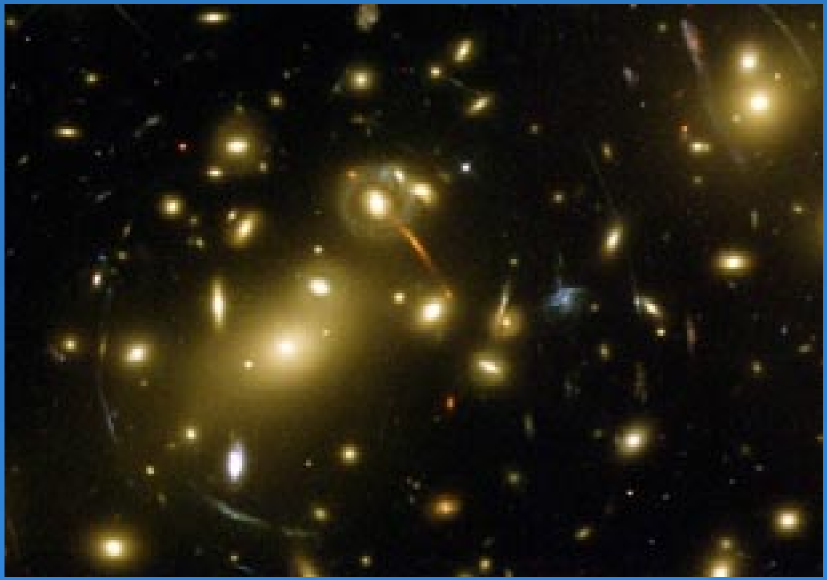


Astronomy 80 B: Light

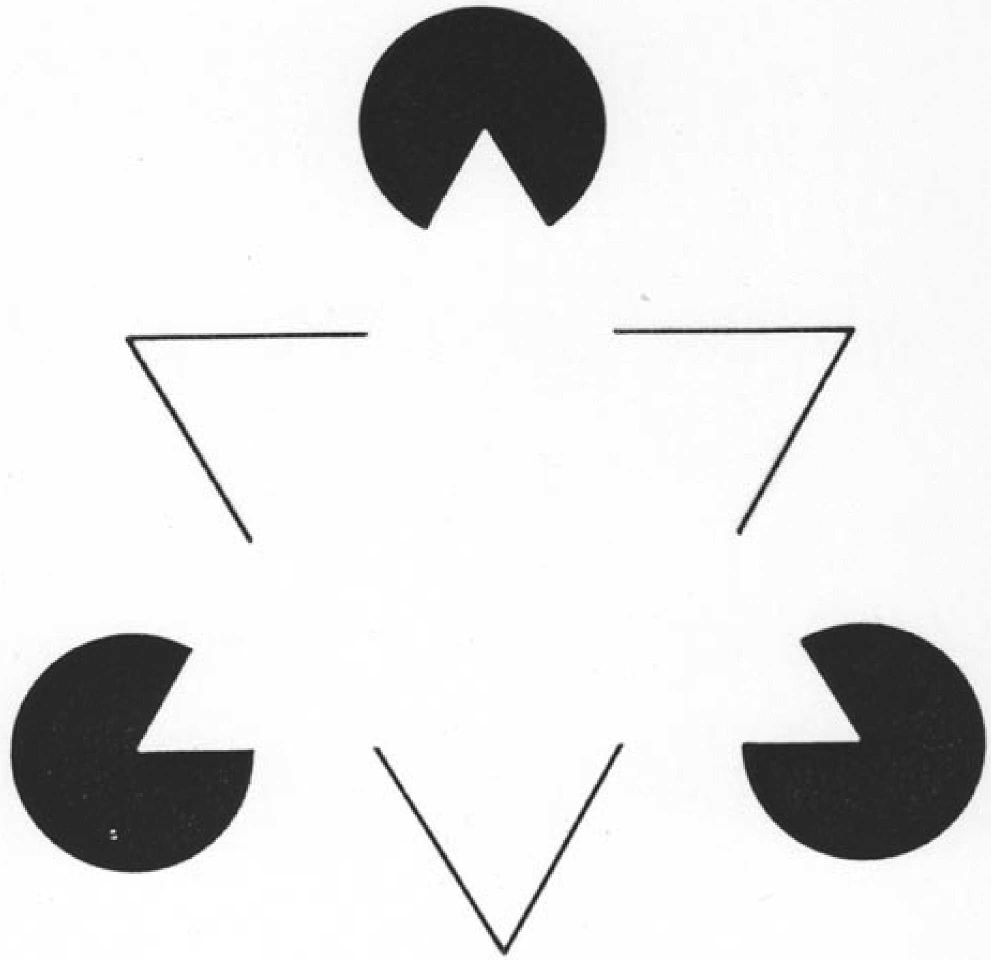
Lecture 5: reflections, speed of light

15 April 2003

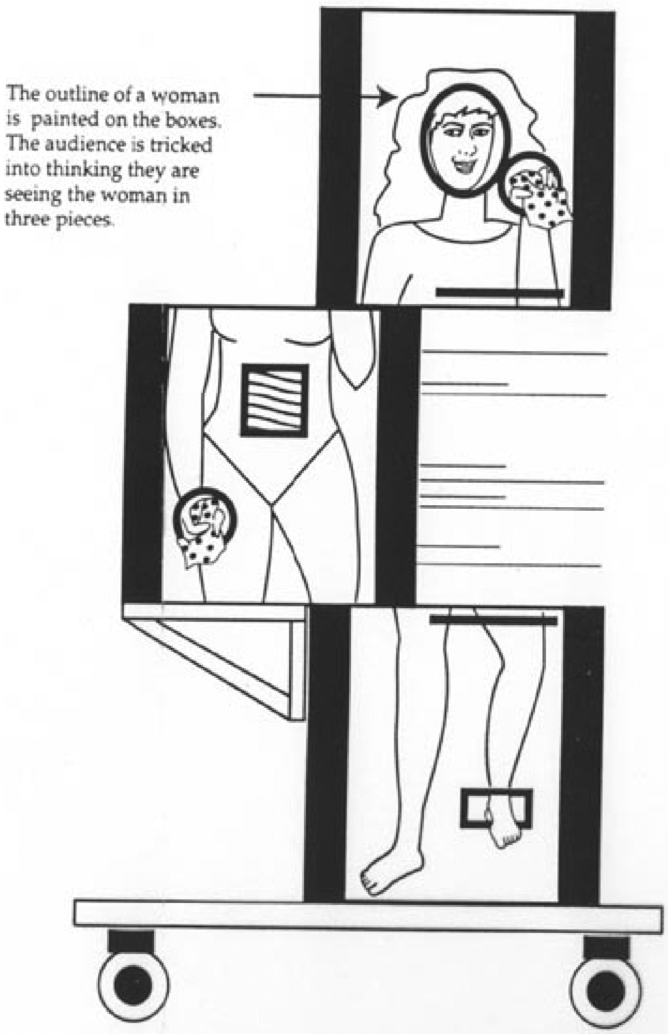
Jerry Nelson

Topics for Today

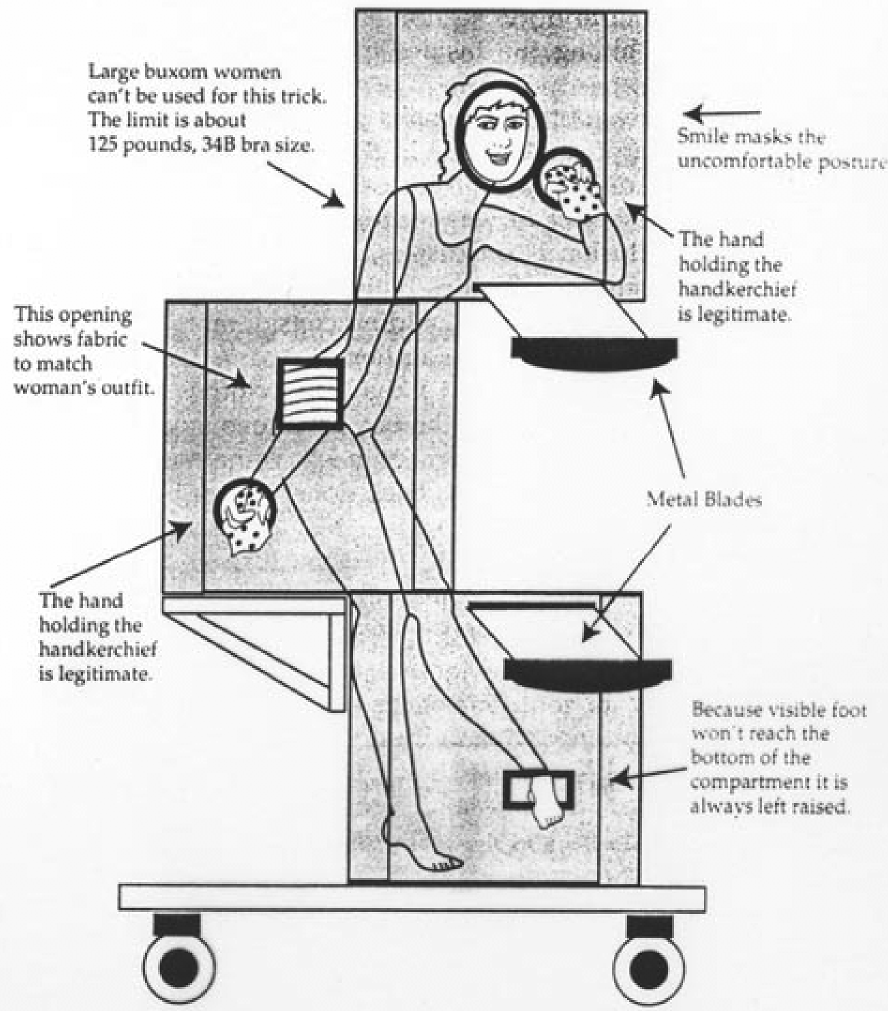
- **Optical illusion**
- **Sonar**
- **Reflections**
  - Reflection from hard surface
  - Reflection from conductors
- **Reflection and principle of least time**
- **Virtual images**
- **Multiple reflections**
- **Partial reflections "one way mirrors"**
- **Back to fundamentals: Michelson-Morley experiment**
- **Quiz**



A figure containing illusory contours. The subjectively constructed figure appears to be whiter than the page itself.



How It *Really Works*



Sonar

- ships, submarines use sound chirps to locate each other, nearby objects, the ocean bottom, by sensing the return echo.
- Fisherman locate schools of fish this way
- some automatic cameras use echolocation to determine the distance to the central object in the field of view.

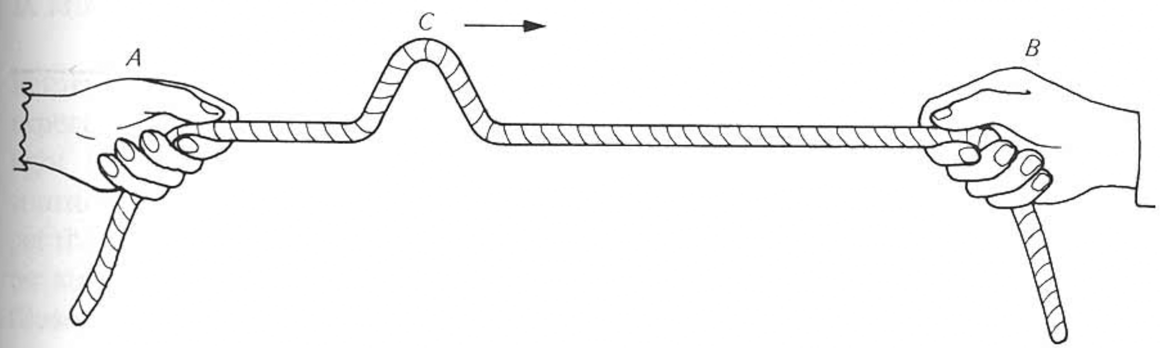
Why do Mirrors Reflect?

- **Mirrors can reflect if there are free charges in the surface that prevent an electric field from penetrating the surface**
  - Free electrons respond to any electric field by moving in such a way as to cancel the electric field
  - Metals are known to have free electrons in their material
  - For low frequencies, the electric field at the surface is thus nearly zero
  - No electric field at the surface means a “reflected” wave of opposite sign can be viewed as created that acts to cancel the incoming wave at the mirror surface

- **Reflection from hard surfaces requires cancellation of wave at surface**
  - This implies that the reflected wave is reversed in phase (upside down or 180° out of phase

FIGURE 2.13

The lady, *A*, keeping her distance, has started a wave propagating toward *B*.



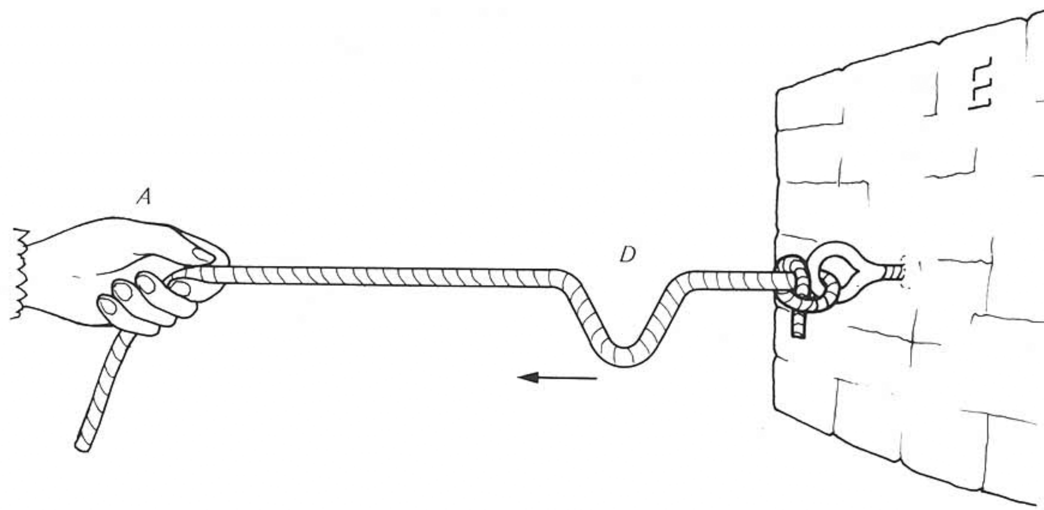
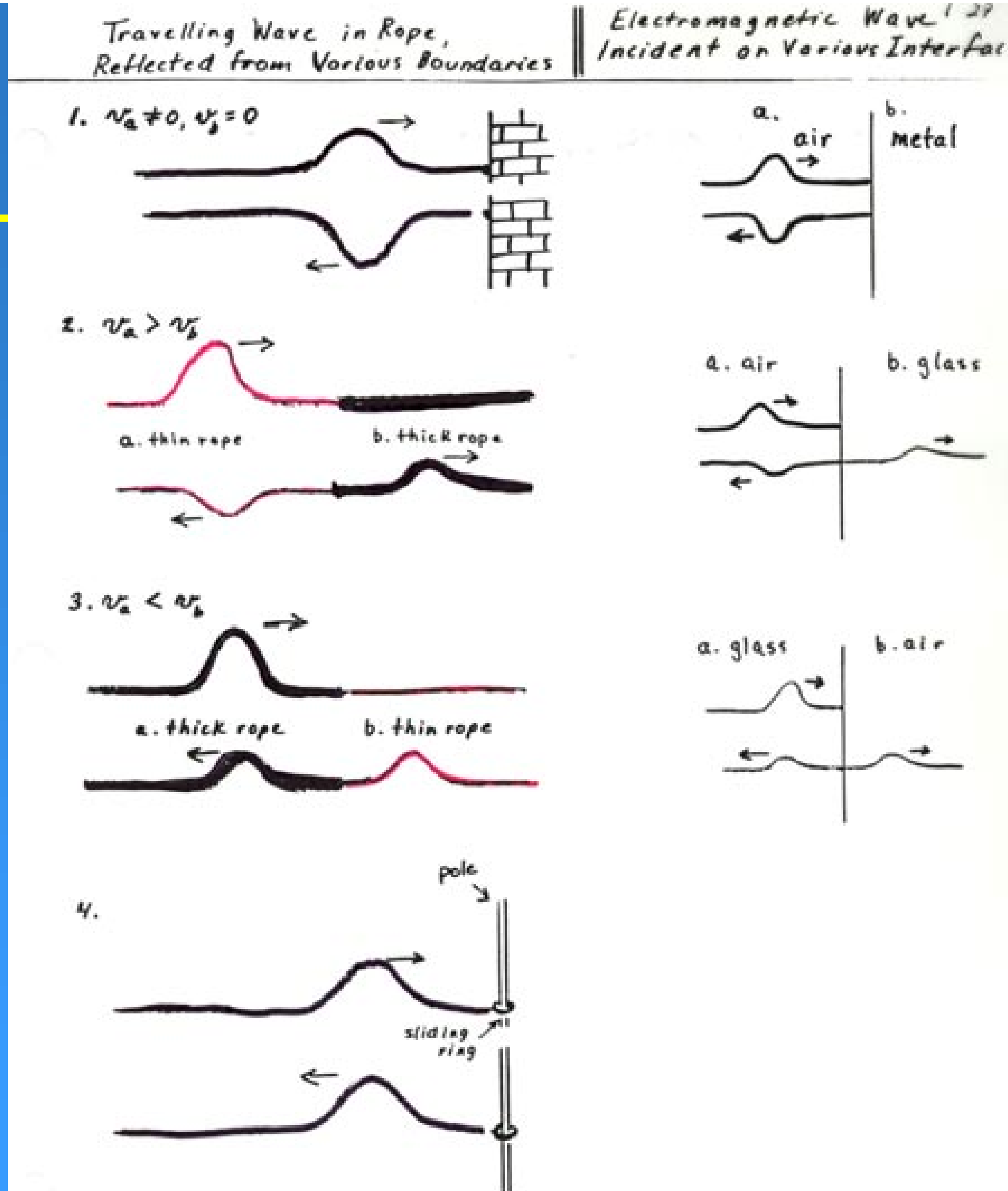


FIGURE 2.14

B, stonewalling the lady's gesture, refused to let his hand be shaken. Consequently, an upside-down wave returns to *A*.

– Phase and amplitude of reflecting wave depends on details of surface



Ionosphere-reflection

- **Long wavelength radiation is reflected from ionosphere (for light whose frequency is below the plasma frequency**
  – Free charges wiggle to prevent the electric field from being transmitted
- **Same principle for reflections from metals**
  – If free electrons can wiggle as fast as the frequency of light, they will prevent the electric field

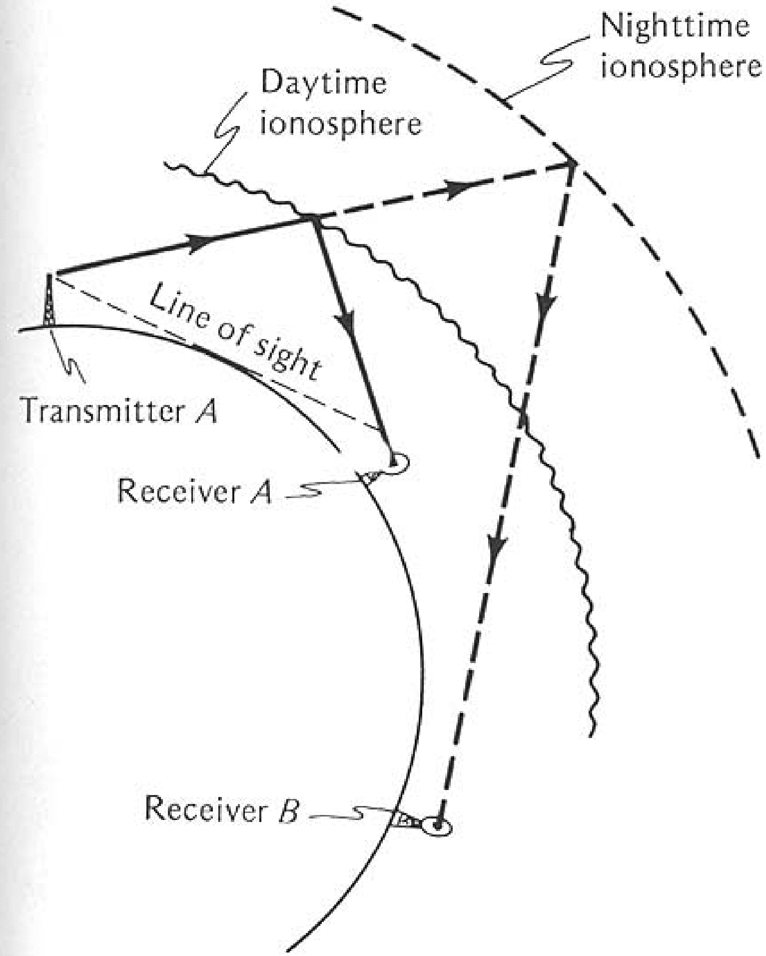


FIGURE 2.15

Reflection of radio signals from the ionosphere makes distant reception possible. The ionosphere rises at night, increasing the range of reception. (Exaggerated for clarity.)

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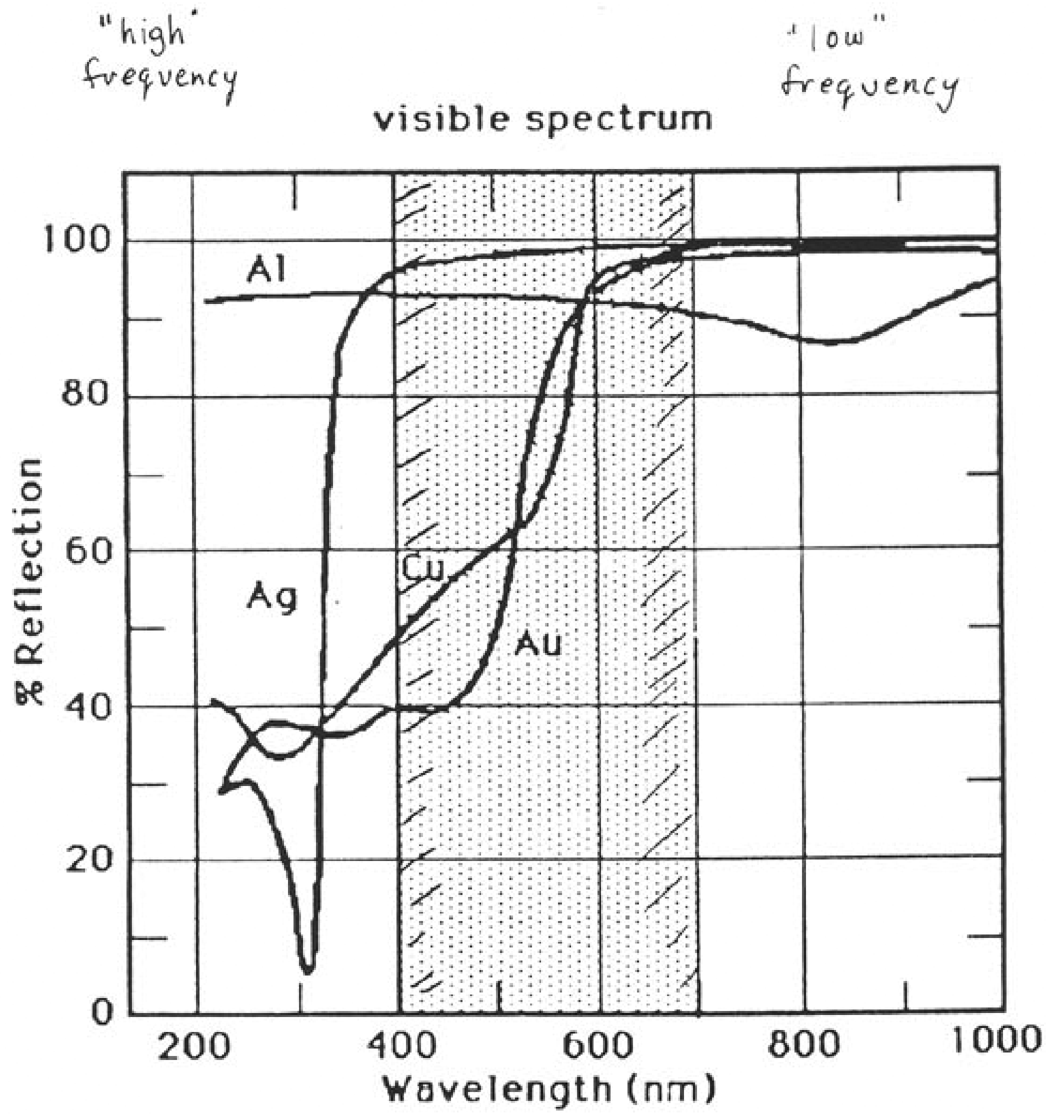
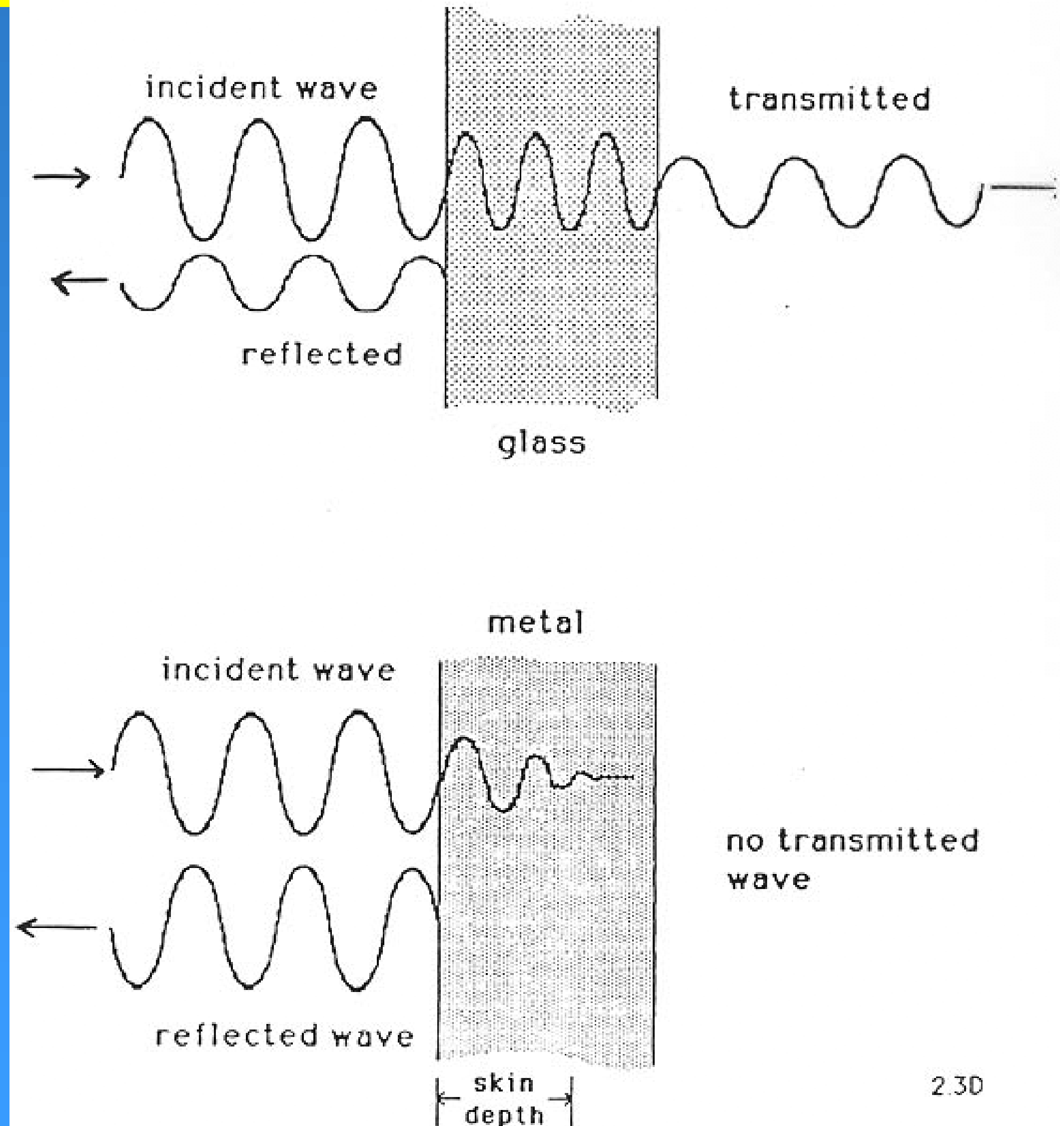
The Plasma frequency of a metal determines its color



Reflections from glass and from metal



2.30

- **Structure of typical mirror**
  - Glass in front
  - Mirror in back (silver can be protected with paint on back and glass on front so it wont blacken)

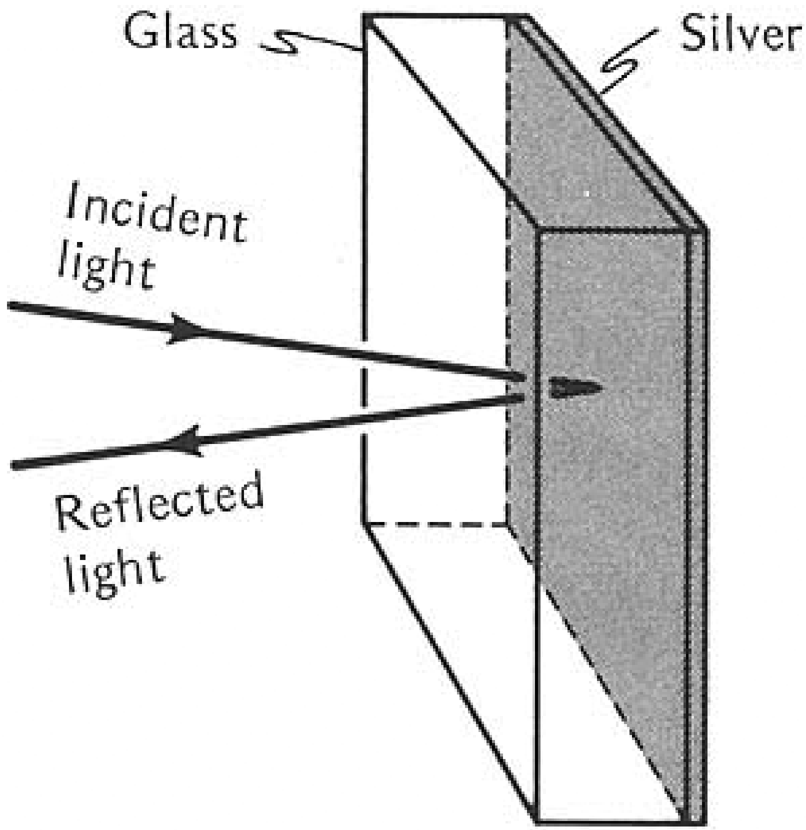
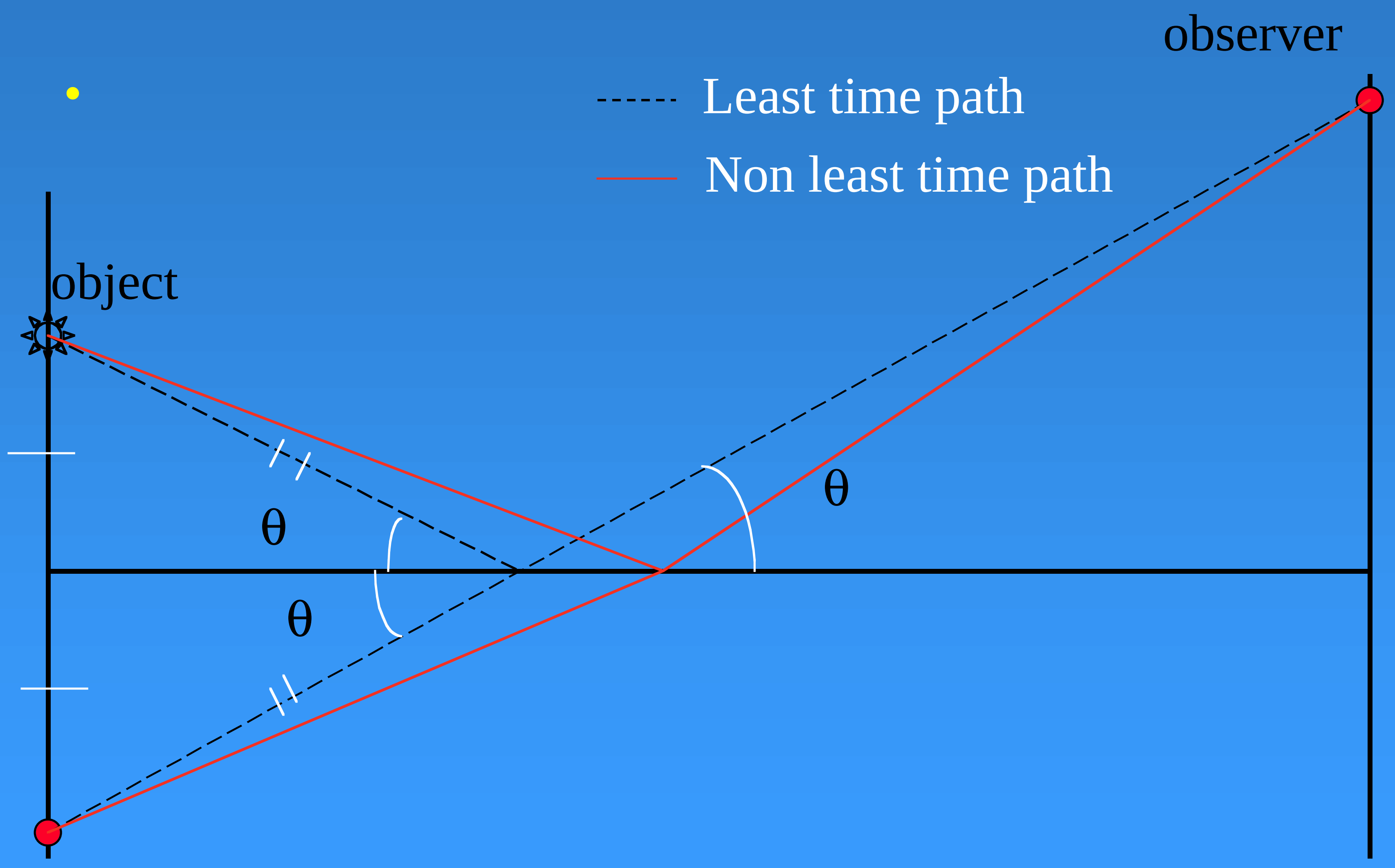


FIGURE 2.16

An ordinary mirror consists of a piece of glass, coated on its back surface with a layer of silver.

Reflection and least time



Virtual image (location is independent of observer location)

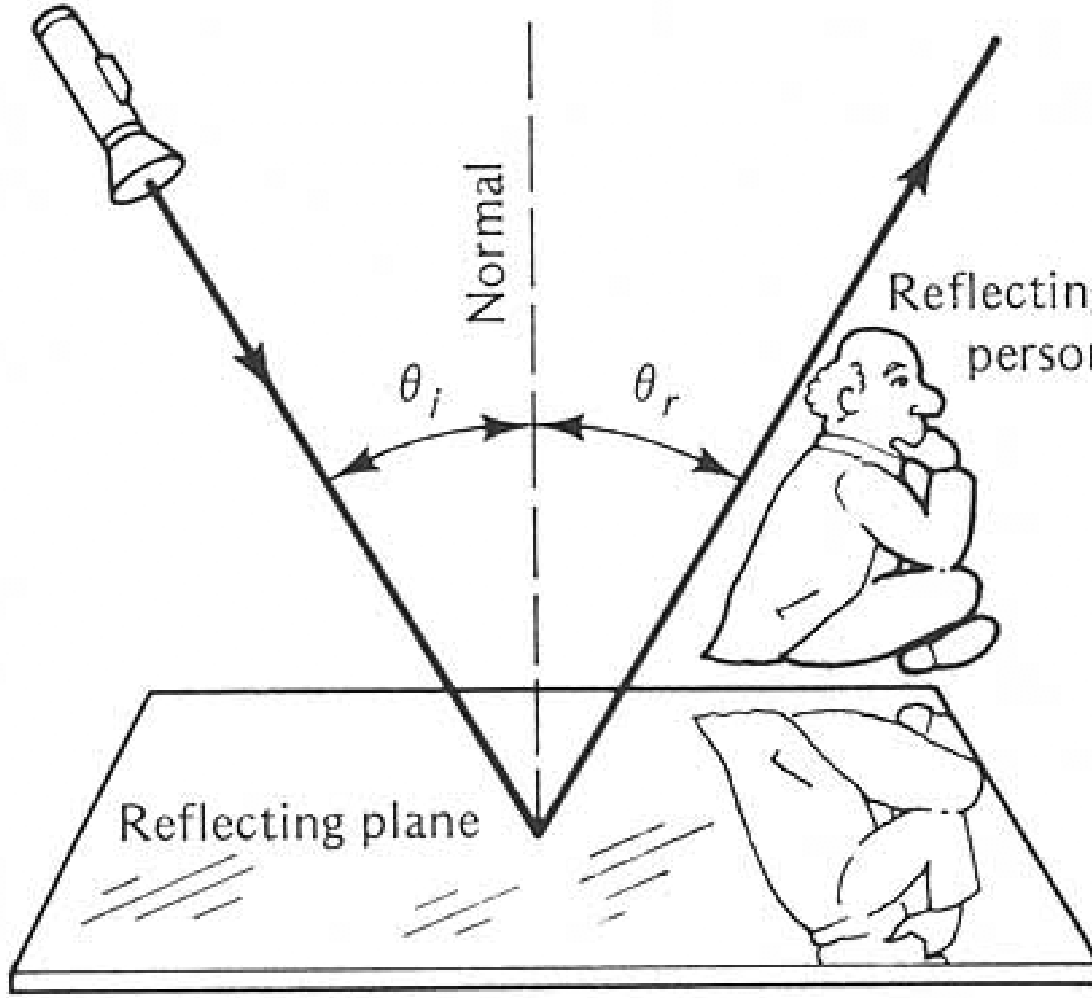
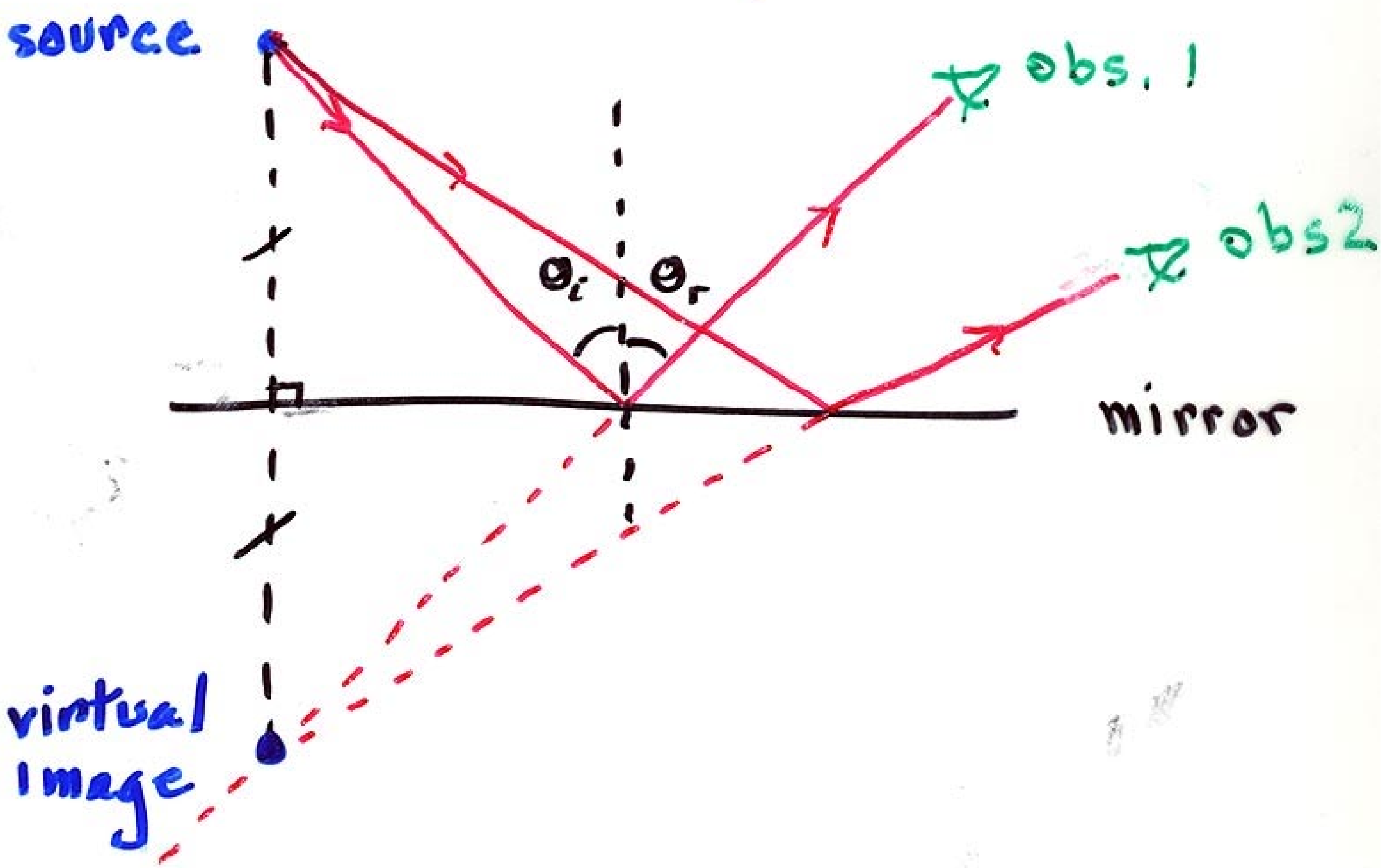


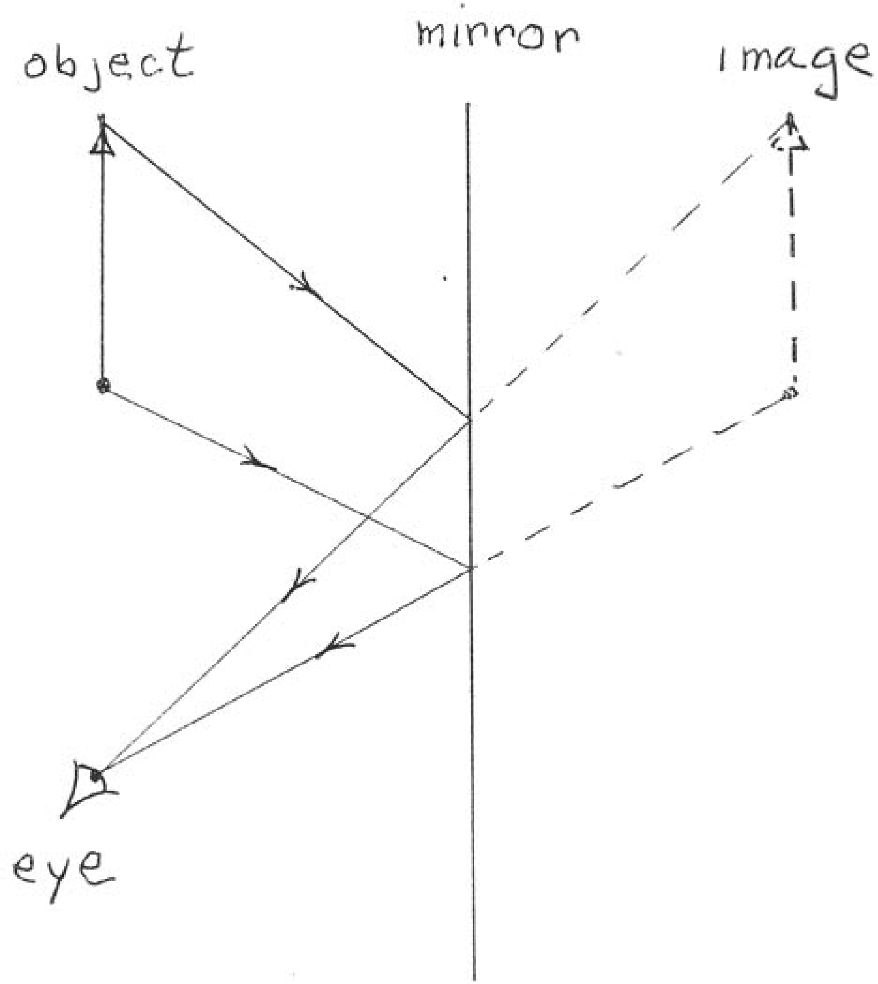
FIGURE 2.18

The law of reflection: $\theta_r = \theta_i$.

Virtual Images



What do we see when we see a reflection?



The image looks like the object, but behind the mirror by the same distance the object is in front of the mirror

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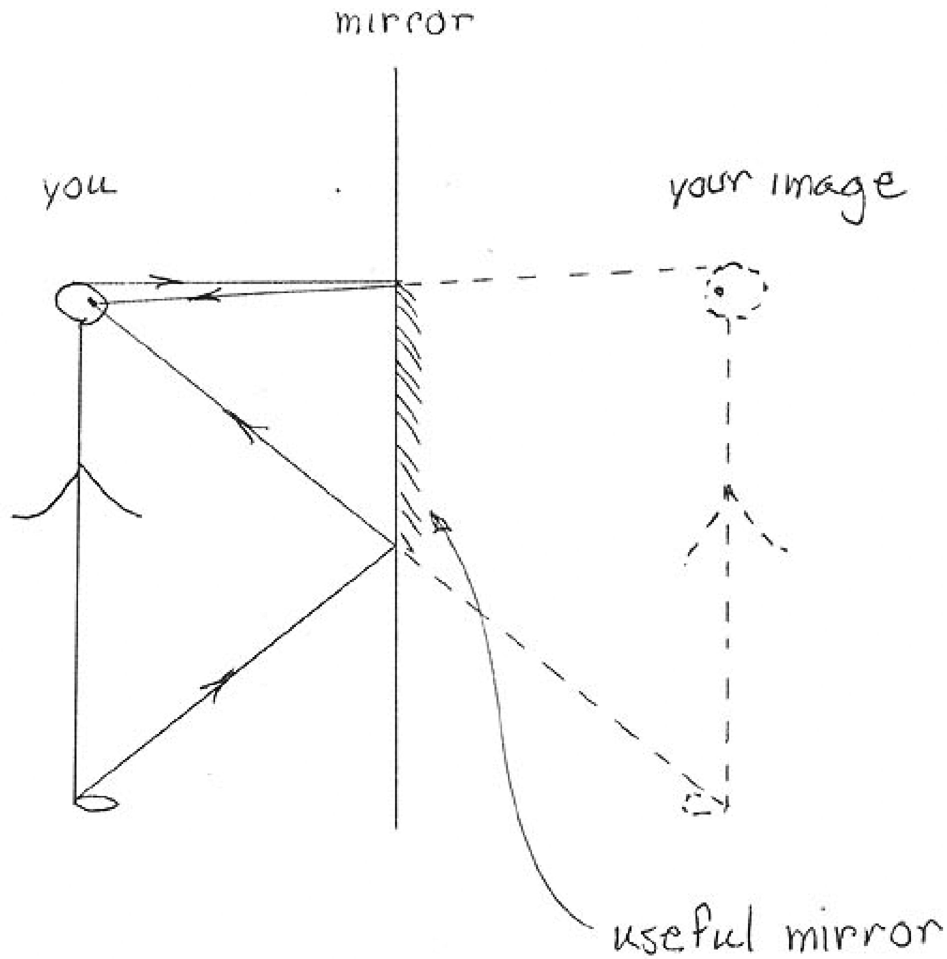
How large a mirror does one need to see oneself?

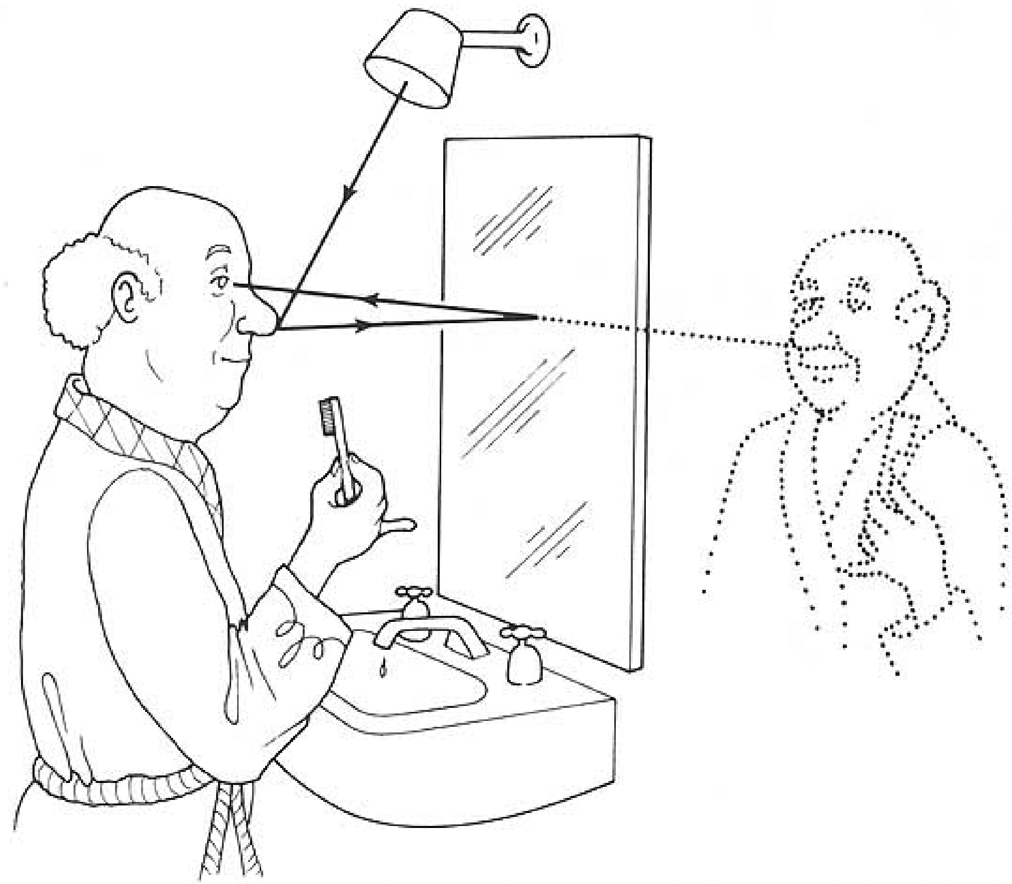


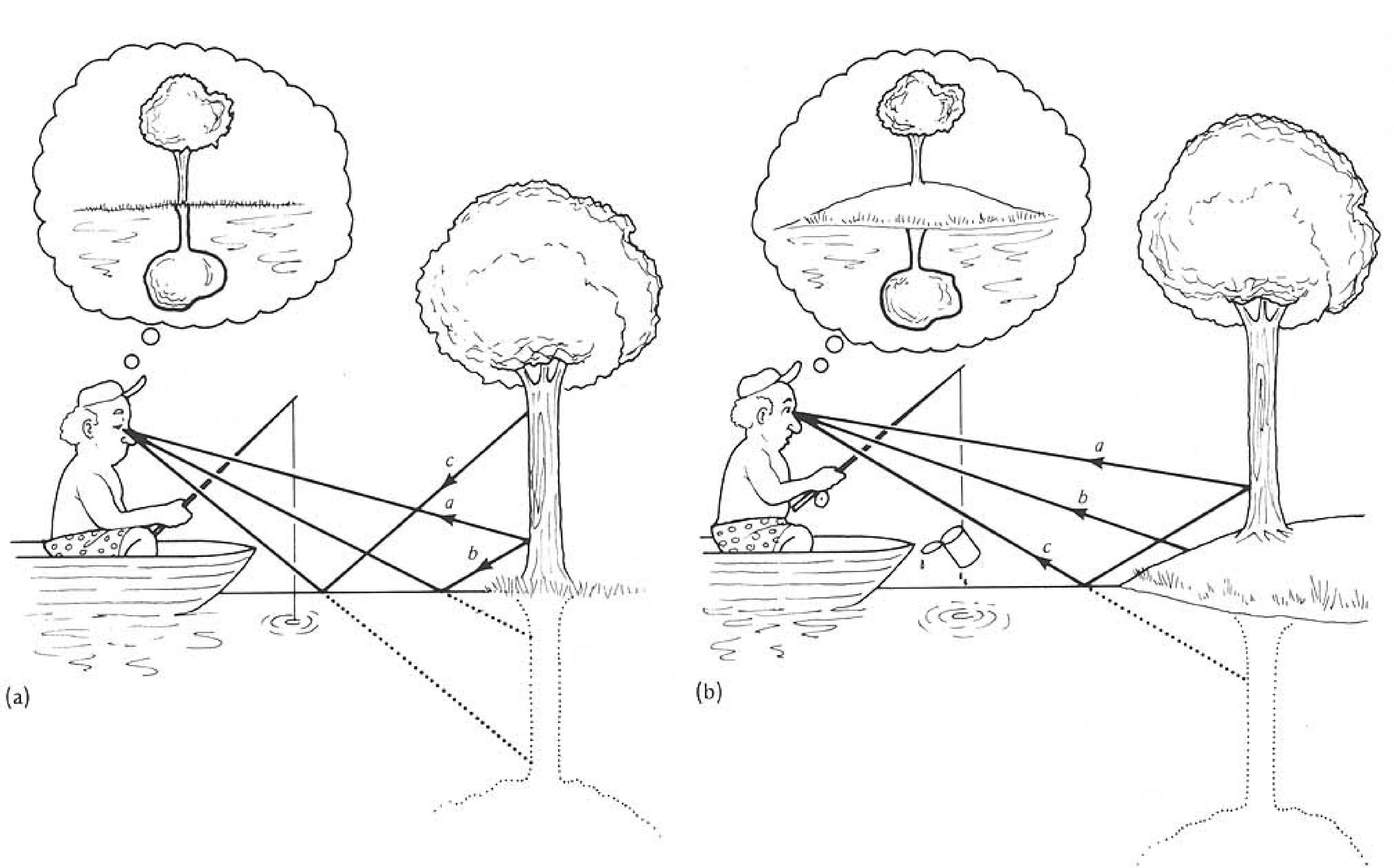
One needs a mirror half one's height

- **Virtual images**

FIGURE 2.19 (below)

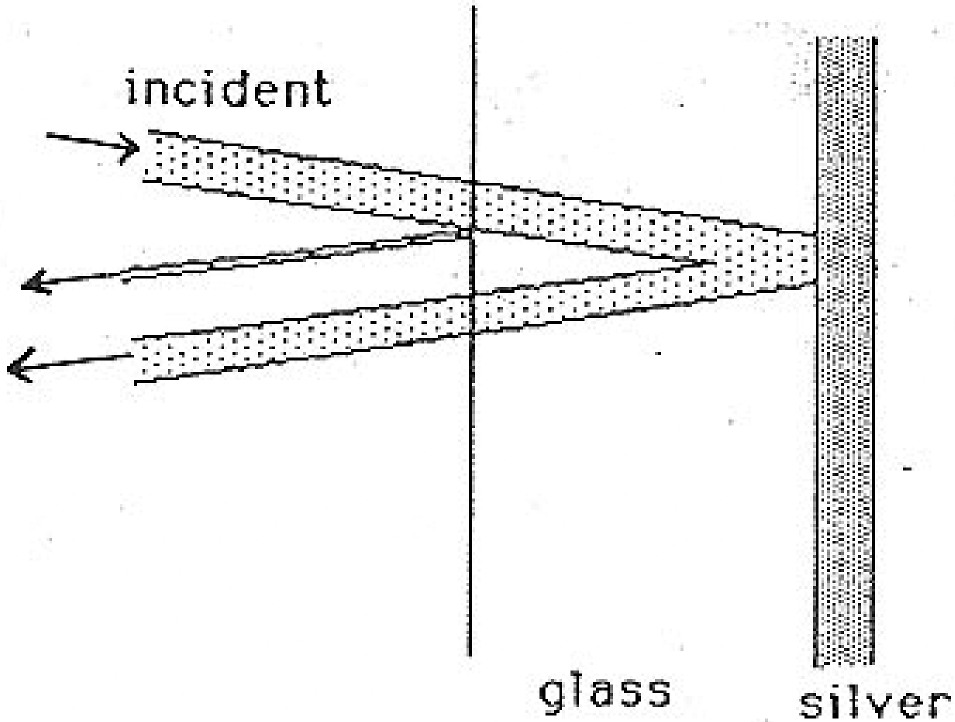
The reflected ray does not originate where the eye thinks it came from. The light scattered from the observer's nose (the object) really takes a sharply bent path to his eye, since it is reflected by the mirror. But the observer's brain interprets the light as if it had come in a straight line from a part of the image behind the mirror. This is because the reflected ray comes from the same direction *as if* it came from an object behind the mirror: the image, which is as far from the mirror as the object, but on the other side.




c
a
b
(a)
a
b
c
(b)

Reflection from back surface mirror

Reflection from plane mirror



Most of the reflection is due to the silver (or aluminum) coated on the back of the glass.

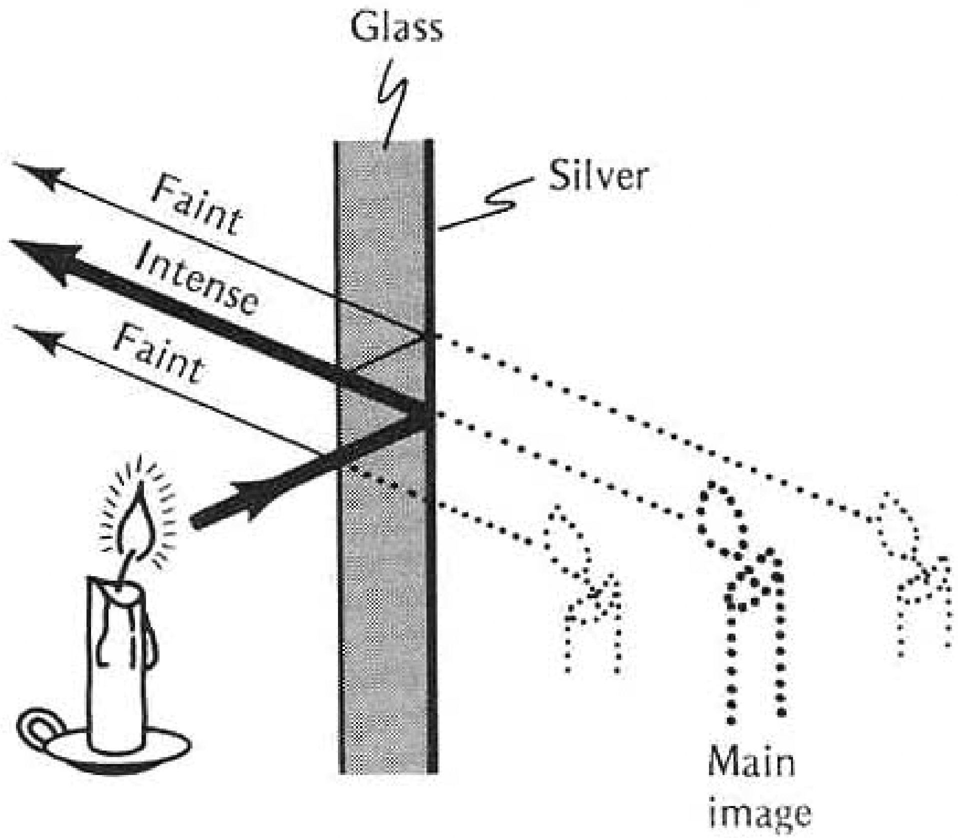


FIGURE 2.42

A single mirror can form several images of a candle. If both the candle and the viewer's eye are held close to the glass surface, the better glass reflectivity at grazing incidence makes the extra images brighter.

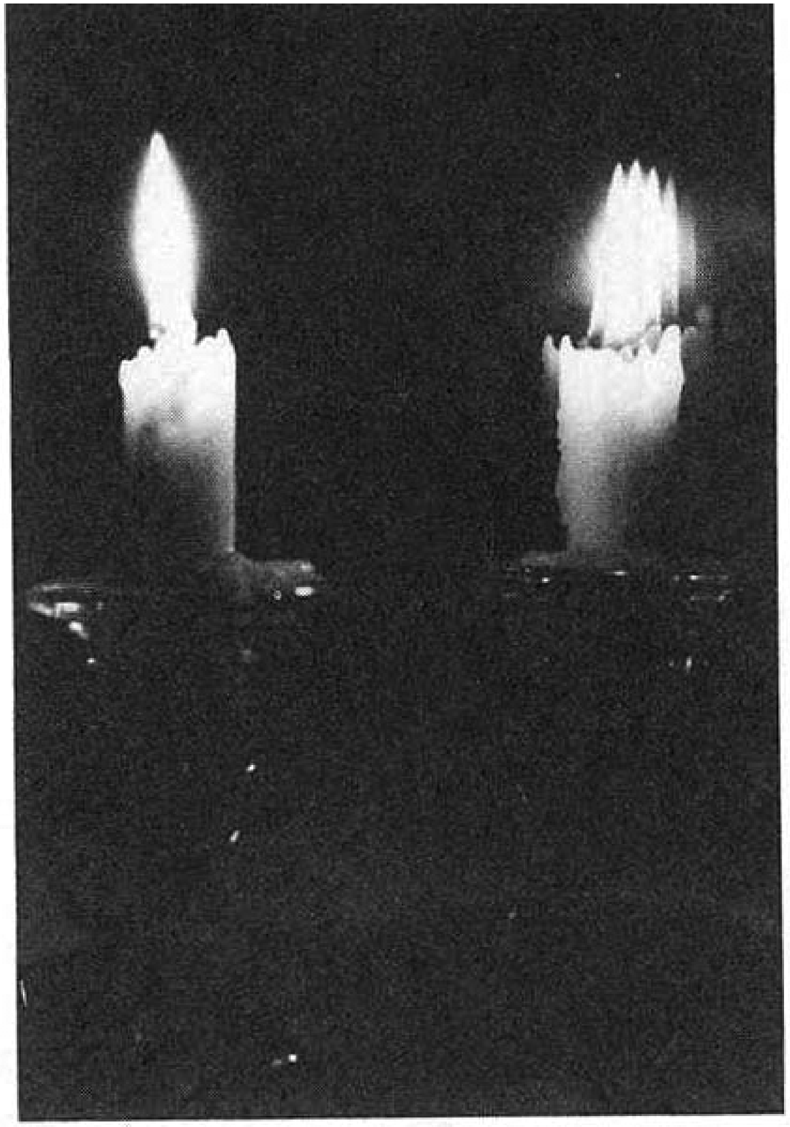


FIGURE 2.43

A candle and its multiple reflected images.

Partial reflection-transmission

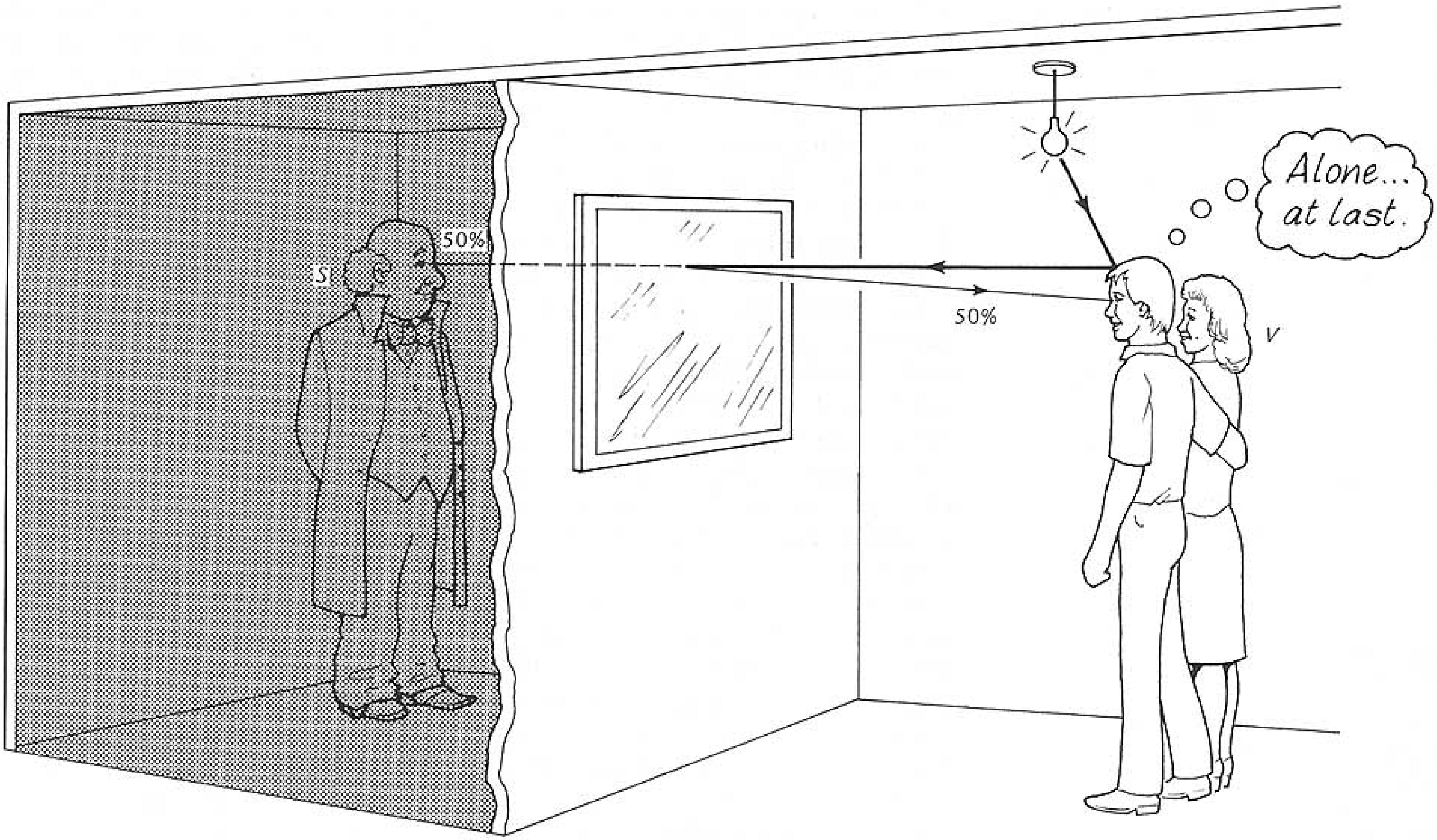
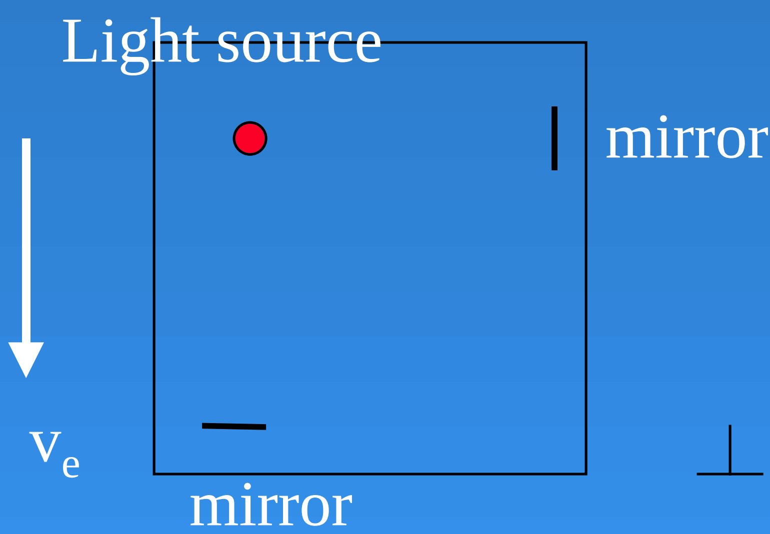


FIGURE 2.17

Illuminated innocents become visible victims of spookish spy behind harmless half-silvered mirror.

Measuring our speed through the Ether



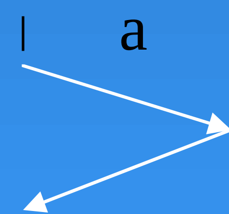
Michelson-Morley Expt 1887

v_e = our speed through the ether

c = speed of light

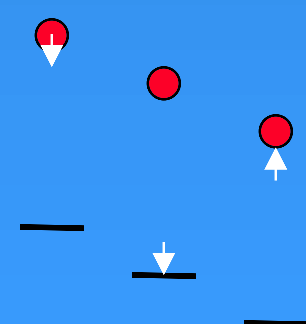
a = distant to mirrors

⊥ path



$$t_{\perp} = \frac{2a}{c} \frac{1}{\sqrt{1 - \frac{v_e^{2}}{c^2}}}$$

|| path



$$t_{C} = \frac{2a}{c} \left(\frac{1}{1 - \frac{v_e^2}{c^2}} \right)$$

Measuring our speed through the Ether

- **Conclusion**

$$\frac{t_\perp}{t_C} = \sqrt{1 - \frac{v_e^2}{c^2}}$$

- **MM measured no difference! (implies $v_e = 0$)**
- **In fact the uncertainty in their measurements was far less than the speed of the earth around the sun, thus the assumption of earth moving through a stationary was incorrect. Thus the ether idea was not supported experimentally.**
- **Einstein's theory of special relativity successfully explained this measurement**