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# The uniaxial negative wave surface—a simple teaching aid

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**Abstract**

A polished sphere of calcite (Iceland spar) embedded in an ellipsoid of clear plastic is a useful teaching aid to demonstrate that the wave fronts of the ordinary and extraordinary waves coincide only in the direction of the optic axis or in a direction normal to the optic axis.

A cleavage rhomb of Iceland spar is commonly used to demonstrate the effect of double refraction in crystalline substances and to show that the two waves are plane polarized. In order to relate these observations to the uniaxial wave surface we suggest the use of a sphere of calcite embedded in an ellipsoid of rotation made from clear plastic.

A cleavage rhomb of Iceland spar as free as possible from flaws was ground to spherical shape and polished. The position of the optic axis of the calcite sphere, 2 cm in diameter, was found by viewing between two pieces of polaroid, and a tiny cross scratched on the surface to mark the point of emergence of the optic axis. The sphere, with its optic axis vertical, was placed centrally in a 2 mm thick layer of partially solidified clear plastic in a polypropylene beaker 4 cms in diameter. This enabled the orientation of the sphere to be maintained while liquid plastic was added to just cover the sphere. The hardened plastic was machined and polished to the shape of an ellipsoid of rotation—the optic axis of the calcite being coincident with the axis of rotation. Figure 1a is a view looking down the axis of rotation of the ellipsoid, and the calcite sphere can be seen within the plastic; Figure 1b is a side view of the ellipsoid of rotation, but in this direction the circular section of the sphere is distorted by the lens shape of the plastic so that the sphere also appears elliptical in section.

On viewing printing on a piece of paper looking down the optic axis only one image is seen, and it can be confirmed that the light is not plane polarized by viewing the image through polaroid. Figure 2a shows a view with the camera slightly displaced from the optic axis showing two images of part of the word

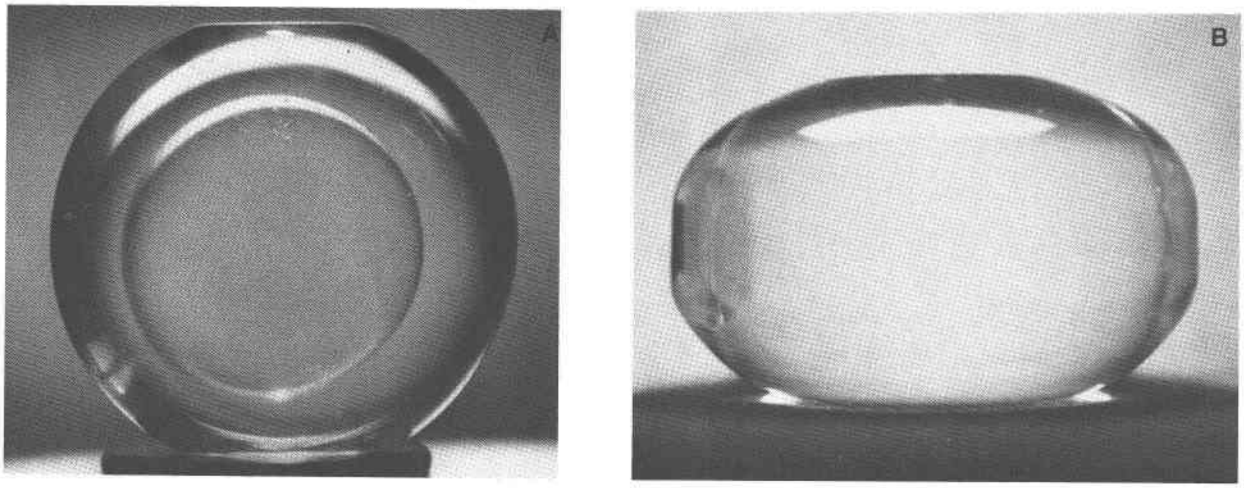


Fig. 1. Calcite sphere embedded in clear plastic: (a) view down the axis of rotation of the ellipsoid; (b) view at right angles to (a).

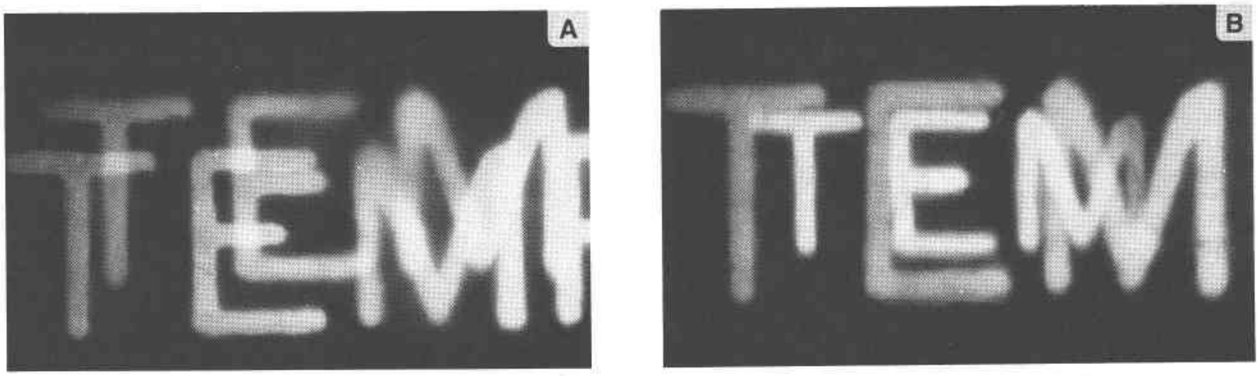


Fig. 2. View of the word TEMPERATURE: (a) with camera slightly displaced from the optic axis; (b) with camera at right angles to the optic axis.

TEMPERATURE: the planes of polarization of the light forming the two images may be confirmed by viewing through polaroid.

To view the image seen in a direction at right angles to the optic axis, two small parallel flats were machined and polished on the surface of the ellipse. When the same letters are viewed in this direction two images of different size are seen, and these are superimposed only in the direction exactly at right angles to the optic axis—thus in Figure 2b the letters E are superimposed, but T and M on either side are appreciably displaced. In one of the images the letters are magnified, whereas in the other the letters are reduced in size. The RI of the clear plastic is 1.55, and for one of the waves ($\omega = 1.658$) the sphere of calcite is acting as a magnifying lens whereas for the other wave ($\epsilon = 1.486$) it is a reducing lens. It can be readily confirmed by observation through polaroid that the larger image is caused by the ordinary wave. That two images are formed when light travels at right angles to the optic axis can be observed by using a clear prismatic crystal of calcite, but since the two images are identical in size and are superimposed, it is difficult to be certain that there are two images unless the crystal is greater than about 1 cm in thickness.

The main use of this model is to demonstrate that the wave fronts of the ordinary and extraordinary waves coincide only in the direction of the optic axis or in a direction at right angles to the optic axis. In any other direction, the images of the letters are not superimposed because the extraordinary wave direction is perpendicular to the tangent to the wave surface and this direction does not coincide for the ordinary and extraordinary waves except in the special directions mentioned.

Because the fragile crystal of calcite is protected in its plastic coating, the model can readily be handled by students. The slight birefringence in the plastic observed through crossed polars has a negligible effect on the usefulness of the model.

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