Optics Fun With Gelatin

BY MICHAEL E. KNOTTS

Edible optics? What optical phenomena have you noticed in a bowl of *Jell-O*™ ? Find a small laser, buy a box of unflavored gelatin, and have some fun in your kitchen. Gelatin is not just for dessert anymore; it's great for illustrating some basic optical principles. (Don't forget to invite the neighbors!)

Most people who have mixed a box of *Jell-O* in their kitchen have probably noticed that gelatin mixed with water in sufficient concentration will form a gel that is stable at room temperature and largely transparent to visible light. But not many people know that such a gel exhibits stress birefringence. Furthermore, it is perfect for demonstrating the refraction of rays, since inhomogeneities in the gel scatter light to a small degree, enabling a laser beam passing through the gel to be seen.

Dessert products, which contain dyes, flavorings, and sweeteners, are better for eating than for conducting demonstrations. But gelatin suitable for optics experiments can be purchased at supermarkets under the brand name Knox.[1] It is sold in a box containing several packets, each filled with enough gelatin to make a gel of normal dessert consistency when mixed with two cups of water.

In addition to use in food products and optical demonstrations, gelatin has commercially significant optical applications: It has remained a key ingredient in photographic emulsions for more than a century, and has recently found use as a medium for recording phase holograms. This wonder-protein is derived from collagen, the most abundant protein in higher animals (up to 60% of the total body protein in mammals).[2] Collagen is the stuff that forms connective tissues such as skin, cartilage, ligaments, tendons, and bones.

Sources of collagen used in the commercial production of gelatin include pig skins and cattle hides and bones. These animal products are cooked and chemically processed to break the collagen into smaller protein molecules, which are themselves long chains of amino acids with molecular weights ranging from 10^4 to 10^6 atomic mass units. Aqueous solutions of these molecules are dehydrated to form gelatin granules. When mixed with hot water, gelatin forms a viscous solution. As the solution cools, the

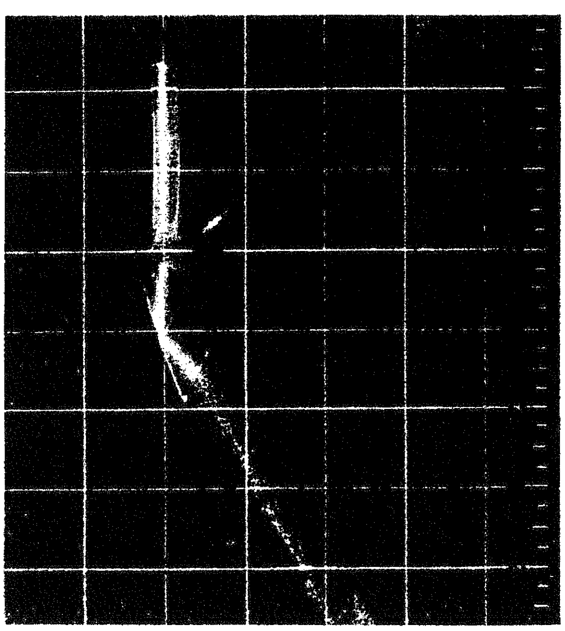

Figure 1.

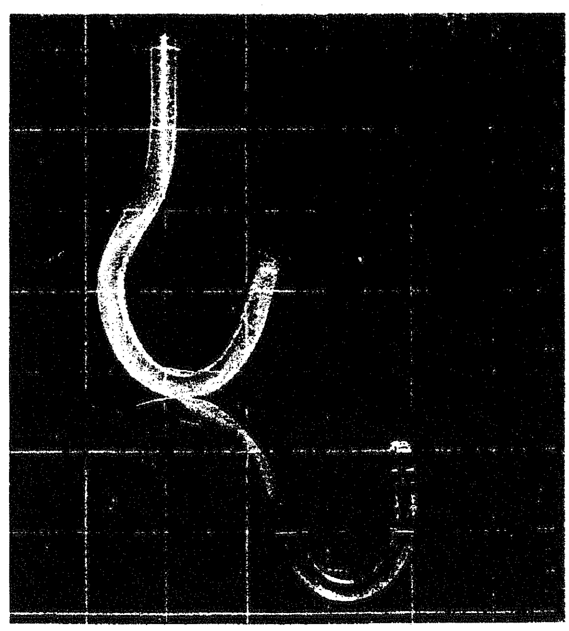

Figure 2.

long chain protein molecules cross-link and become weakly bonded, trapping water to form a colloidal gel.

To prepare gelatin optics, bring clean water to a boil and mix clear, unflavored gelatin *triple strength* (use only 2/3 cup of water for each packet). Mix thoroughly in a clear glass container until no undissolved gelatin is visible (about 5 minutes); then use a spoon to scoop away bubbles on the surface. Next, slowly pour the solution into a clean, flat-bottomed glass tray or bowl (*e.g.*, a casserole dish or serving tray) to form a layer about 10–15 mm thick. Place the solution in a level spot in a refrigerator, and wait for a couple of hours while it forms a gel with a firm, rubbery consistency. Then you can remove the gel from the tray and cut it into prisms, cylindrical lenses, long strips, and other interesting shapes using a pen knife and drafting tools. Experiment with different ways of forming gelatin optics. It may be helpful to use a spoon, spatula, or knife to remove a strip of gelatin from the edge of the tray and then use your fingers to pull out a large sheet of the gel before cutting it into various shapes.

Instead of cutting shapes from a sheet, you may wish to try pouring the gelatin solution into small molds with the desired shapes. With several gel shapes handy, conduct some experiments.

Use a small helium-neon laser or a laser pointer to demonstrate **refraction**, and trace the rays inside these optics. Estimate the index of refraction of the gel using nothing more than a laser and a protractor. **Total internal refraction** is easy to demonstrate with a right angle prism (see Fig. 1).

Create a gelatin **"fiber" waveguide** by cutting a long strip of gel and bending it into a wiggly curve (see Fig. 2). Launch a laser into the end of this strip to demonstrate light piping by total internal refraction; the beam will be seen to propagate along the strip by multiple internal reflections. Demonstrate a **"fiber coupler"** by bringing a second strip in contact with the first strip near one of the reflections; the reflection can be frustrated so that the beam couples into the second strip.

Last, but by no means least, find a white light source and illuminate a fat strip of gel placed between two polarizers. Rotate the polarizers, and notice that the gel is **birefringent** (not surprising, given the long chain molecule structure of gelatin). Try bending and squeezing the gelatin strip to see beautiful color patterns resulting from **stress-induced birefringence** (see "After Image," page 64).

Be sure to recruit some "young scientists" for these experiments, and have plenty of fun!

Footnotes

1. *Knox Unflavored Gelatine For Recipes*, (Knox Gelatine Inc., Englewood Cliffs, N.J.).
2. For more details about gelatin, see the section by P.I. Rose in Chap. 2 of *The Theory of the Photographic Process*, 4th ed., T. H. James, ed. (Macmillan, N.Y., 1977), pp. 51–67.

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Bose–Einstein Condensation

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would enhance greatly the brightness of atomic sources for atom interferometry and atom optics in much the same way as the development of the laser did for optics.

References

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2. D.A. Bell *et al.*, "Relaxation and recombination in spin-polarized atomic hydrogen," Phys. Rev. B **34**, 7678–7683 (1986); For reviews of the hydrogen work see T.J. Greytak and D. Kleppner, in *New Trends in Atomic Physics*, Proceedings of the Les Houches Summer School, Session XXXVIII, Les Houches, France, 1993, G. Greenberg and R. Stora, eds. (North-Holland, Amsterdam, Netherlands, 1986).
3. J.M. Doyle *et al.*, "Hydrogen in the submillikelvin regime: Sticking properties on 4He," Phys. Rev. Lett. **67**, 603–606 (1991).
4. H.F. Hess, "Evaporative cooling of magnetically trapped and compressed spin polarized hydrogen," Phys. Rev. B. **34**, 3476–3479 (1986).
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