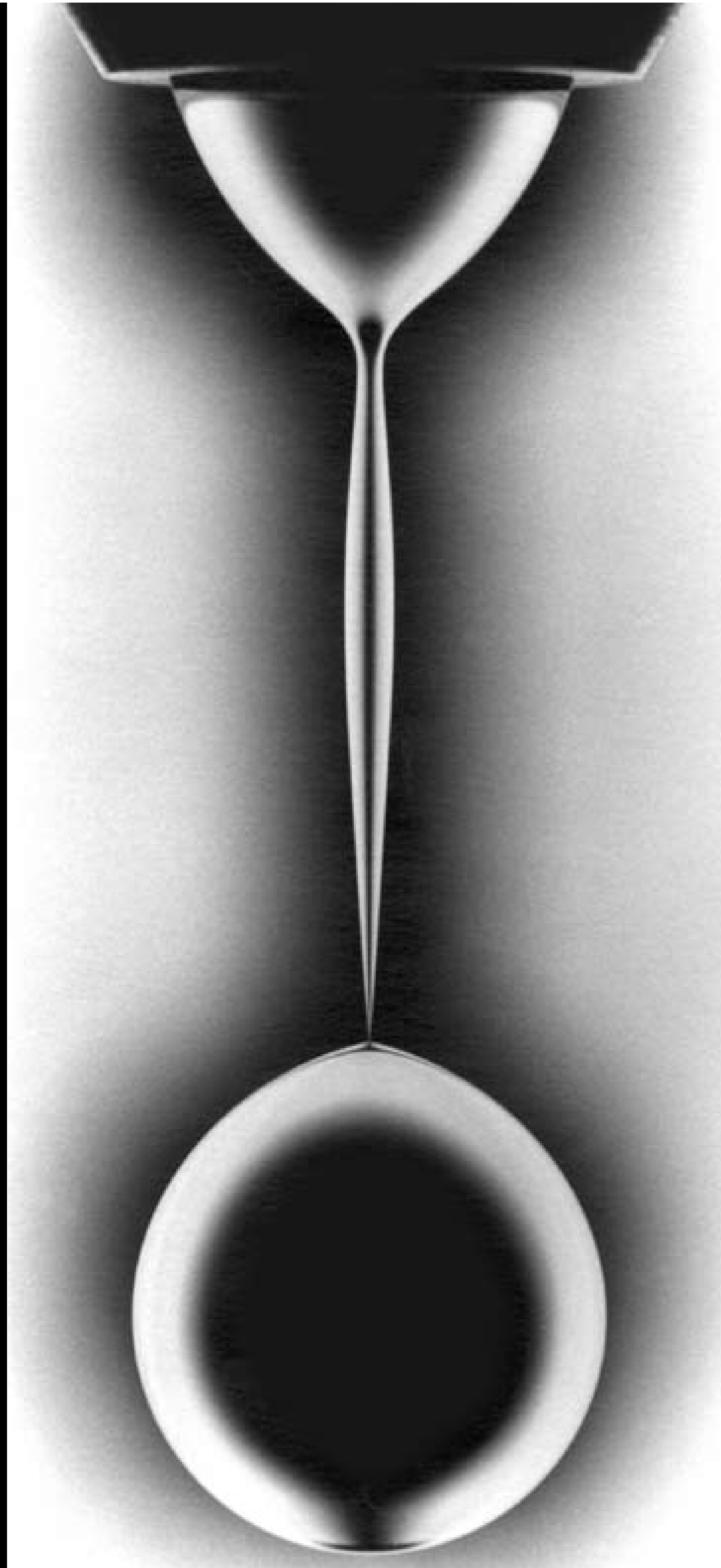

Photograph by Sidney Nagel and Itai Cohen shows a breaking-apart liquid drop from a 0.48-centimeter-diameter nozzle. The image was recorded on ASA 100 black-and-white film with a medium-format camera and a strobe light with a very short flash duration (approximately 5 microseconds). The light was positioned behind the drop, facing the camera. The liquid inside the drop is glycerol; it is surrounded by polydimethylsiloxane (PDMS) oil.

This image again is of one viscous fluid breaking apart inside another fluid, although the ratio of viscosities is not the same as that of the liquids shown in the main picture. As in the other photograph, there is not a large index-of-refraction mismatch between the fluids. Note that even though the neck of the drop is still rather wide, the profile washes out at the neck and is difficult to see.

Felice Frankel

Sid Nagel is an accomplished photographer who sometimes uses his talents for documenting his work in physics at the University of Chicago. When I first saw this particular image, I knew I had to own it, and now I do, 36 inches high. Sid's work reminds us that science images can be both highly informative and stunningly beautiful.

F. F. The purpose of this photograph [of a drop of glycerol in a medium of polydimethylsiloxane (PDMS) oil] was to see the shape of the drop at the point where it split into two pieces. What was the most challenging problem in capturing the image?

S. N. The most difficult problem was that the drop itself was difficult to see because both glycerol and the surrounding PDMS were transparent. Compounding this problem was that glycerol and the PDMS had indices of refraction that were close to one another, so that the interface between them was nearly invisible. This made the profile of the drop close to the breakup point very indistinct. We were interested in measuring the shape accurately so that we could try to understand the nature of the singularity as the neck curvature diverged (that is, as the radius of the drop neck went to zero.)

In order to see the interface, we did not want any direct light from the strobe entering the camera lens. We needed the image to be formed only from light scattered off the drop interface. To do this, we placed a mask, of roughly the shape of the drop, between the drop and the strobe. This mask was surrounded by a diffusing plastic. This blocked all direct light from the strobe from entering the camera and created a dark background for the drop. Light going through the diffuser was directed toward the drop and was scattered by the drop interface into the camera. Because the drop itself acts like a spherical lens, the image of the mask can be seen as the dark shadow inverted in the main part of the drop.

The bright regions are the image of the illuminated plastic diffuser that extend laterally out from the mask. A crucial part of getting a satisfying image was setting the aperture (and therefore the depth of focus) so that the background was neither too dark nor too light. If the aperture was too small, the mask itself came into partial focus, along with the drop, and the background became too dark.

F. F Is this the only way that a drop of fluid will break apart?

S. N. The nature of this singularity varies as the viscosity of the drop and the viscosity of the surrounding fluid is changed. Both the glycerol and the PDMS oil are highly viscous, each with a viscosity about 1,000 times that of water. When the inner fluid is water (with very low viscosity) falling into air (which also has low viscosity), one is in a different regime at snap-off. Here we see the breakup of the drop occurring as shown in the second image.

F F. Since the snap-off event lasted for only a very brief time, how did you precisely control the shutter?

S. N. As the drop started to fall, it intersected a laser beam that was incident on a photodiode. This initiated a signal that, after a programmed time delay, triggered the strobe light to flash. The lights in the room were turned off and the camera shutter opened. After the strobe flashed, the shutter was closed. The time delay between when the drop first intersected the laser beam and when the flash occurred could be varied so that we could capture the precise instant of snap-off.

F. F. How were you able to get accurate measurements, with the drop so small and the neck connecting the two pieces even smaller?

S. N. We knew we would have to magnify the drop for final measurements, so we used a medium-format camera and 120-millimeter macro lens on a bellows. The medium-format negative permitted us a more resolved enlargement.

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Resource: Making Science and Engineering Pictures: A Practical Guide to Presenting Your Work
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