Mysterious soda can

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We recently found an ordinary looking soda can with an extremely rare characteristic. Our experience with the can has potential for a physics classroom activity and hence might be of interest to *TPT* readers. The can, initially containing carbonated water without sugar, had been stored on a plastic liner in a cupboard for eight years. We found it intact and unopened, but empty! What caused the loss of its content? This question could be presented to students, potentially during class discussion about pressure, to come up with ways to find out the answer. We used the following non-destructive investigation to figure out what had happened.

The ubiquitous aluminum can is composed of two parts, the body and the lid. Our suspect was a leak/gap somewhere along the seam between the two parts, especially in the absence of any sign of compromise at the tab. We submerged the can in hot water, which had been heated to near boiling, in a pot on the stove. A smaller pot lid made of glass and with a metal skirt was used to safely hold the can horizontally against buoyant force. Our reasoning was that heating the gas in the can would raise its pressure, and, if a gap existed, escaping gas would show up as bubbles. Quickly after immersion, small bubbles of < 1 mm across started to escape from the surface of the can at a rate of multiple bubbles per second. But to our surprise the bubbles originated from an apparently small hole at the base, and not from the seam. Using a digital microscope we confirmed the hole, about 70 μm across, at the base where the can was in contact with the liner for years (see Fig. 1). We also observed some scratch marks from abrasion of some sort at the base.

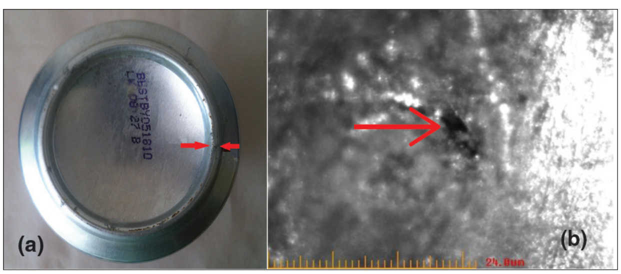

Fig. 1. (a) Arrows point toward the location of the hole at the base. (b) The hole with 42X magnification. Note: scale increment is 24 μm.

To the best of our knowledge, perhaps some combination of food residues on the liner near the areas of scratches caused the aluminum can to undergo pitting corrosion that eventually created the hole. The initial gage pressure in the can, typically about 3.5 atm, would force out the liquid through the hole. In the process, dissolved CO_2 would escape carbonated water and maintain a positive gage pressure. Over a long period of time the can lost all of its liquid through the hole, first due to positive gage pressure and then evaporation, and to a lesser degree diffusion. We have documented our investigative process with details including estimation of leak rate and references. Interested readers may contact sshakerin@pacific.edu to receive a copy free of charge.

The empty but unopened aluminum can is an intriguing object. With a bubble test and optical inspection tool we discovered why such a can lost its content without ever being opened, and provided a plausible explanation of how it happened.

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Another pictorial approach to Lenz's law

After reading Andrew Duffy's fine article, "A Pictorial Approach to Lenz's Law,"[1] I want to share a similar method that I presented to the Michigan Association of Physics Teachers (MIAAPT) four years ago and have been teaching since graduate school.

The method consists of constructing a table with vector symbols representing Φ_1, Φ_2, $\Delta\Phi$, and $\boldsymbol{B}_{\text{induced}}$. The magnetic flux $\Phi = \boldsymbol{B} \cdot \boldsymbol{A} = BA \cos\theta$ is a real number represented in the table as a one-dimensional vector. The coordinate system is chosen to be positive in the direction of the normal to the surface $\boldsymbol{A}$, which is always oriented such that the first measurement Φ_1 is positive. After a sufficiently small interval, a second flux Φ_2 is measured.

Applying the method (as in Duffy's Fig. 2) to a conducting loop that approaches from above a straight wire carrying a current directed to the left gives

Φ_1	Φ_2	$\Delta\Phi$	B_{ind}
x	X	x	⊙ I_{ind}

The third column, $\Delta\Phi$, is the directed quantity $\Phi_2 - \Phi_1$, or equivalently $\Phi_1 + \Delta\Phi = \Phi_2$. Lenz's law then requires that $\boldsymbol{B}_{\text{induced}}$ be directed *opposite* to $\Delta\Phi$.

Finally, the sense of the induced current I_{induced} is obtained from the direction of $\boldsymbol{B}_{\text{induced}}$ using the right-hand rule for the magnetic field circulating around a current-carrying wire. The method is not restricted to situations with increasing flux and is also applicable to $\boldsymbol{B}$ fields parallel to the page. For instance, if a bar magnet with its north end facing left were pulled rightward out of a coil, we would have

Φ_1	Φ_2	$\Delta\Phi$	B_{ind}
⟵	←	→	X ← ⊙ I_{ind}

Interested readers should feel free to contact me for an animated PowerPoint slide illustrating the procedure.

1. Andrew Duffy, "A pictorial approach to Lenz's law," *Phys. Teach.* **56**, 224 (April 2018).

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Comment on "Two Balls' Collision of Mass Ratio 3:1"

Ogawara and Hull[1] describe an interesting experiment where a small steel ball of mass m is incident at speed v on a larger steel ball of mass M at rest, each ball being suspended as a pendulum. For a perfectly elastic collision, the small ball bounces off the large ball at speed $v/2$, while the large ball recedes at speed $v/2$, provided $M = 3m$. When the balls subsequently collide for a second time, the large ball comes to rest.

The authors imply that the large ball will come to rest during the second collision only if $M = 3m$. In fact, it is easy to show that the large ball will come to rest after the second collision regardless of its mass, at least for a perfectly elastic collision. For example, suppose that both masses are equal and one is initially at rest. Then for a perfectly elastic collision, the ball that is initially at rest comes to rest after the second collision. The authors' observation about the large ball coming to rest could therefore be repeated even if $M = m$ or if $M = 2m$; the distinctive feature of the $M = 3m$ case is that the balls leave with the same speed after the first collision and collide with equal speed before the second collision.

Reference

1. Y. Ogawara and M. M. Hull, "Two balls' collision of mass ratio 3:1," *Phys. Teach.* **56**, 222 (April 2018).

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Color mixing with four prisms redux

An article of the January issue of *TPT*[1] clearly shows that two prisms cannot recombine a dispersed white beam back together, a false demo that is still subsisting, and a letter to the editor in the April issue of *TPT*[2] reports of a more advanced setup that actually can. We think that readers might also be interested in knowing about a similar setup for exploring and discovering additive and subtractive color mixing.

Such a setup consists of four prisms used to disperse and recombine colors coming from a projector (or any appropriate white light source). The recombined white light can be seen on a screen at the right end of the setup (Fig. 1). Note that this setup works only for a steady beam but not a pulsed beam (see ref. 2).

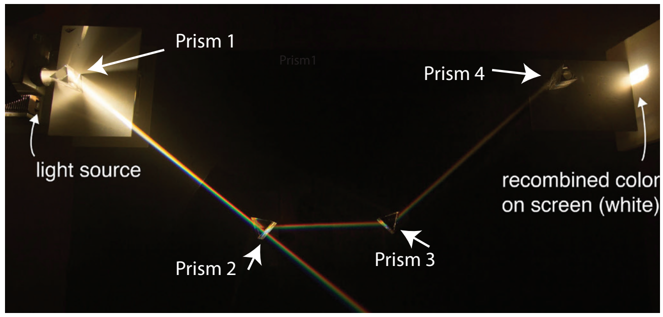

Fig. 1. Recombining light with four prisms.

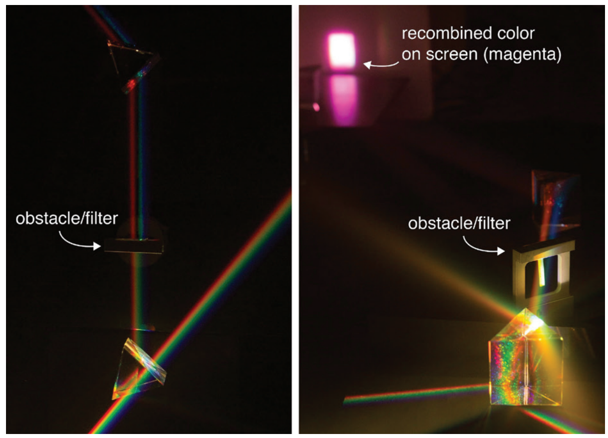

Fig. 2. Color selection and recombination arrangement.

Between the second and the third prism, parallel-traveling colored "rays" can be clearly distinguished using fog or another dispersive medium. By inserting a small obstacle in this area, it is possible to remove (to "subtract") any desired combination of colors. For example, in Fig. 2 the central part of the spectrum was blocked (containing colors approximately ranging from orange to cyan), therefore leaving red, blue, and violet. The resulting perceived color on the screen is given by the superposition of these colors, in this case magenta. Of course, any color filter may also be put in this same area instead of the obstacle.

Using this simple approach, both additive and subtractive color mixing can be discussed. In fact, there are two ways to interpret this experiment: we can see what happens when one or more colors are removed from the entire spectrum, or, looking at what happens after the obstacle/filter only, we can see the result of additive color mixing. We uploaded a video of this experiment at this link:

https://www.youtube.com/watch?v=b-bsQCnCyws.

In the video, the small obstacle used to obtain magenta in Fig. 2 is moved across the beam to remove different chromatic components, thus resulting in different colors on the screen. An entire teaching/learning sequence about these topics might be designed by adding qualitative and quantitative analysis of the resulting colors using do-it-yourself, low-cost spectrophotometers.[3]

References

1. R. Garcia-Molina, A. del Mazo, and S. Velasco, "A simple experimental setup to clearly show that light does not recombine after passing through two prisms," *Phys. Teach.* **56**, 14 (Jan. 2018).
2. K. McDonald, "Recombining rainbows," *Phys. Teach.* **56**, 196 (April 2018).
3. T. Rosi, M. Malgieri, P. Onorato, and S. Oss, "What are we looking at when we say magenta? Quantitative measurements of RGB and CMYK colours with a homemade spectrophotometer," *Eur. J. Phys.* **37**, 6 (2017).

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