Astronomy 80 B: Light

Lecture 6:reflection, refraction, mirages

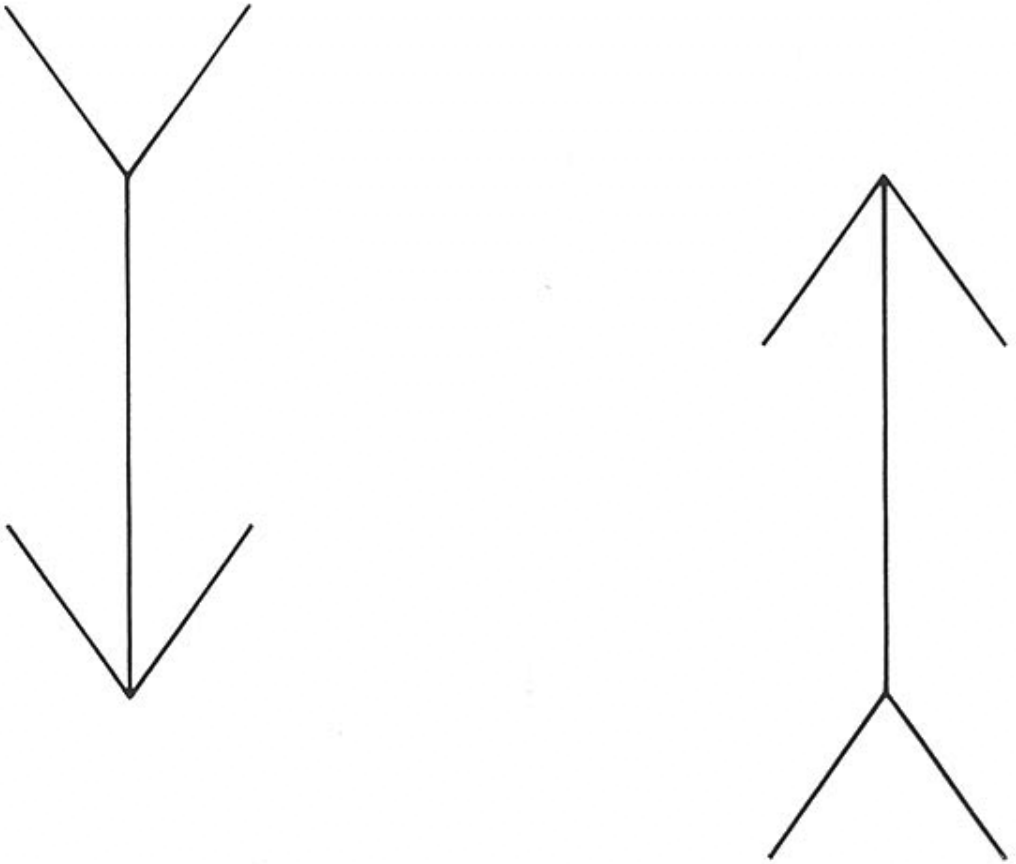
17 April 2003

Jerry Nelson

Topics for Today

- **Optical illusion**
- **Mirrors and partially reflecting mirrors**
- **Atmospheric reflections subsuns, pillars**
  - Reflection from hard surface
  - Reflection from conductors
- **Diffuse reflections, escher**
- **Cube corners, periscopes**
- **Refraction principles, derivation, examples**
- **Total internal reflection**
- **Mirages**
- **Index of refraction of materials**

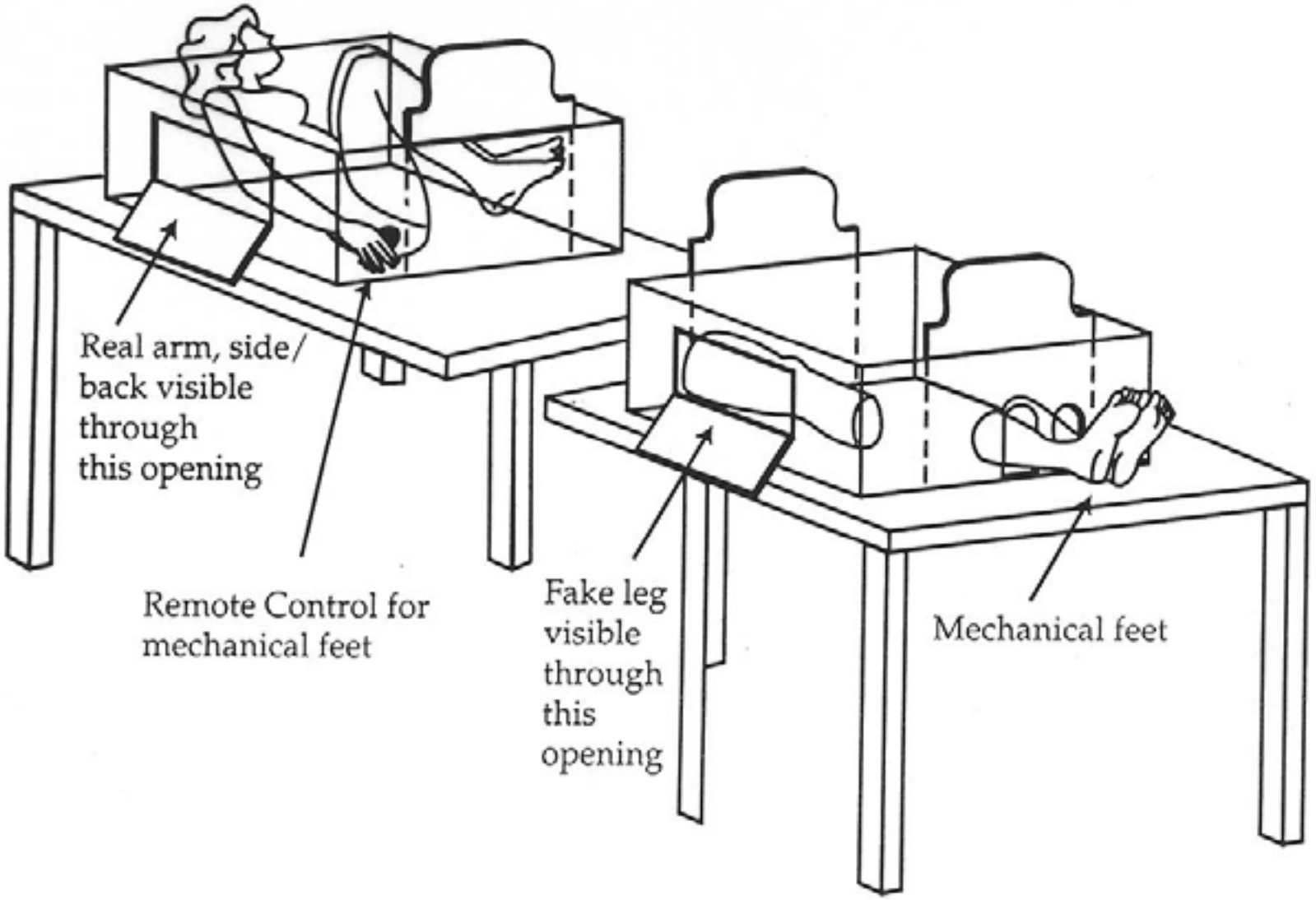
Illusion

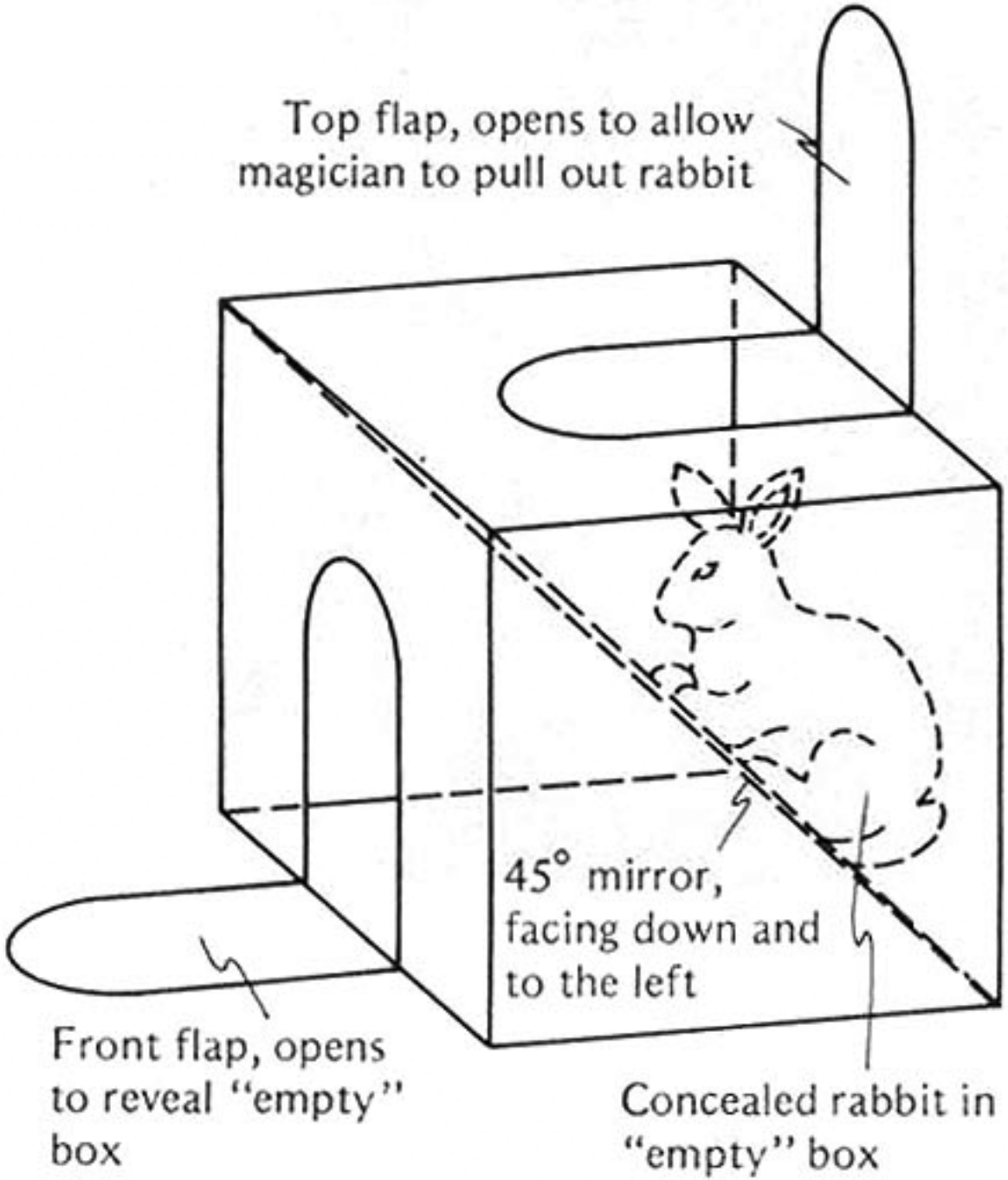


Two identical figures, one being an inversion of the other. The shaft on the left appears to be higher than the one on the right, although both are at equal heights on the page.

2003 April 17

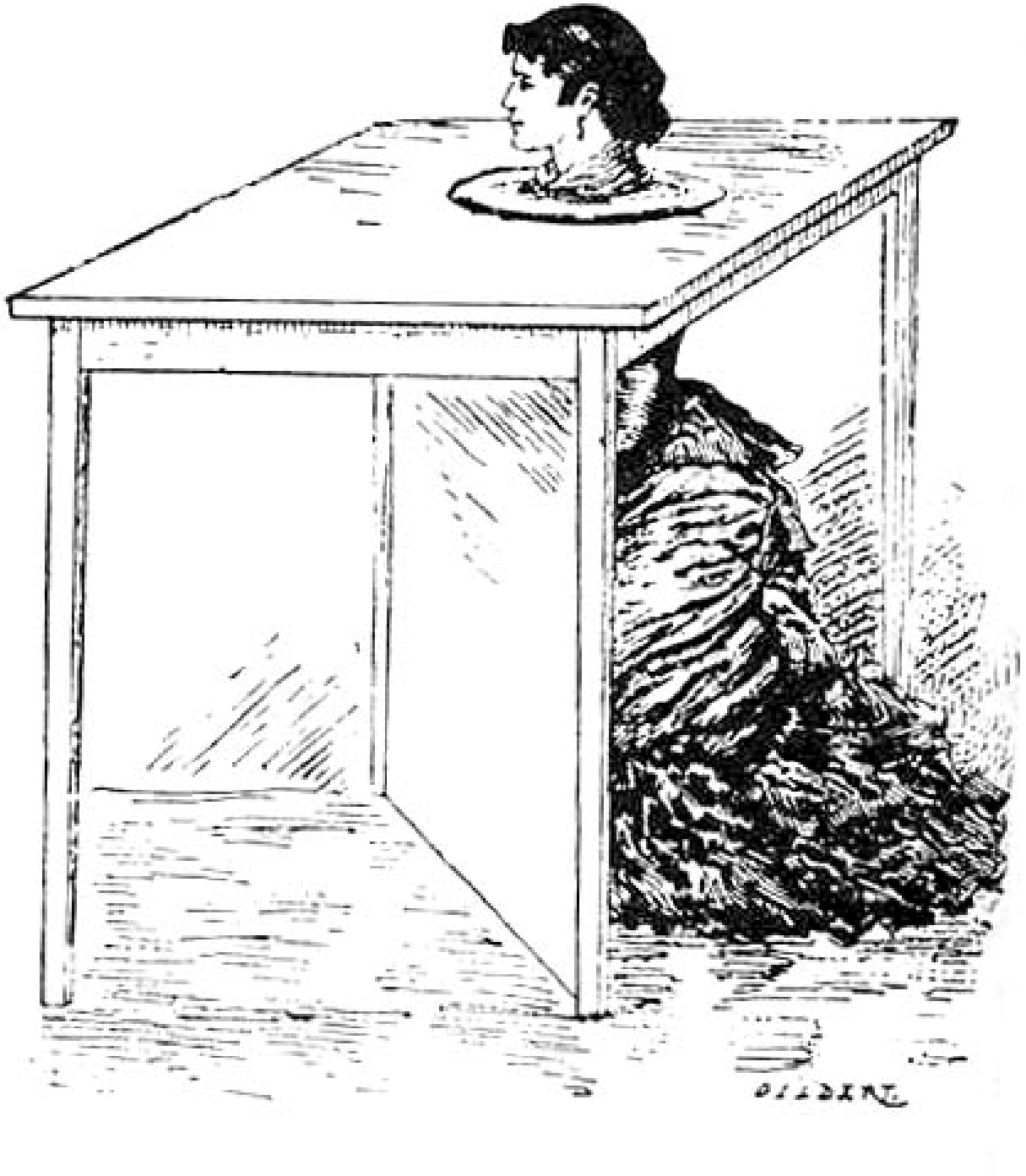
All the Secrets of Magic Revealed

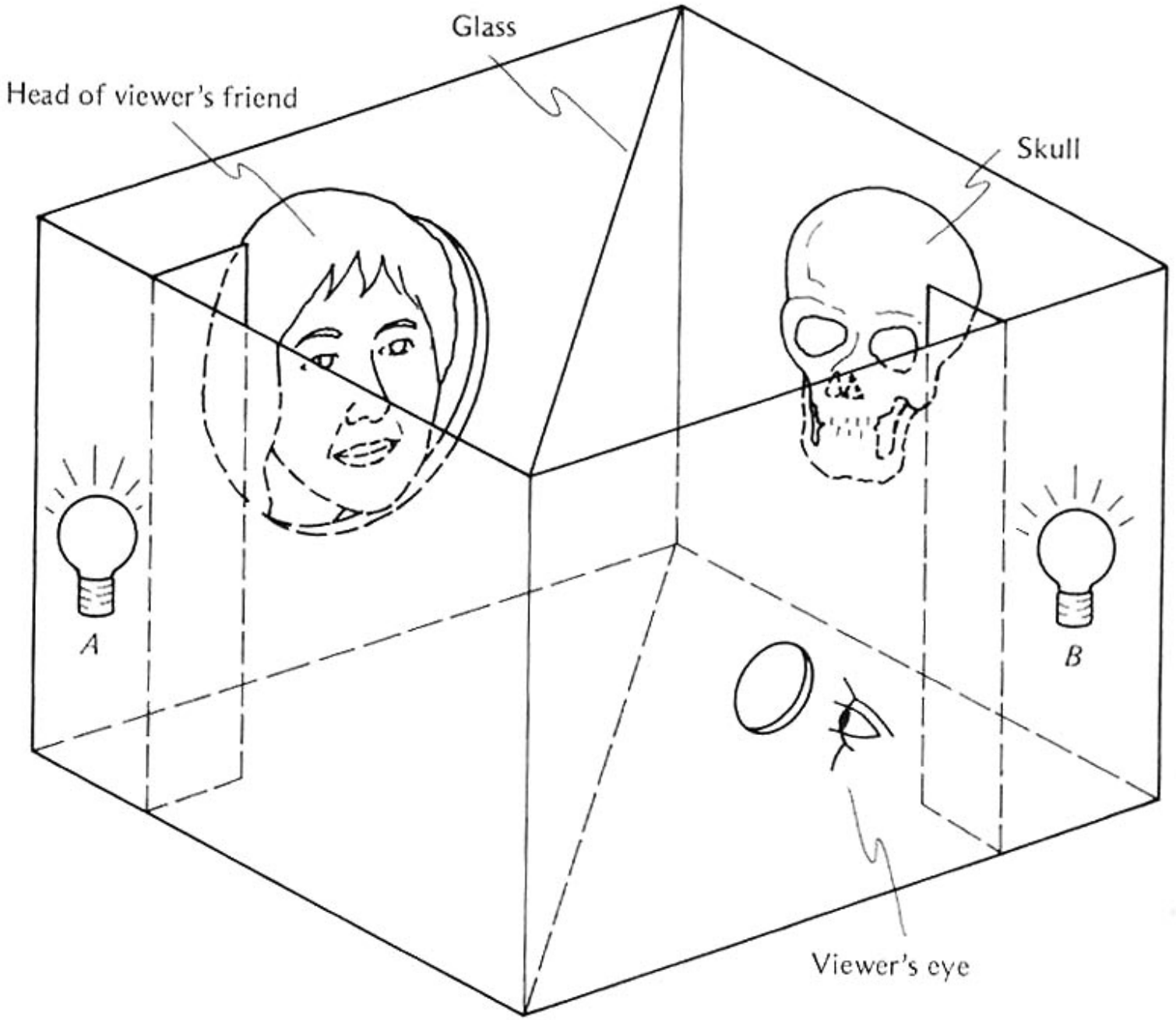




2003 April 17

2003 April 17

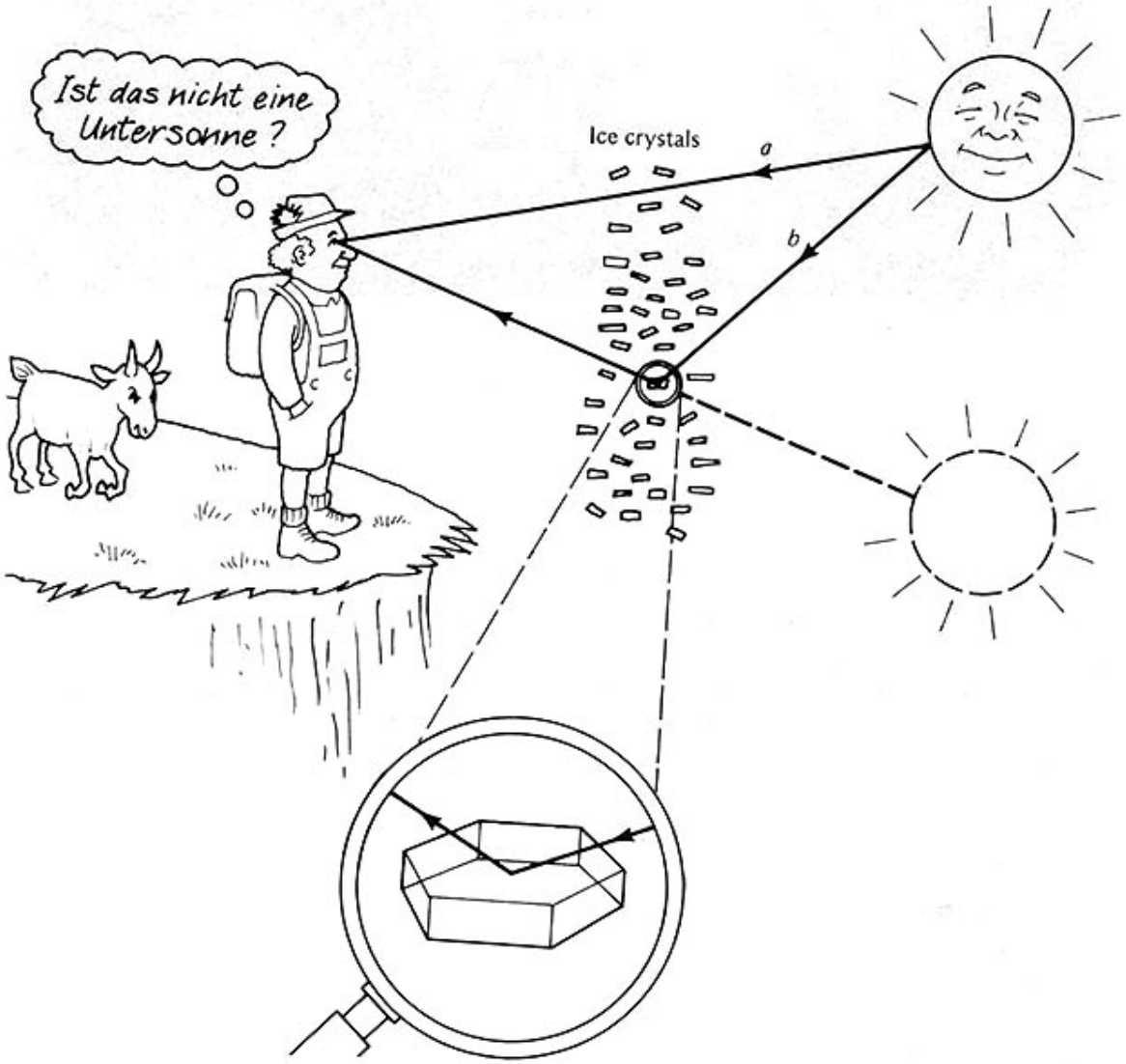



Glass
Head of viewer's friend
Skull
A
B
Viewer's eye

2003 April 17

FIGURE 2.30

A sub sun is formed when sunlight reflects from the horizontal surfaces of ice crystals. The magnifying glass shows a single crystal.



2003 April 17

A sun pillar can be seen when the ice crystals are not all exactly horizontal.

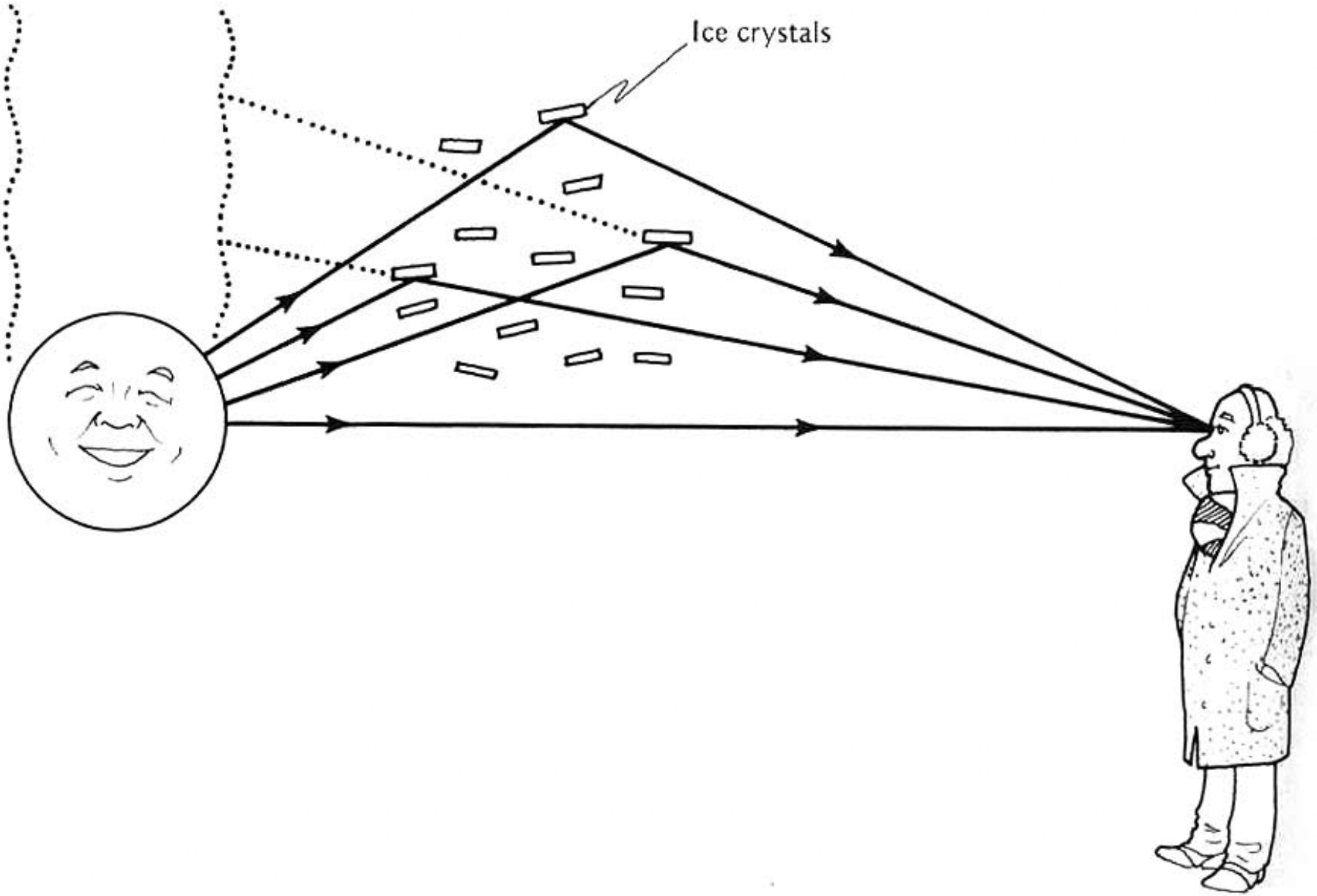
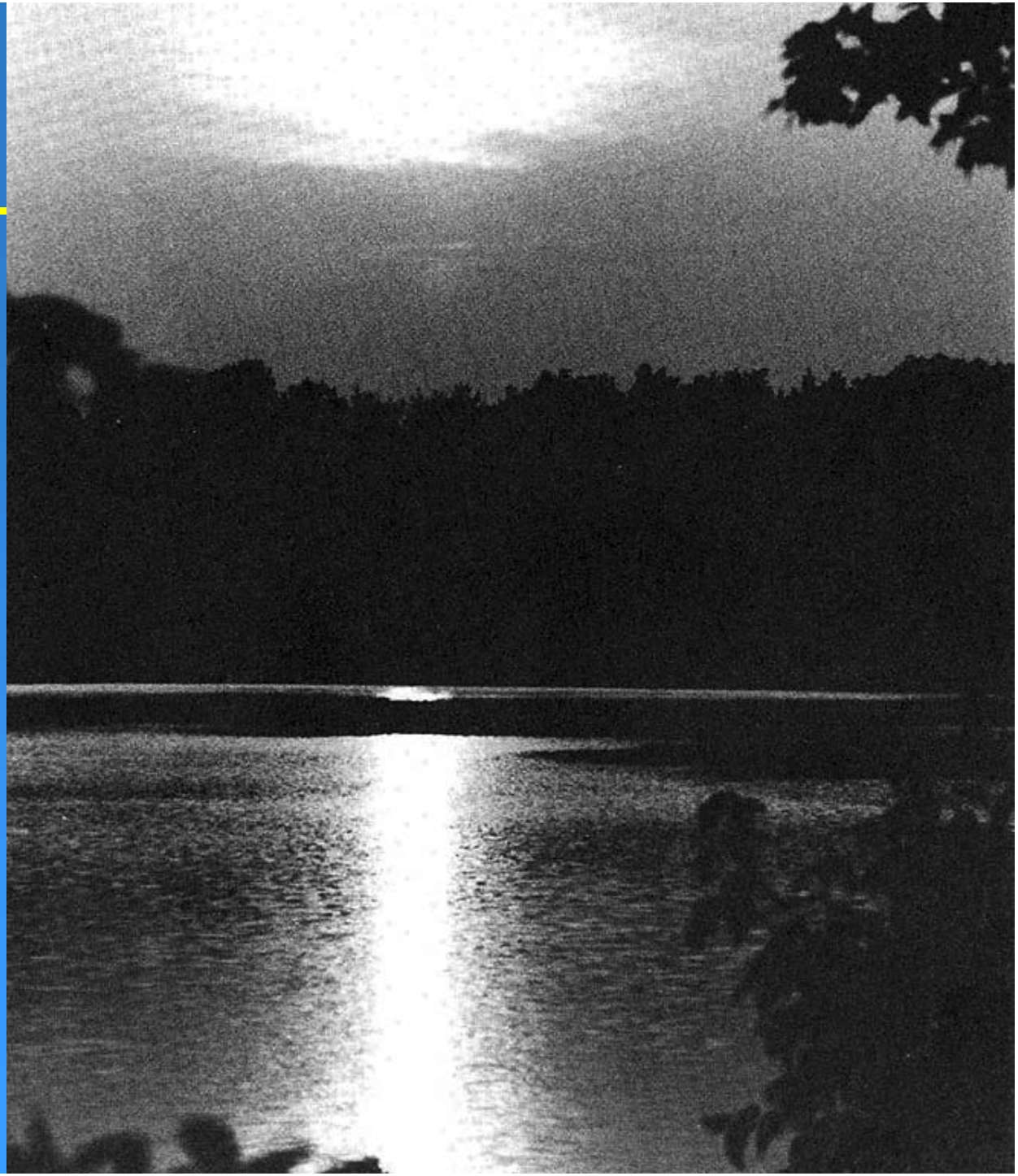


FIGURE 2.33

The setting sun, with a sun pillar above it. (The horizontal line is a thin cloud layer.)

2003 April 17



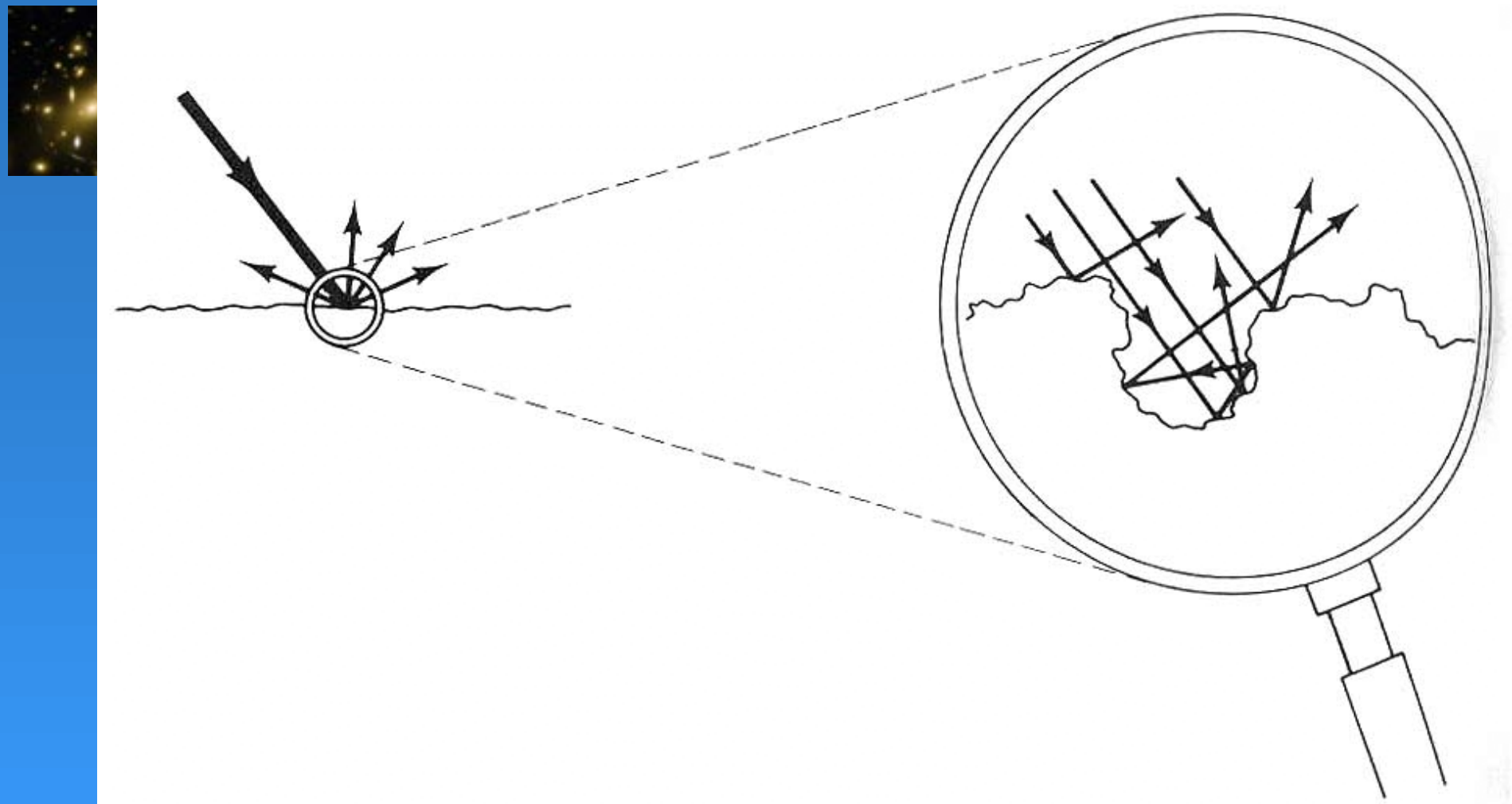
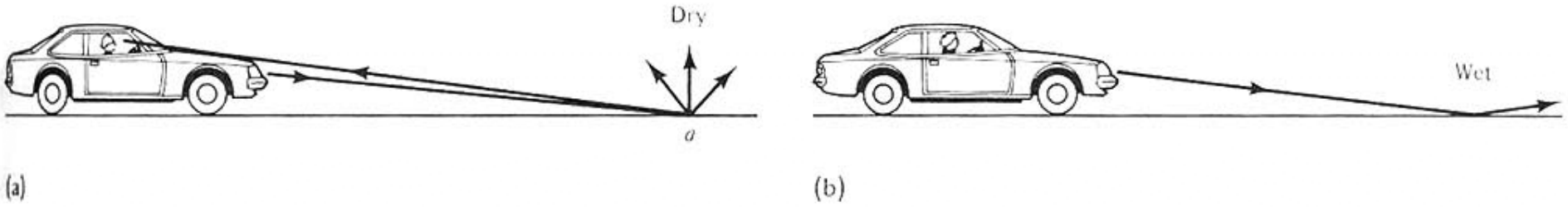


FIGURE 2.36

Diffuse reflection of a beam of light from a rough surface.


Dry
a
(a)
Wet
(b)

2003 April 17

80B-Light

M. C. Escher, "Three Worlds." We see the trees by reflection, the leaves by scattering (or diffuse reflection), and (at a steeper angle) the fish by refraction.

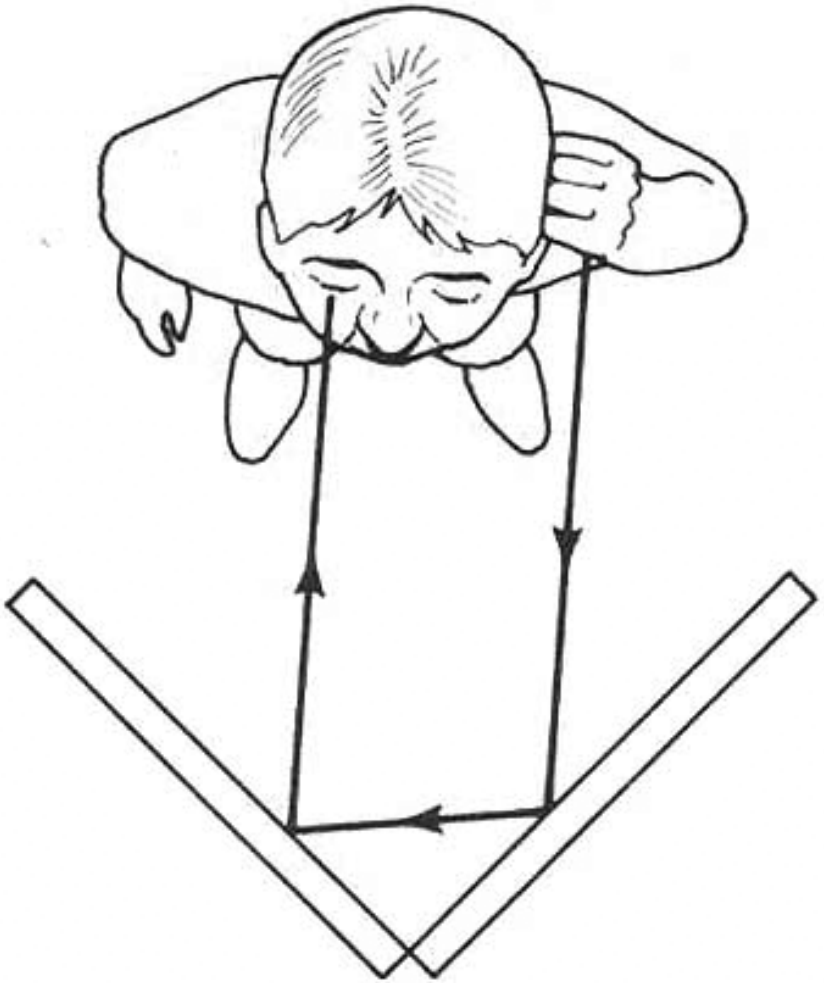
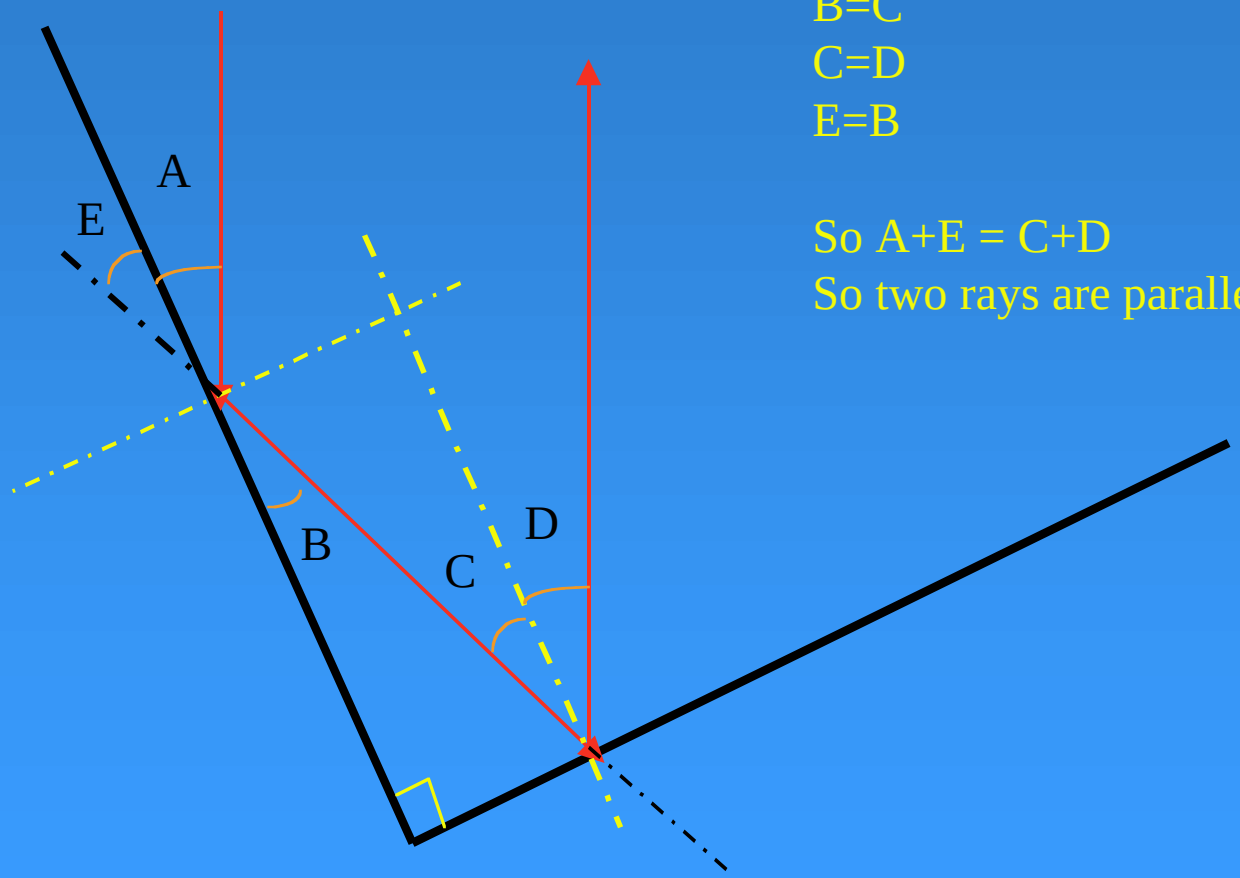


FIGURE 2.39

A corner mirror, made from two plane mirrors.

Light reflecting from cube corner

- 

A=B
B=C
C=D
E=B

So A+E = C+D
So two rays are parallel

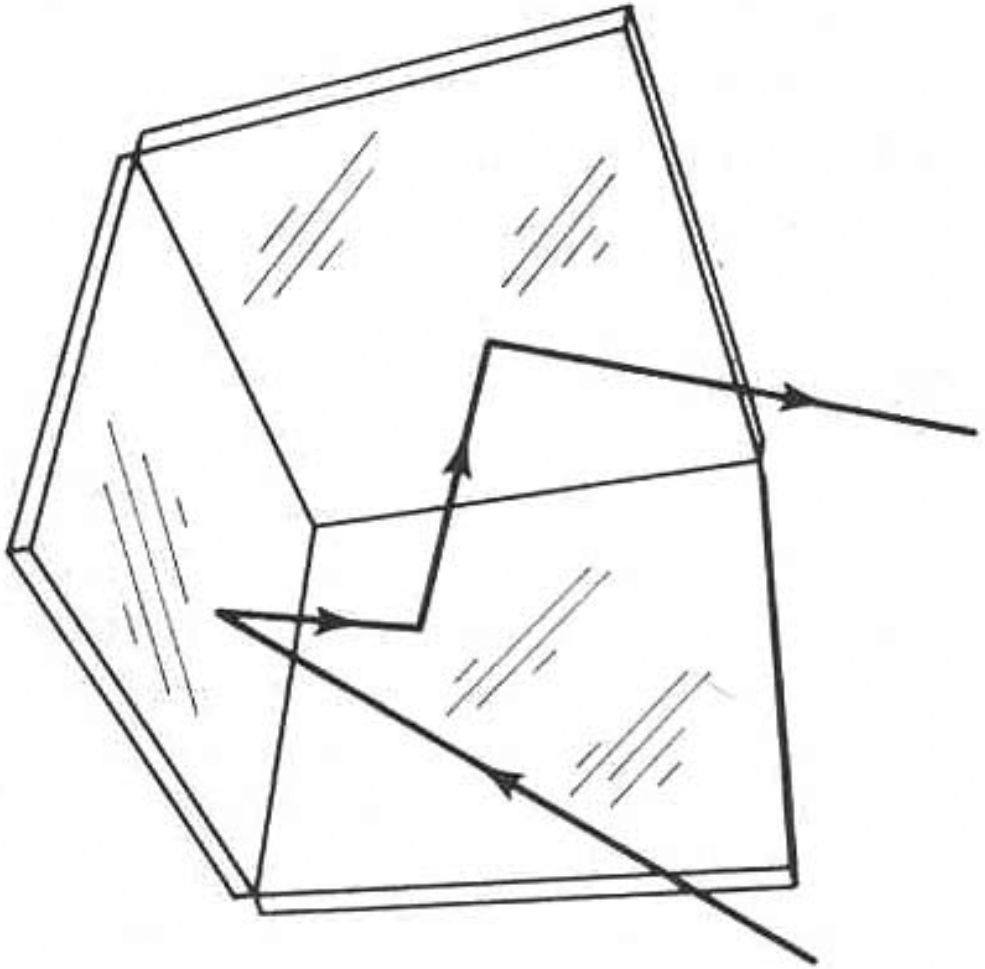


FIGURE 2.40

A corner reflector, made from three plane mirrors.

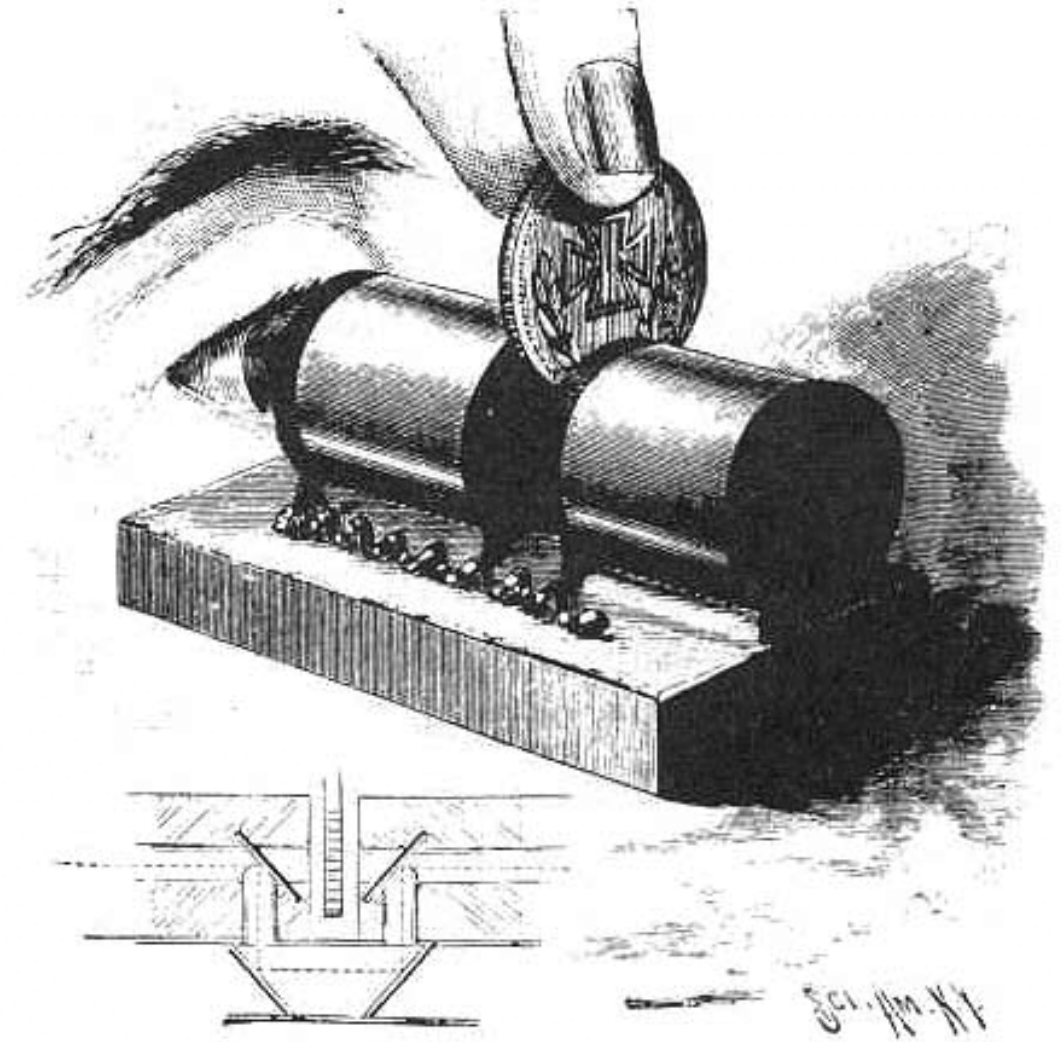
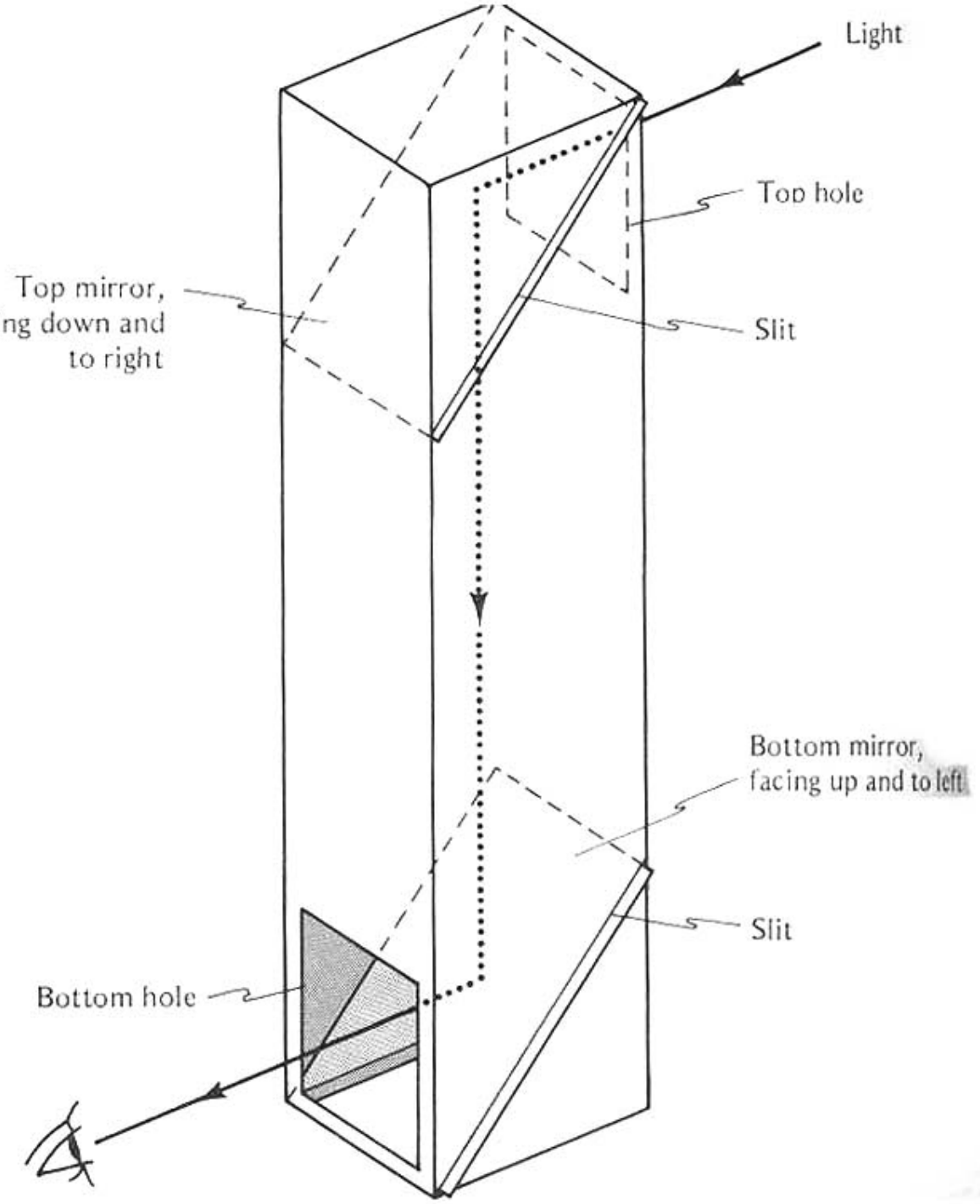


FIGURE 2.44

A toy "X-ray Machine." The diagram reveals the secret.

FIGURE 2.46

Design for a periscope.



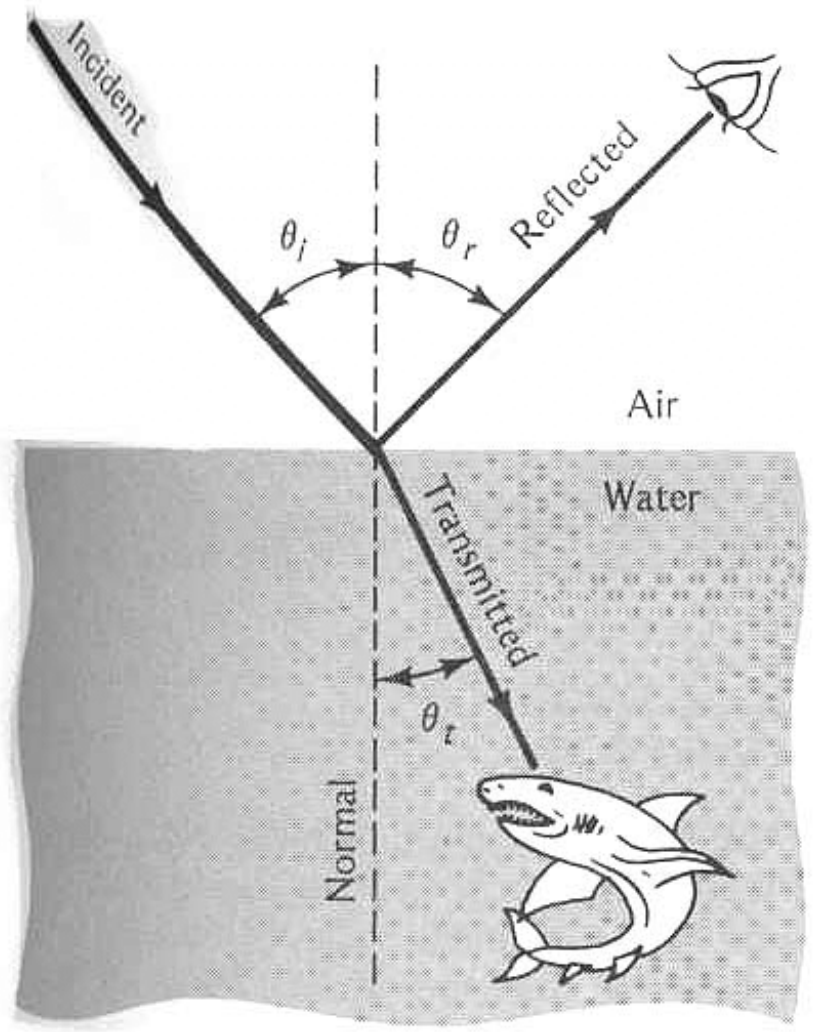
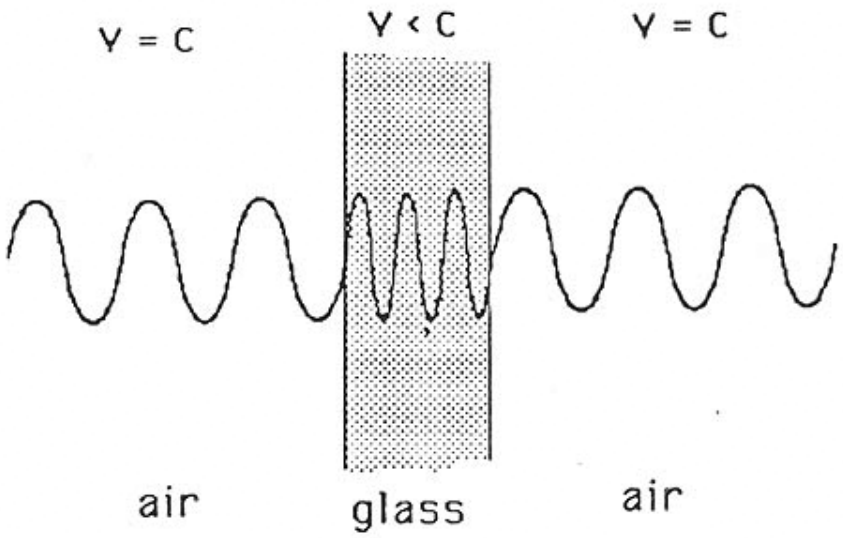


FIGURE 2.47

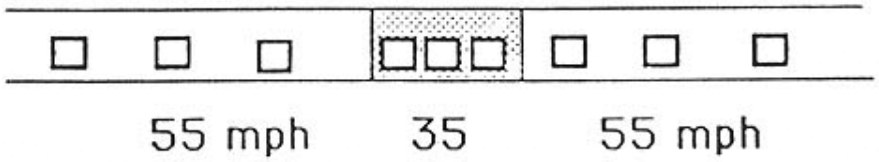
A beam incident on a transparent medium is split into a reflected and a transmitted (refracted) beam.

- **Constancy of frequency of light**
- **Wavelength changes**

When light passes into a new medium, its frequency remains constant and its wavelength changes

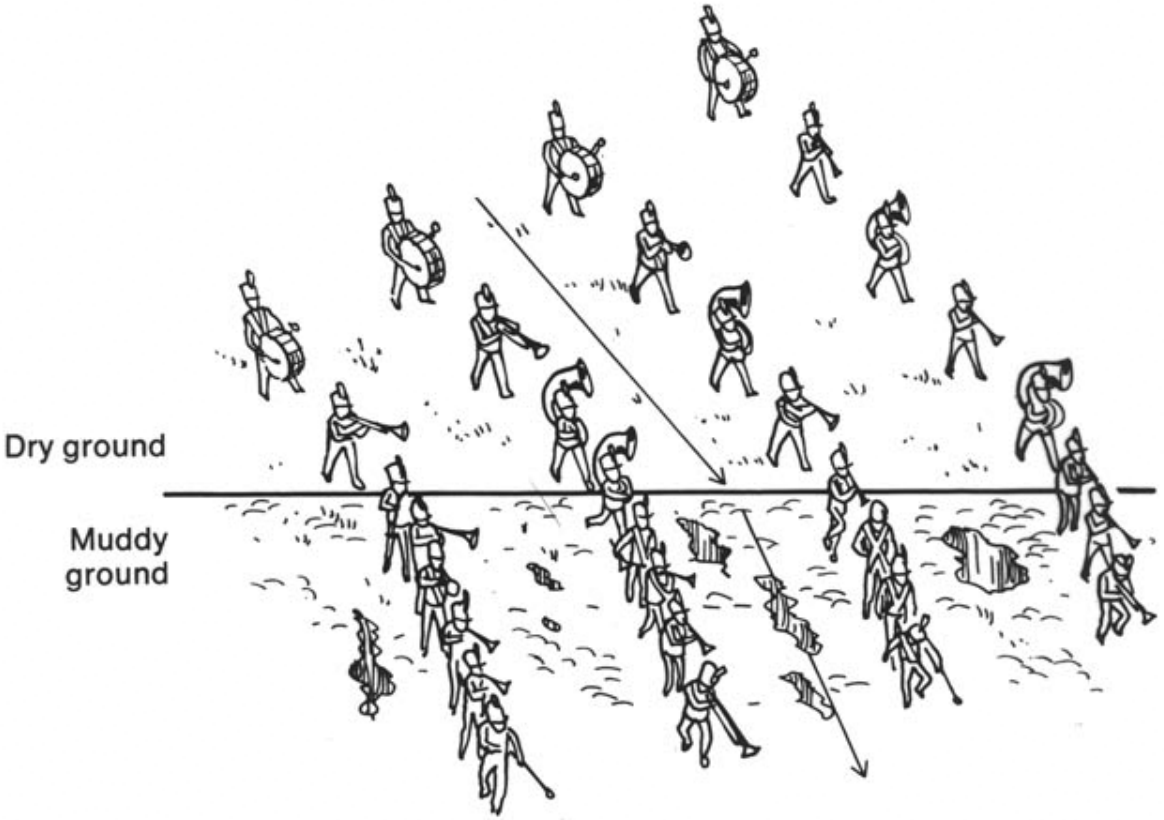


analogy with cars on a highway:



- **Refraction analogy: marching band**

FIGURE 2.15
As band members march from dry ground into muddy ground, the mud sticks to their feet and slows their pace. Because the right-hand members enter the muddy ground first, their row is gradually diverted to move in a new direction. Light behaves in a similar manner.



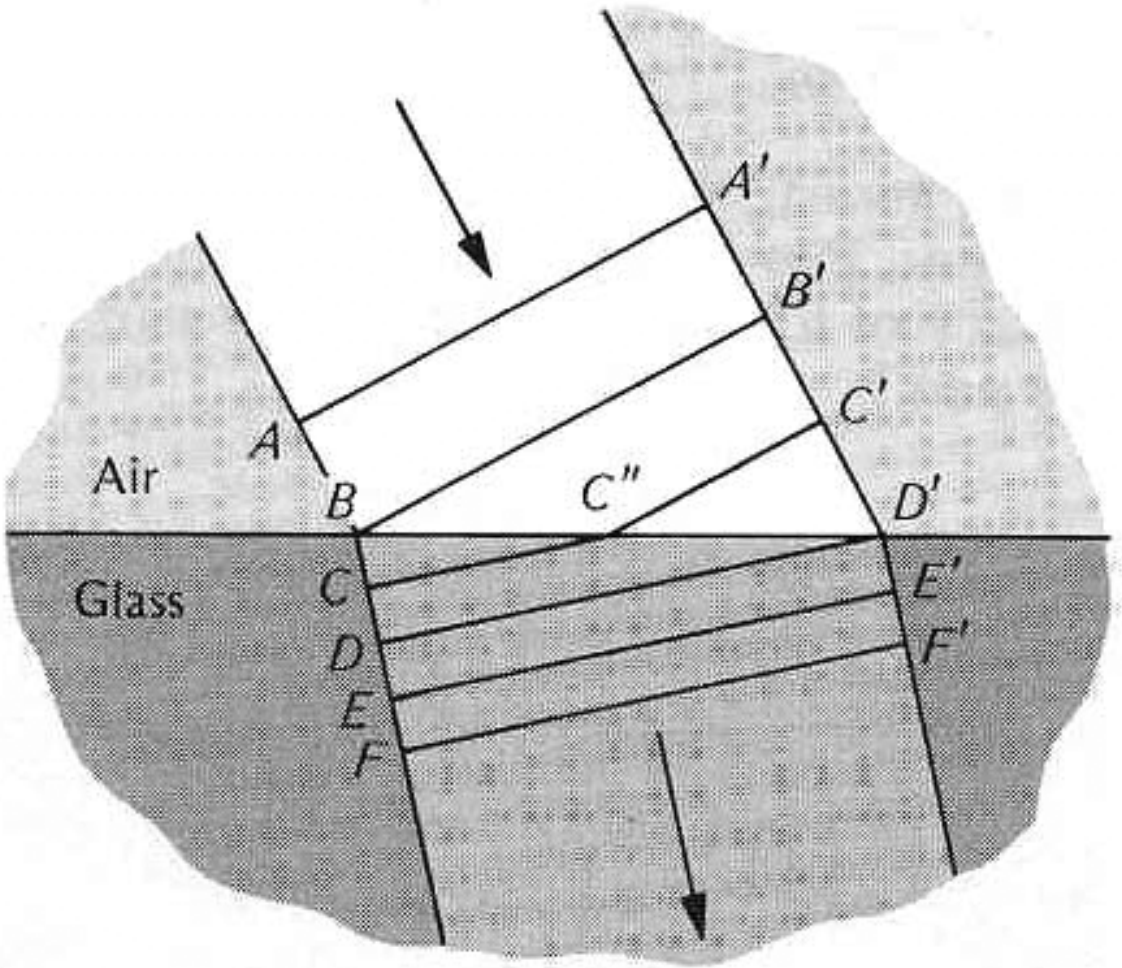
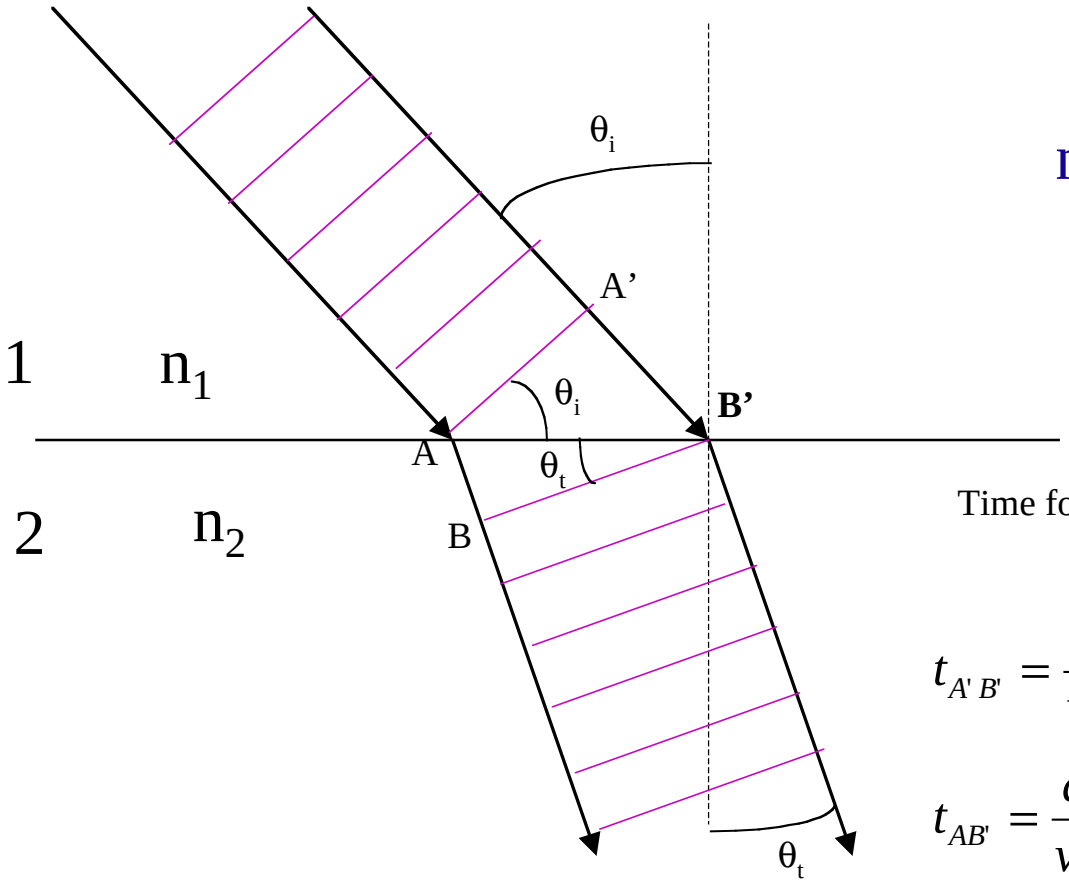


FIGURE 2.48

The wavefronts of a beam entering a slower medium explain why the beam refracts.

Derivation of Snell's law from wavefront continuity



n=c/v

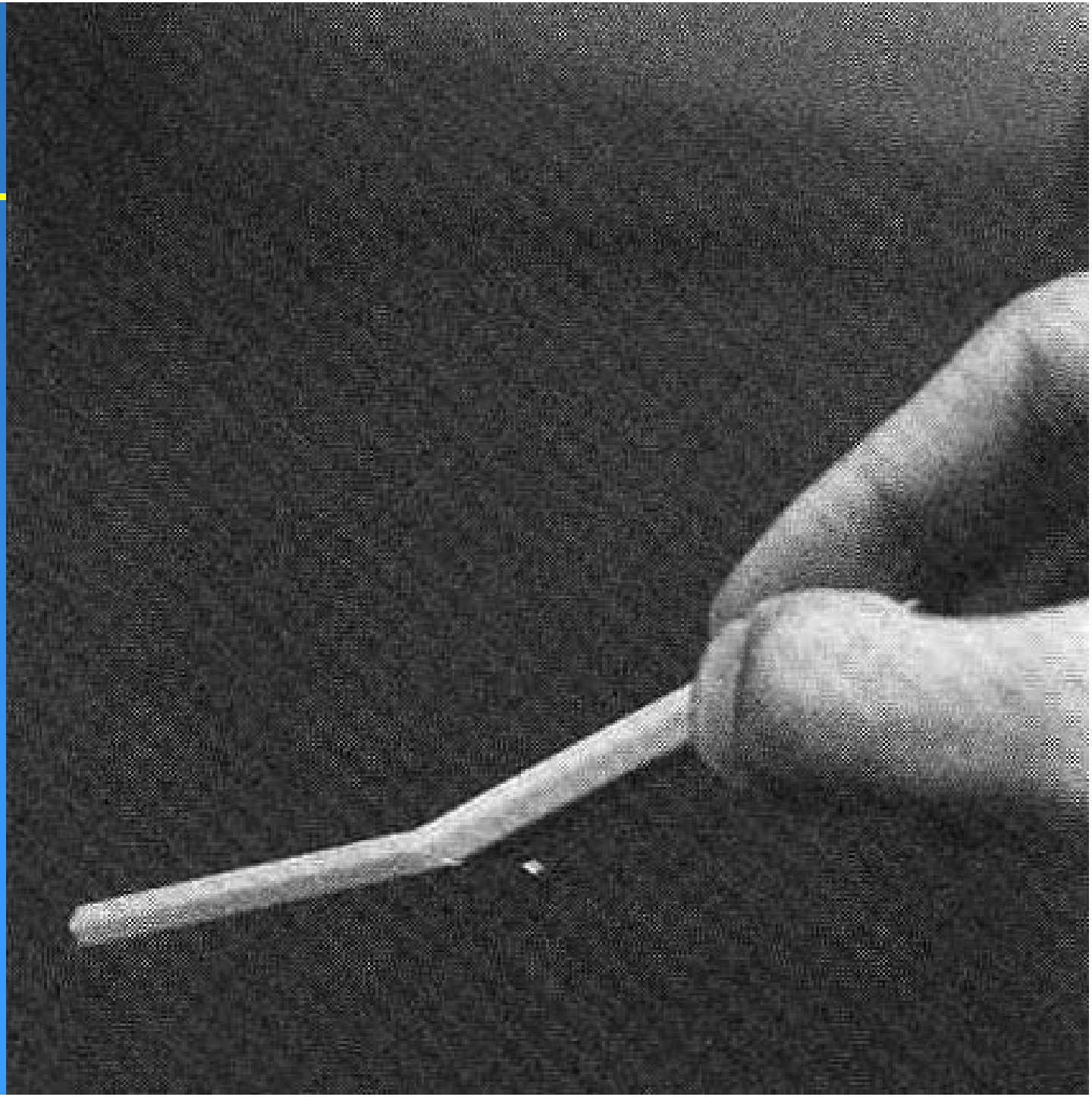
Time for light to go from A' to B'

$$t_{A'B'} = \frac{d}{v_1} = \frac{A'B'}{c/n_1} = \frac{n_1}{c} AB' \sin\theta_i$$

$$t_{AB'} = \frac{d}{v_2} = \frac{AB}{c/n_2} = \frac{n_2}{c} AB' \sin\theta_t$$

so $t_{A'B'} = t_{AB}$

Which yields $n_1 \sin\theta_i = n_2 \sin\theta_t$

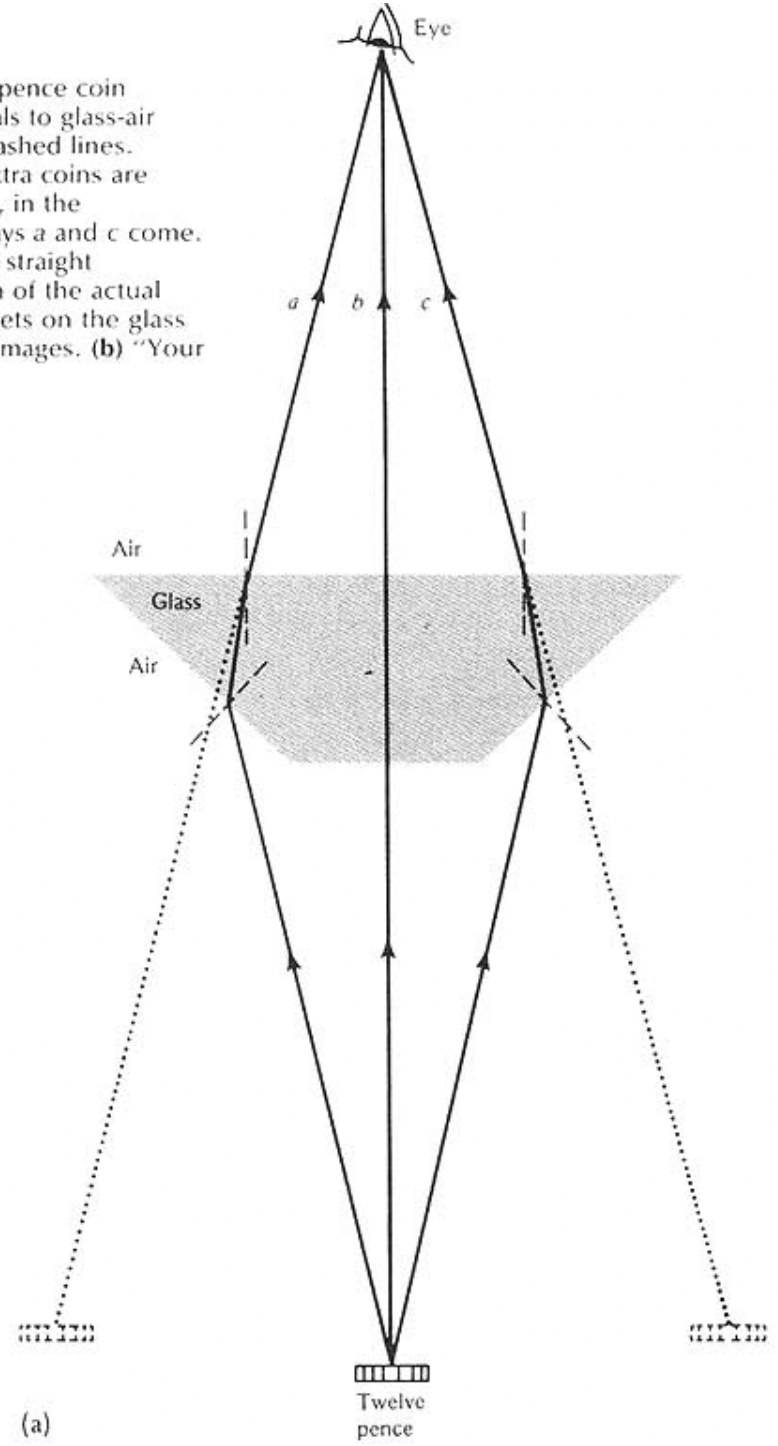


2003 April 17

2003 April 17

FIGURE 2.51

(a) Wherein one twelve-pence coin appears as three. Normals to glass-air surfaces are shown as dashed lines. Apparent positions of extra coins are shown in dotted outline, in the directions from which rays a and c come. The eye also sees a coin straight through, in the direction of the actual coin, via ray *b*. More facets on the glass may produce still more images. **(b)** "Your wife tying her shoes."



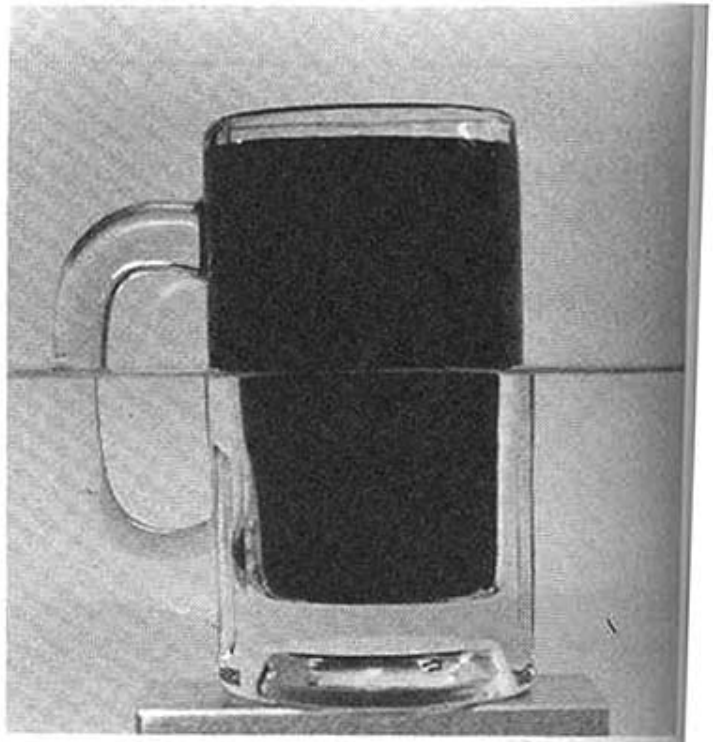


FIGURE 2.52

Mug shot shows deception. Not only is there hardly any beer in the foam—which nonetheless reflects a lot of light—but the beer seems to go all the way to the side of the mug, not showing the thick wall. In the photograph, refraction in the lower half of the mug has been reduced by placing the mug in water. (Because *some* refraction occurs at the glass-water surface, the walls still look thinner than they are.)

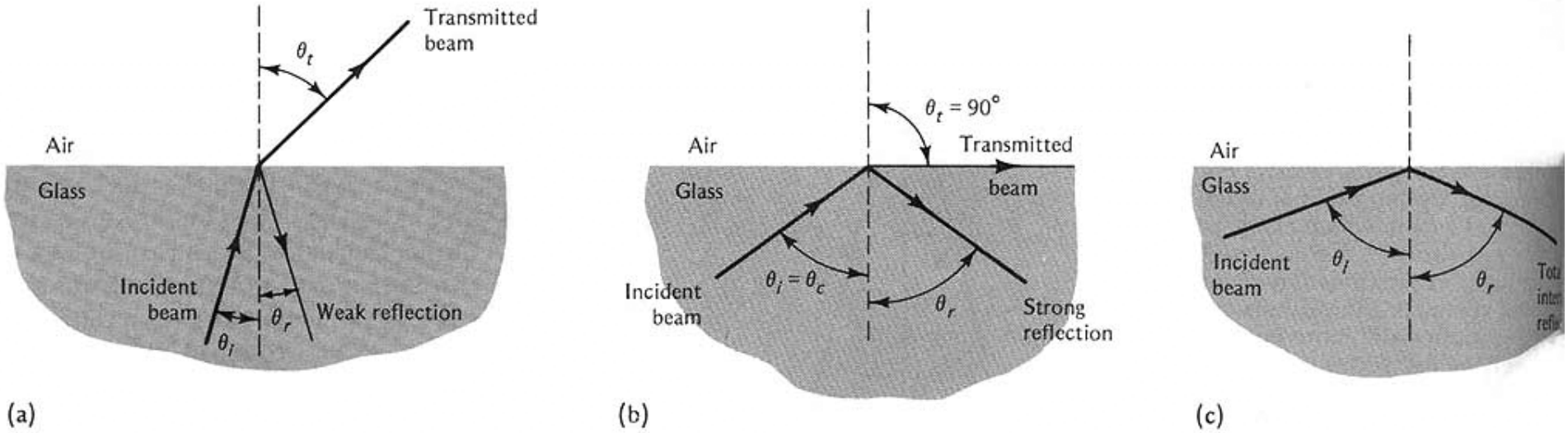


FIGURE 2.53

Reflected and transmitted beams when incident angle is **(a)** smaller than the critical angle, **(b)** equal to the critical angle, **(c)** larger than the critical angle.

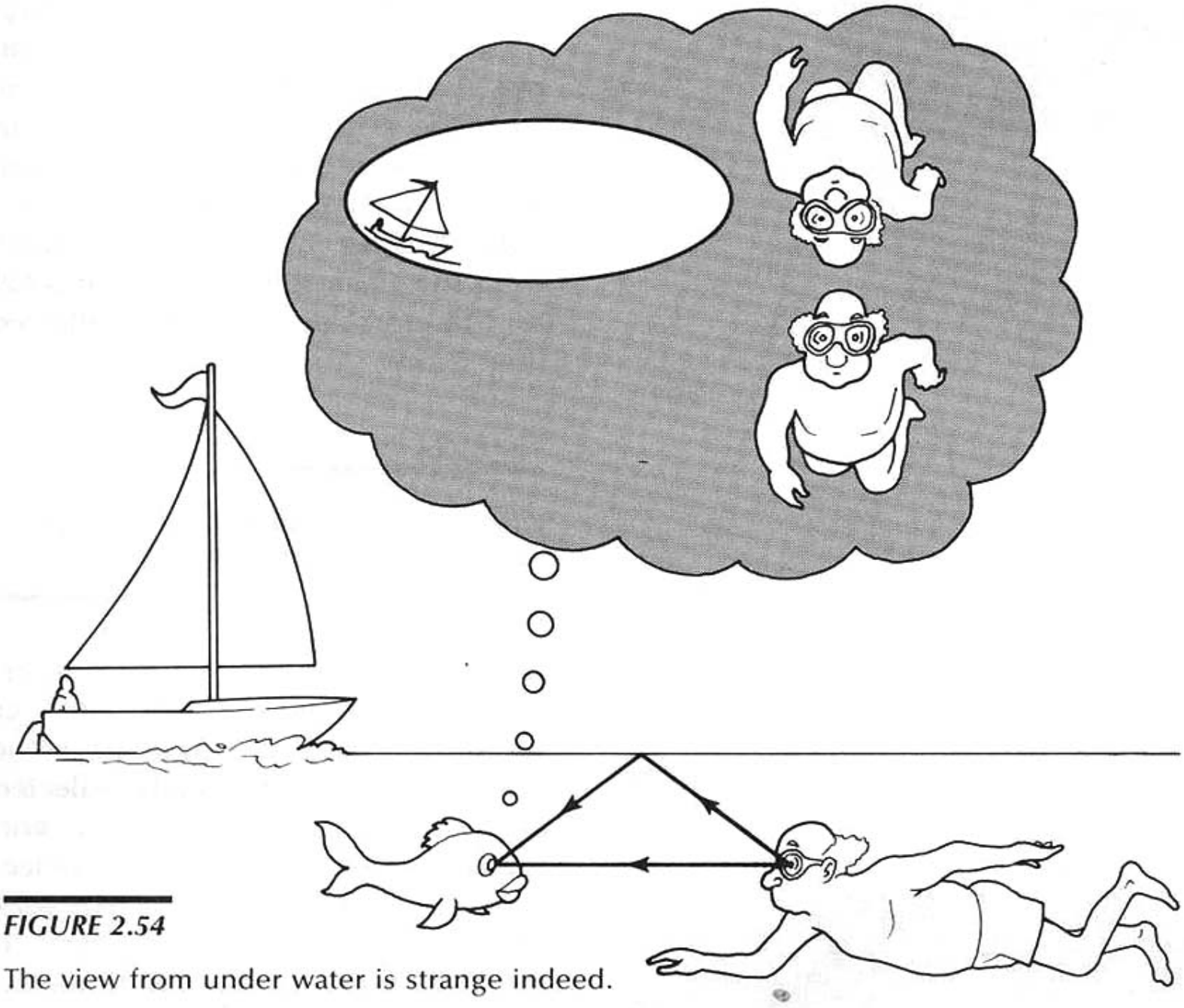


FIGURE 2.54

The view from under water is strange indeed.

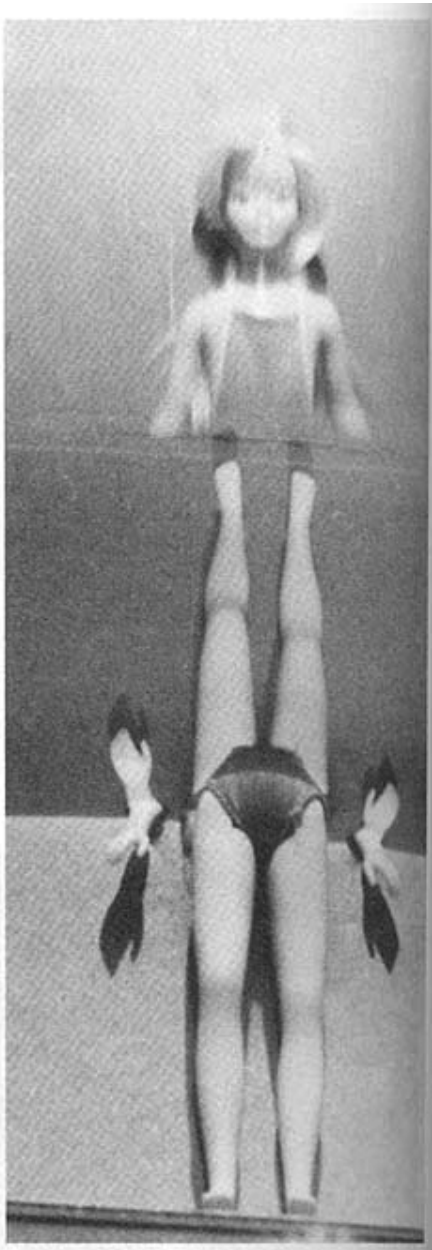
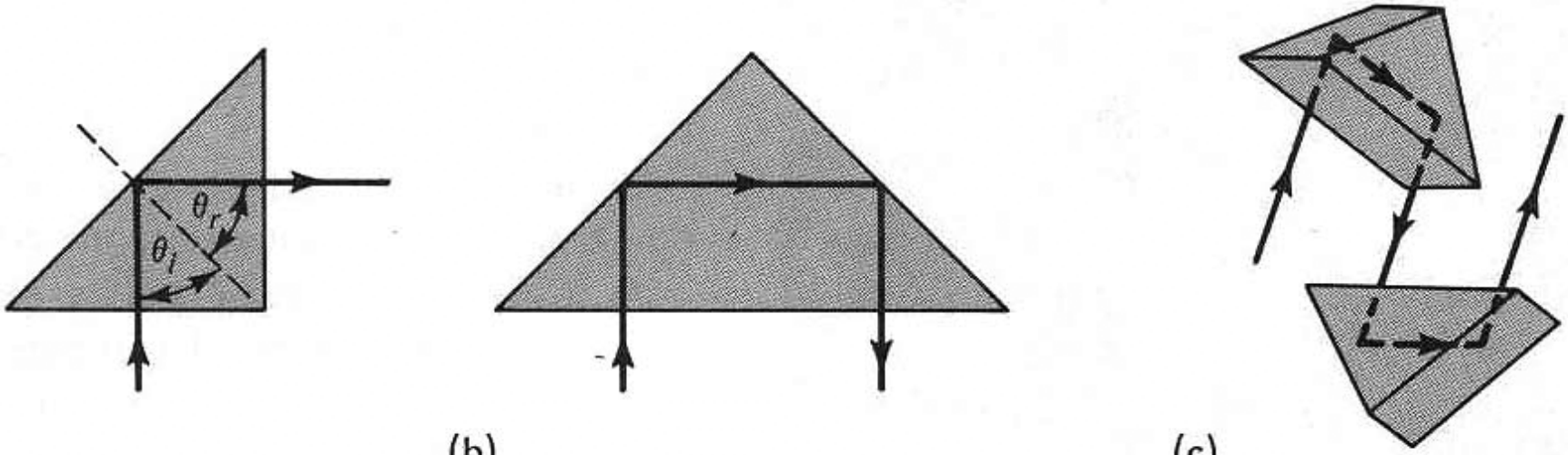


FIGURE 2.55

An underwater photograph of a doll standing in water, showing both direct and reflected views of her legs and hands.

FIGURE 2.56

Use of the total internal reflection to change the direction of a light beam, **(a)** by 90° ($\theta_i = \theta_r = 45°$), **(b)** by 180° using a Porro prism. **(c)** Two Porro prisms as used in binoculars (actually, they would be touching).



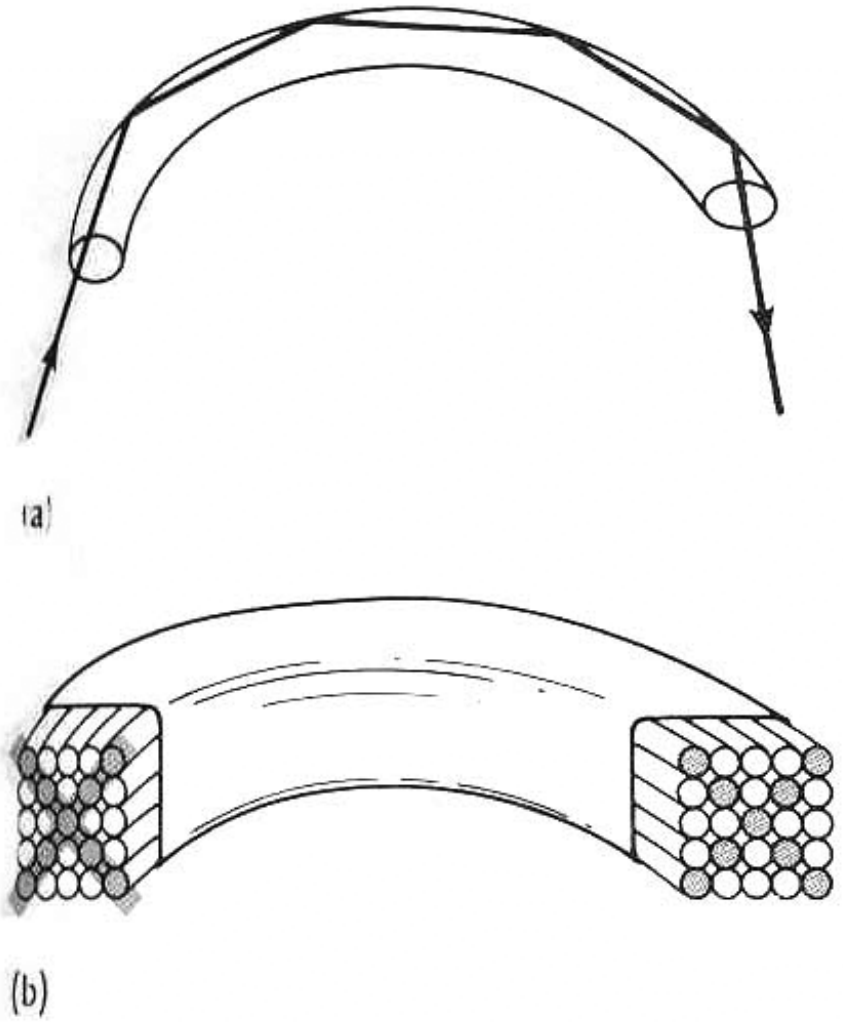


FIGURE 2.57

(a) A glass or plastic fiber can be used as a light pipe. **(b)** Many light pipes packed together can transmit an image.