form an image at the back of the balloon and an additional convex lens is needed for forming a sharp image. The balloon can be compressed to make its optical axis longer or shorter to model shortsightedness or farsightedness (be careful not to pop it!). A shortsighted eye can be corrected by placing a concave glasses lens in front of the eyeball.

One unique feature of this eye model is its intraocular pressure. To make students aware of the pressure, they can be asked: What keeps the lens fixed inside the balloon, sealing off the exit? The pressure is important because it keeps the shape of the eyeball so that a fixed optical axis is maintained for the formation of a sharp image on the retina. The model is also useful for teaching about glaucoma. Students are asked to predict what happens to the pressure when more water is injected into the balloon but the size of the balloon is limited by an inelastic sclera. Glaucoma is caused by more aqueous humor flowing into the eye than flowing out, resulting in increased intraocular pressure. The blood vessels at the choroid are thereby compressed, and less blood flow leads to the death of some rod and cone cells on the retina. Intraocular pressure is also related to the mechanisms of accommodation. In

Figure 1. A water balloon eye model.

Figure 2. Making the water balloon eye model.

Figure 3. Use the eye model to show how an inverted image is formed in the eye. An additional convex lens is sometimes needed to help focus the image at the back of the balloon. The balloon eyeball is put inside a tray to prepare for accidental rupture of the balloon.
the widely held theory of von Helmholtz (1855), the relaxation of the ciliary muscle and increased tension of the suspensory ligaments cause the crystalline lens to become less convex when looking at distant objects. How can muscle relaxation lead to increased tension of the suspensory ligaments? It is hardly comprehensible without considering the intraocular pressure that pushes on the lens.

It is paramount to discuss the limitations of the eye model with students. One major shortcoming of the model is the absence of the cornea and aqueous humor. The cornea is an important structure that is responsible for most of the refraction of light into the eye. A watch glass can be put in front of the eyeball to model the cornea. On the other hand, the balloon membrane differs from the sclera in being elastic and translucent. This can be corrected by wrapping the balloon with aluminum foil, leaving a hole at the back for seeing the image. Another limitation of the model is that its lens has a fixed shape and is thus not able to model accommodation. The adjustable lens developed by Colicchia et al. (2008) may help, but it is highly difficult to insert this lens into the balloon.

The eye model is relevant to one of the Science and Engineering Practices of the Next Generation Science Standards – building models to describe and explain natural phenomena and work out design (NGSS Lead States, 2013). An extra challenge for students would be to have them construct the eye model without any instruction except an example of the final product.

○ Conclusion

The water balloon eye model is a self-made, inexpensive, functional model capable of showing how an image is formed in the eye. It is unique in having a fluid-filled eyeball with intraocular pressure, which makes it particularly suitable for teaching about the vitreous humor, the shape of the eyeball, shortsightedness, farsightedness, accommodation, and glaucoma. The modeling activity itself is fun and provides students kinesthetic learning.

○ Supplemental Material

A Teacher’s Guide for the activity is available with the online version of this article.

References

Colicchia, G., Wiesner, H., Waltner, C. & Zollman, D. (2008). A model of the human eye. Physics Teacher, 46, 528.

Fleming, N.D. (2001). Teaching and Learning Styles: VARK Strategies. Christchurch, New Zealand: N.D. Fleming.

Institute of Physics (2019). Model eye demonstration with flask. https://spark.iop.org/collections/eye.

NGSS Lead States (2013). Next Generation Science Standards: For States, by States. Washington, DC: National Academies Press.

Pulley, J. (1968). Home-made eye models that “see.” American Biology Teacher, 30, 653–654.

Rapp, D.N. & Kurby, C.A. (2008). The “ins” and “outs” of learning: Internal representations and external visualizations. In J.K. Gilbert, M. Reiner & M. Nakhleh (Eds.), Visualization: Theory and Practice in Science Education (section A, pp. 29–52). Dordrecht, Netherlands: Springer.

von Helmholtz, H. (1855). Uber die akkommodation des augues. Graefes Arch Ophthalmology, 1, 1–89.

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Figure 4. An inverted image is formed at the back of the balloon.