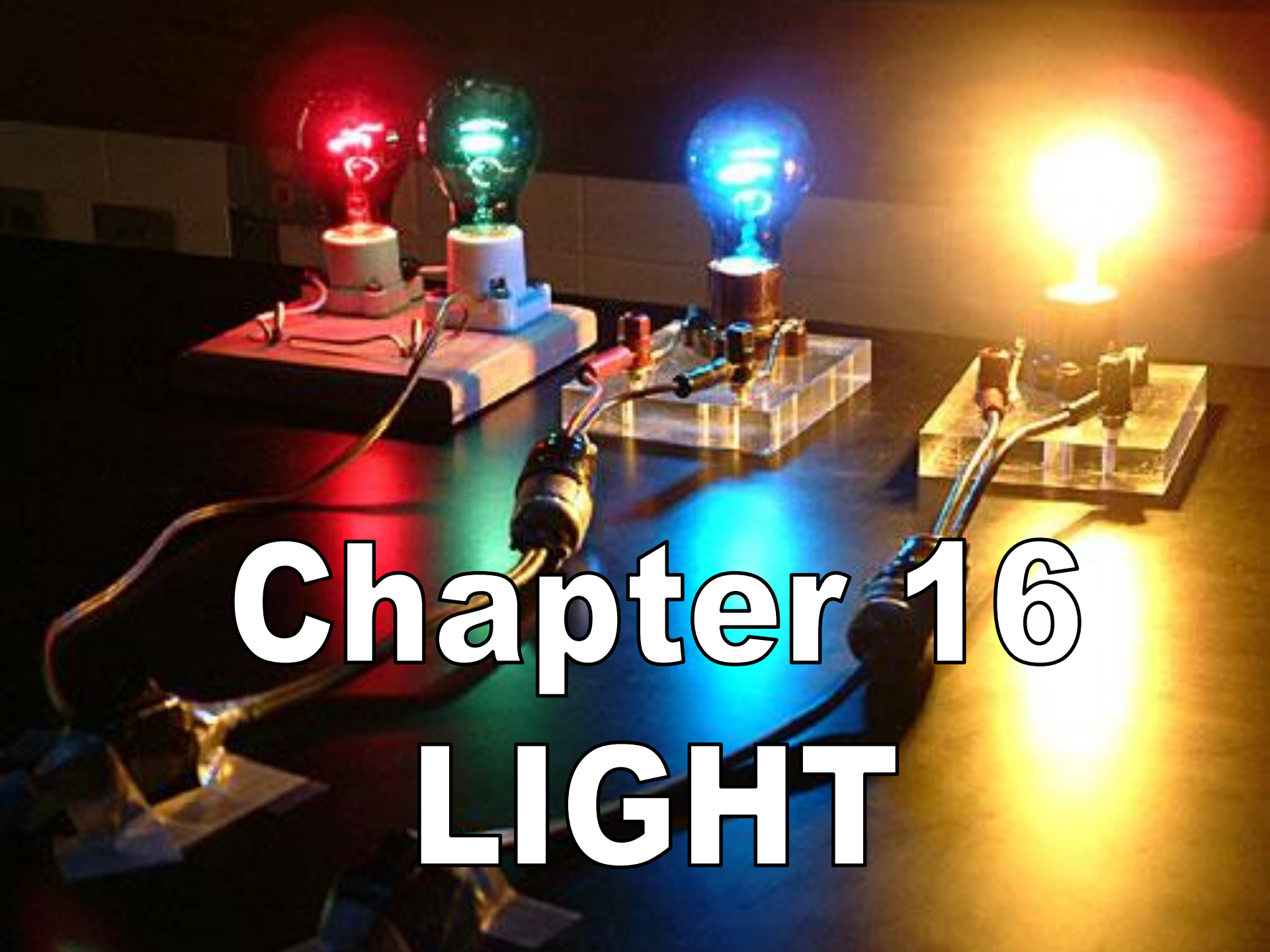

Chapter 16
LIGHT

State Standards Addressed

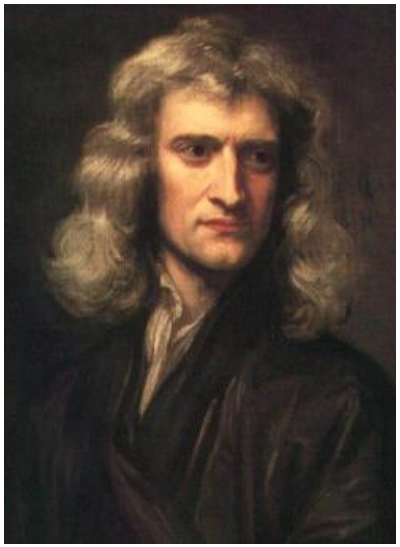
Waves *Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:*

- *Students know* waves carry energy from one place to another.
- *Students know* how to identify transverse and longitudinal waves in mechanical media, such as springs and ropes, and on the earth (seismic waves).
- *Students know* how to solve problems involving wavelength, frequency, and wave speed.
- *Students know* sound is a longitudinal wave whose speed depends on the properties of the medium in which it propagates.
- *Students know* radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second).
- *Students know* how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

Chapter 27: Light

I. Early Concepts of Light (27,1)

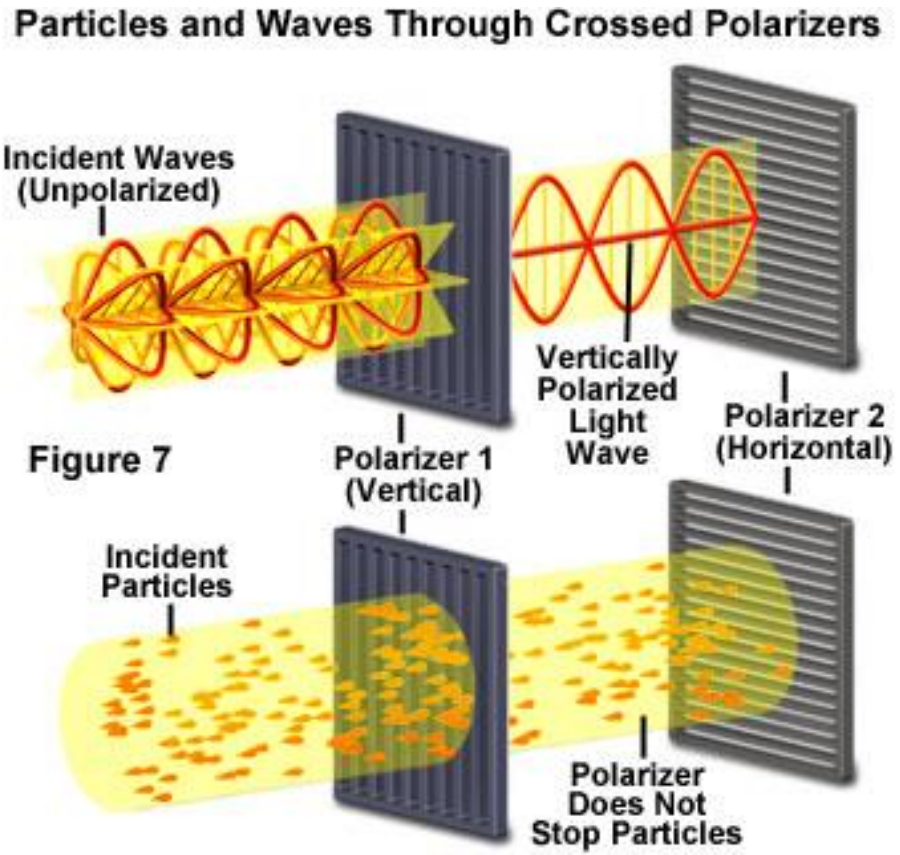
A. Light studied for thousands of years



1. Up until **Newton** and beyond, most philosophers though light consisted of **particles**
2. One Greek, Empedocles taught light traveled in **waves**
3. **Wave theory** accepted theory in nineteenth century

B. **Einstein** published theory explaining photoelectric effect in 1905. Said light consists of **particles** (later called ***photons***)

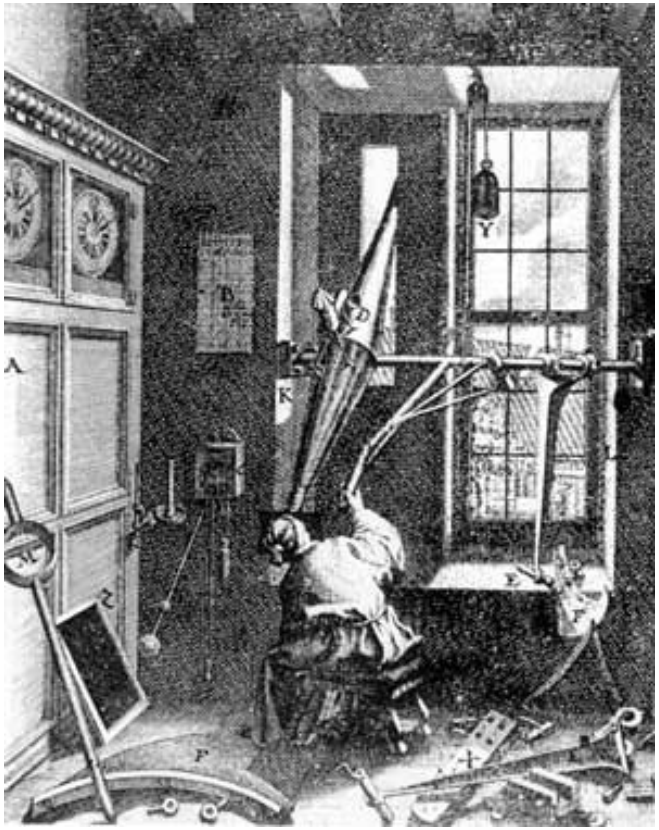
C. Scientist now agree that light has a **dual nature**, **part particle and part wave.**



II. The Speed of Light (27.2)

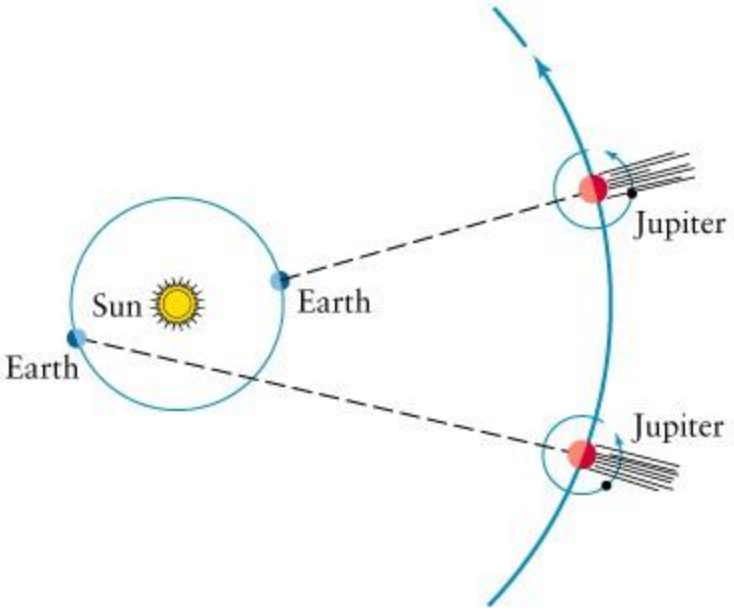
A. It was not known whether light traveled instantaneously or with finite speed.

1. Danish astronomer Olaus Roemer (1675) measured the **periods** of Jupiters moons.



a. Measured period of innermost moon (Io)

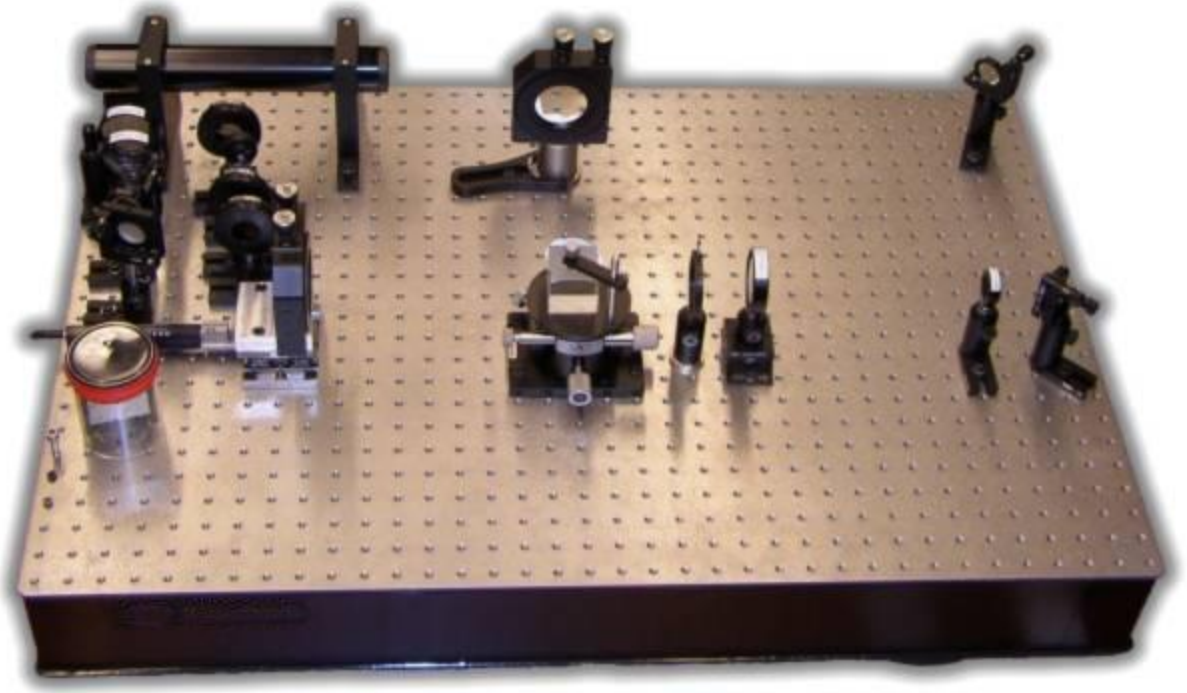
b. **Periods** longer when Earth moving **away** from Jupiter and shorter when Earth moving **toward** Jupiter

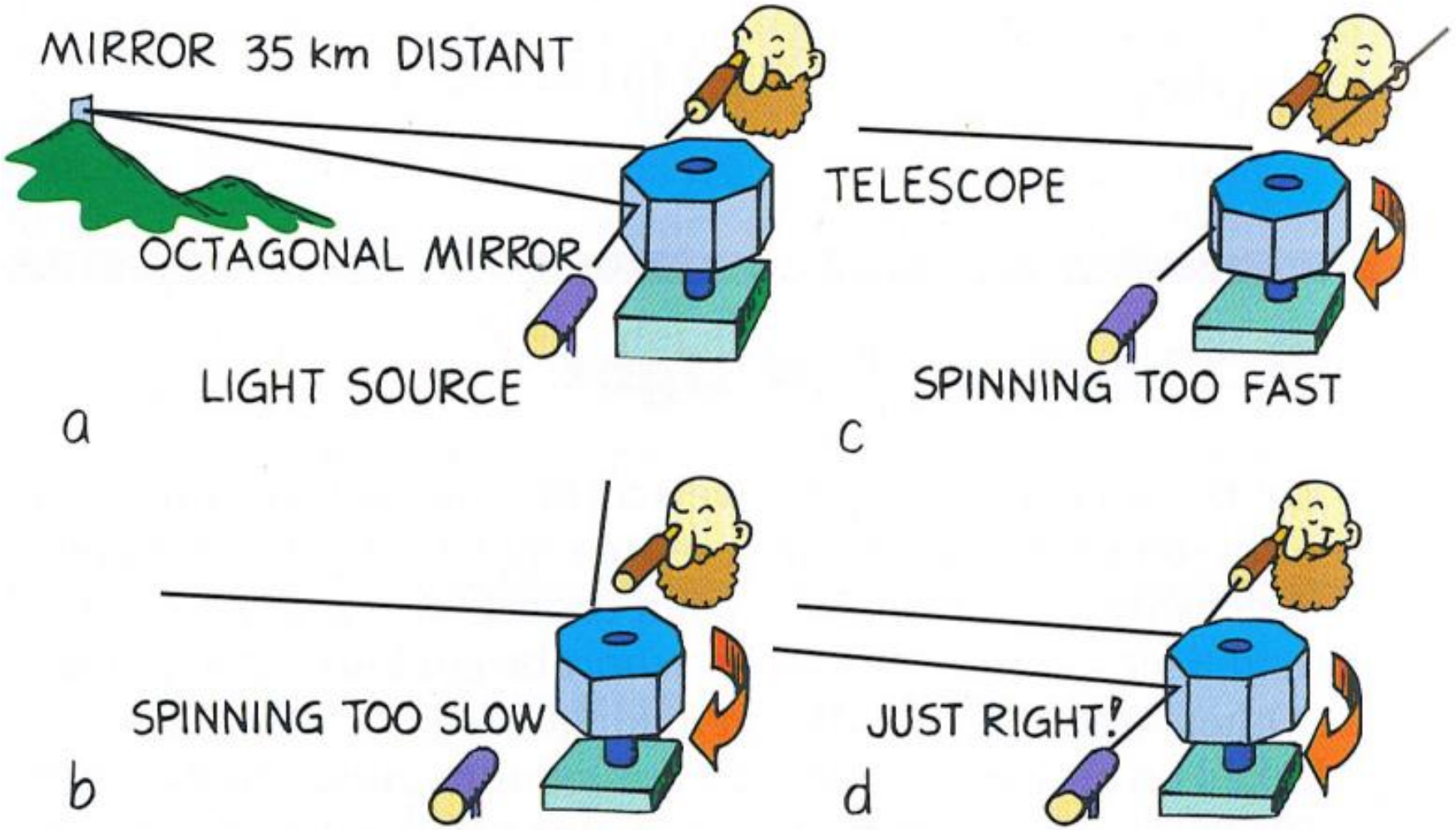


2. Albert Michelson (late 1880's) conducted most famous experiment

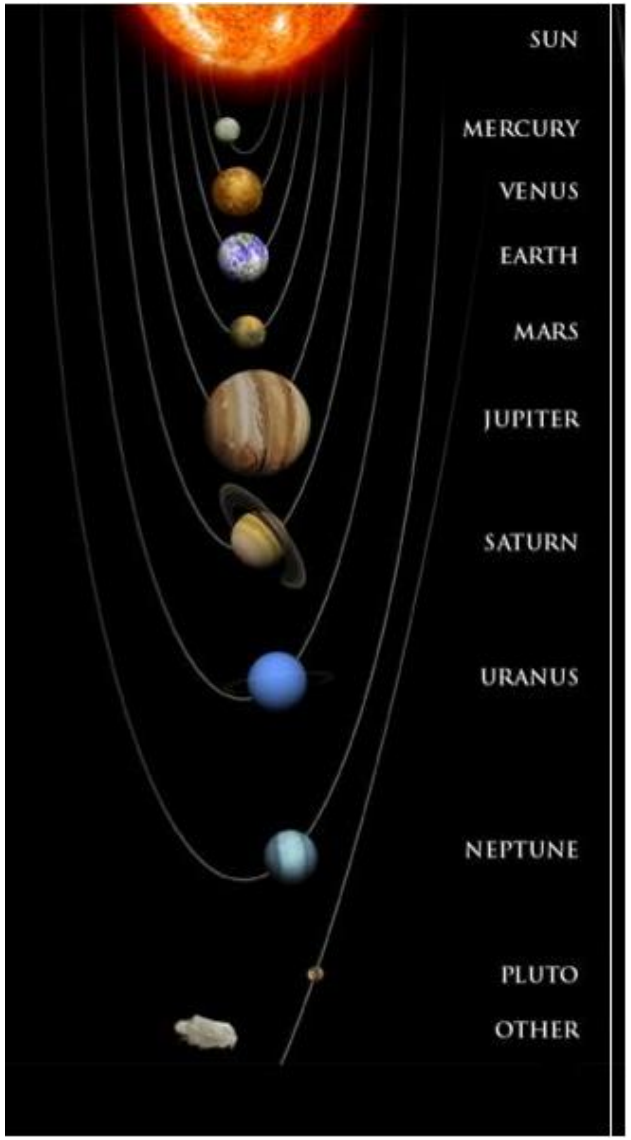
   a. Bounced light off mirror arrangement

   b. Calculated the speed of light to be **299,920 m/s** (which we rounded to **300,000 m/s**) He received Nobel prize for this




MIRROR 35 km DISTANT
OCTAGONAL MIRROR
LIGHT SOURCE
a
TELESCOPE
SPINNING TOO FAST
c
SPINNING TOO SLOW
b
JUST RIGHT!
d

B. We know **speed of light** in a <u>vacuum</u> is a **universal constant**



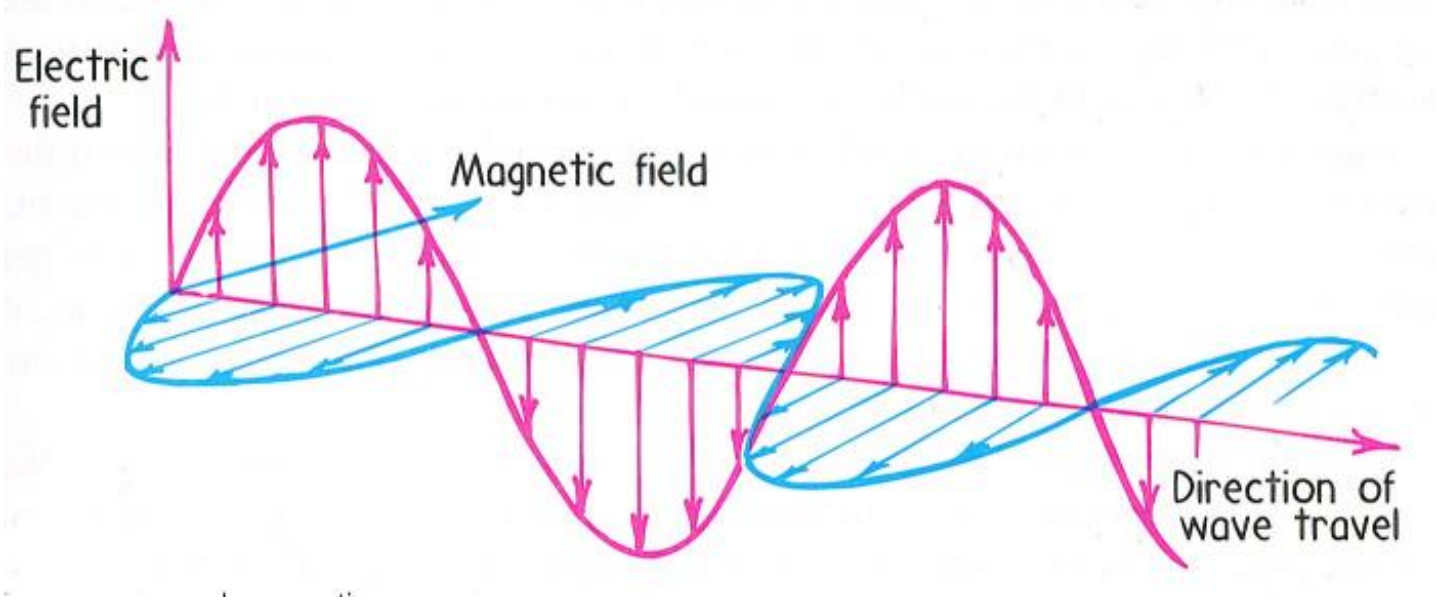
1. Light takes **8 minutes** to travel from **Sun to Earth**
2. Distance light travels in one year called **light year**
3. Our galaxy is 100,000 light years in diameter

III. Electromagnetic Waves (27.3)

A. **Light** is <u>energy</u> emitted by **accelerating electric charges**

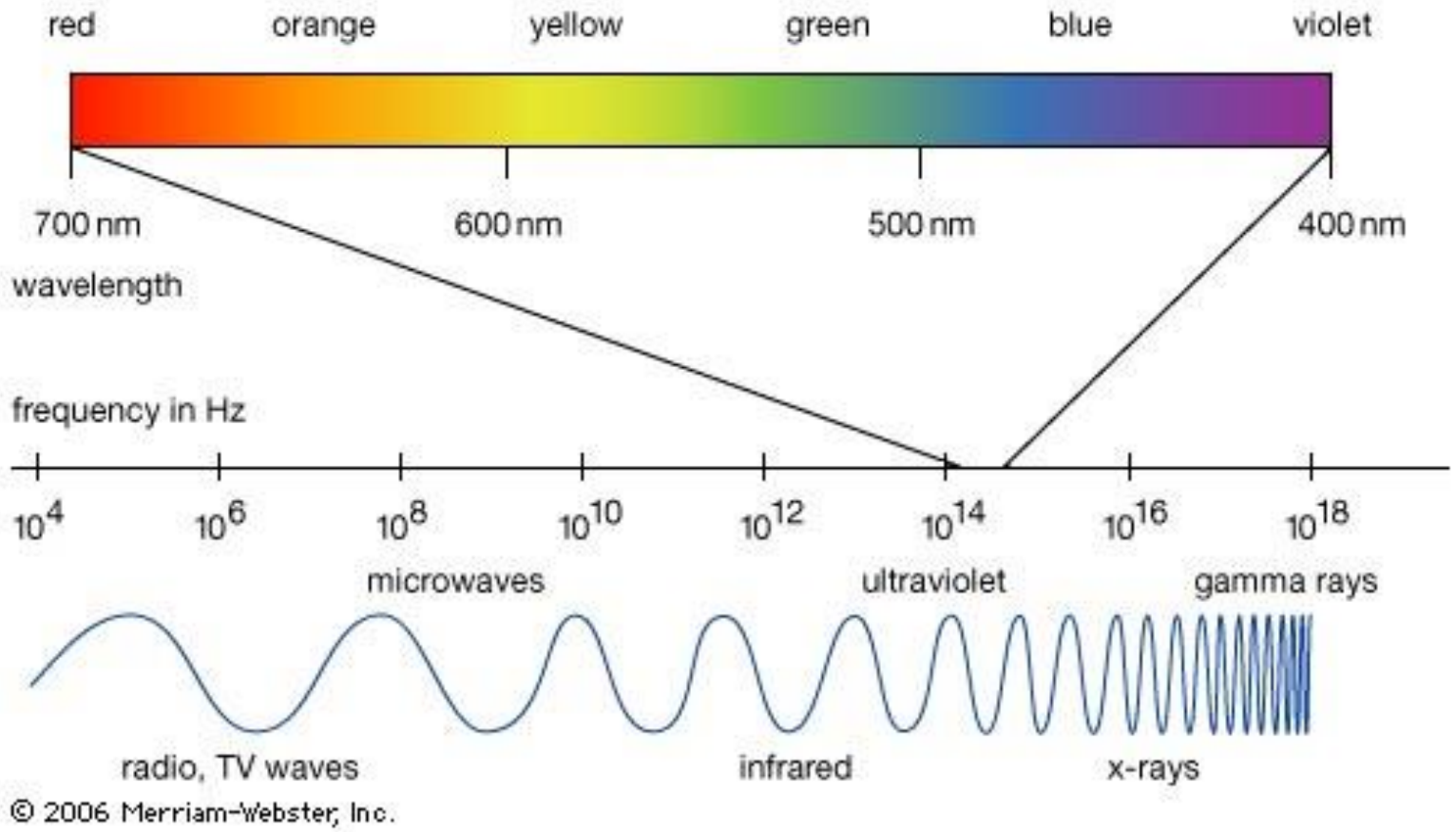
1. The energy travels in a **wave** that is partly **electric** and partly **magnetic**

2. This is called an **electromagnetic wave**

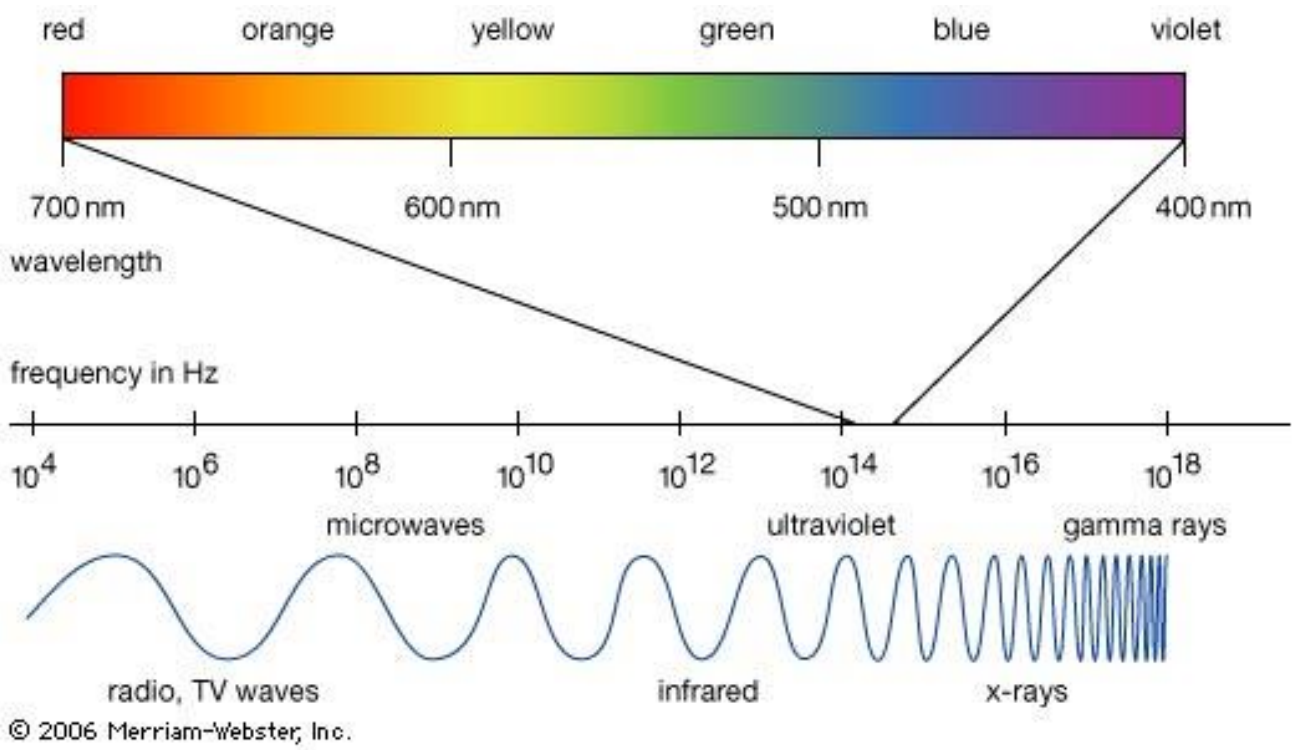


B. Light is small portion of broad family of electromagnetic waves.

1. The range of electromagnetic waves shown in **electromagnetic spectrum**



2. **Lowest** frequency of light we can see with our eyes is **red**
3. **Highest** frequency we can see appears **violet**
4. Frequencies **lower than red** are infrared (heat lamps give off **infrared**)
5. **Higher** than violet called **ultraviolet** (causes sunburn)

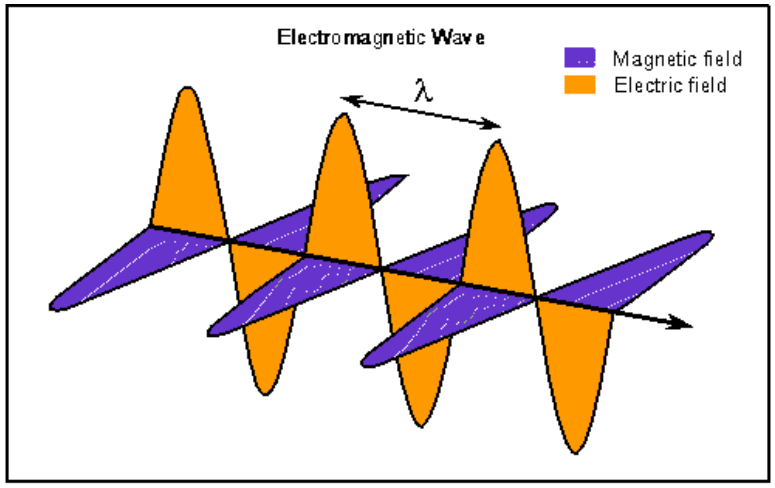


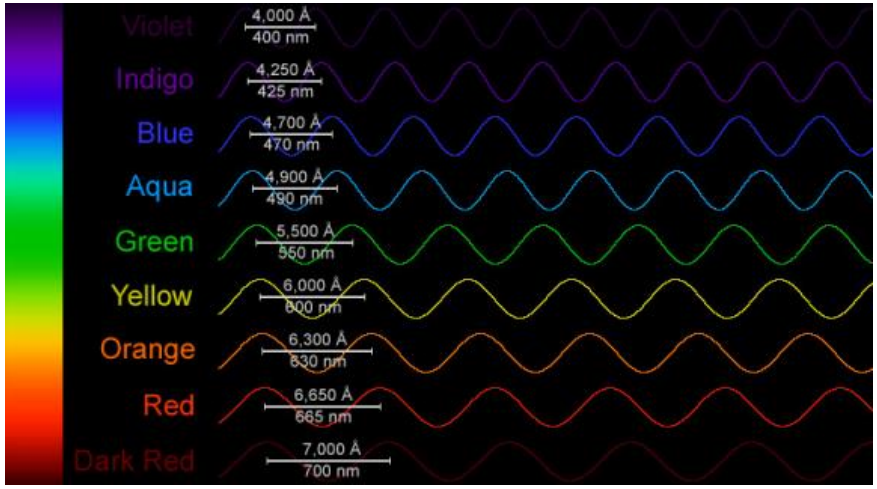
IV. Light and Transparent Materials (27.4)

A. **Light is energy carried in an electromagnetic wave that is generated by vibrating electric charges.**

1. Vibrations in an **emitter** are transferred to vibrations in **receiver**

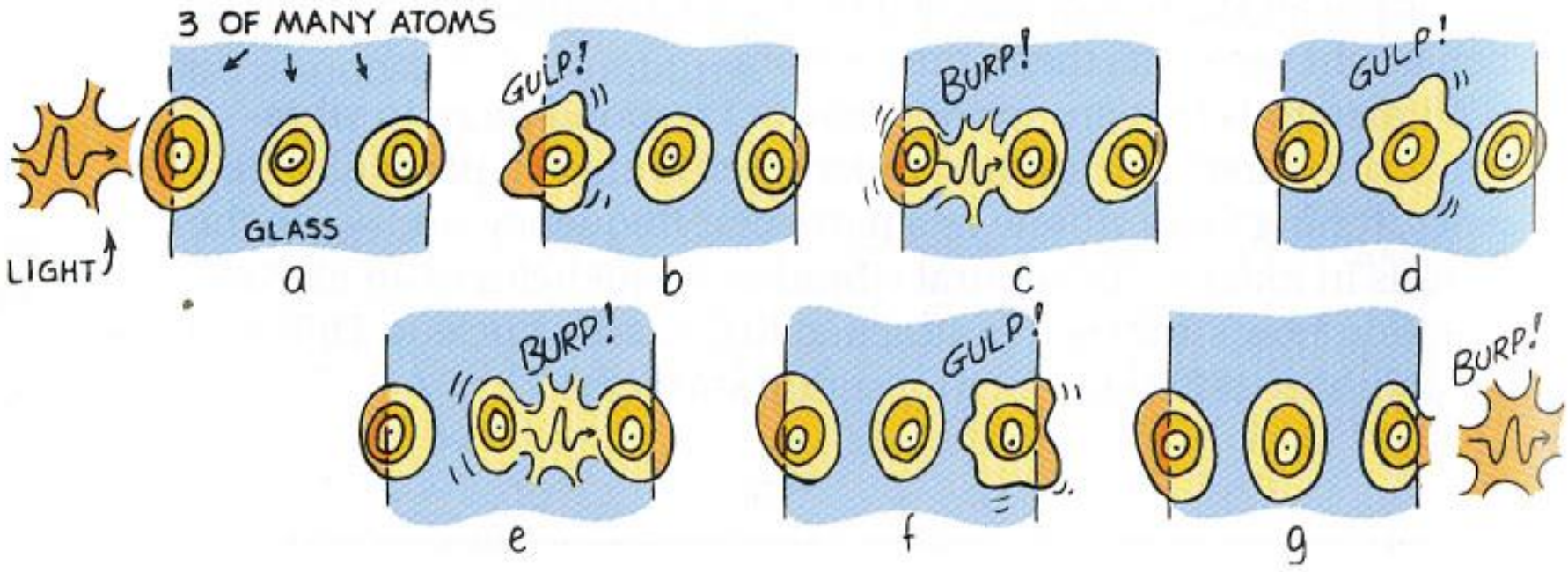
2. Visible light vibrates at very high rate (100 trillion times per second. **1014 Hertz**)





B. **Transparent** materials (like glass and water)

1. Allows light to pass through
2. Visible light sets up **vibrations** in atoms the produce a **chain of absorptions** and **reemissions** that pass the light energy through the material and out the other side



3. There is a **time delay** when light passes through a **transparent material**.

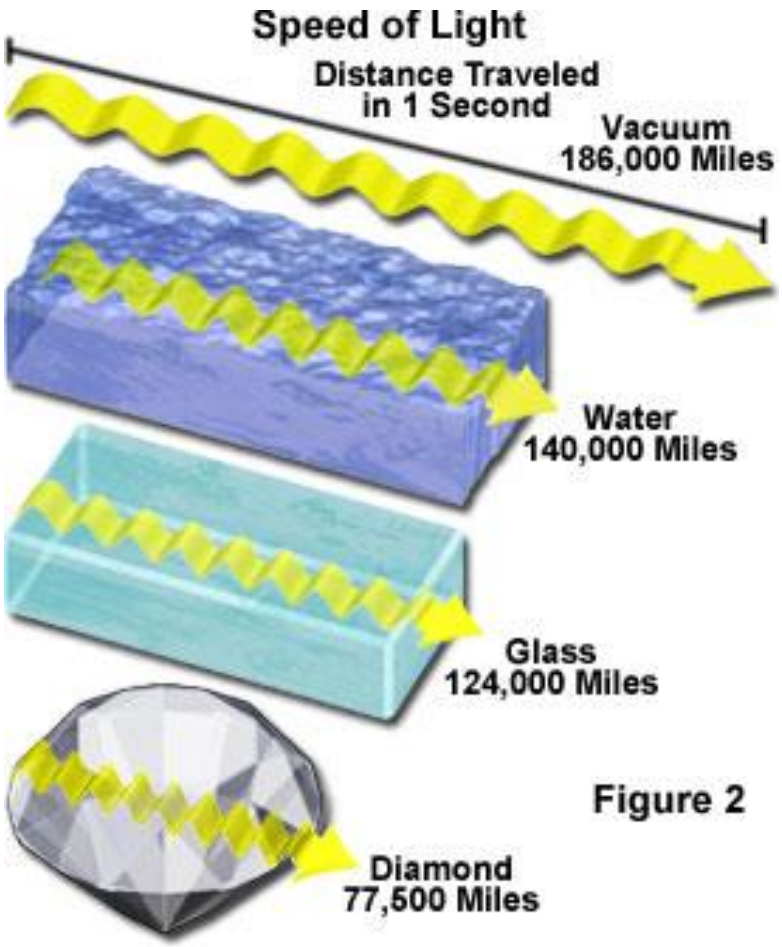


Figure 2

a. Light travels at different **speed** in different **materials**

b. In **water** light travels at 75% the speed of light or **0.75c**

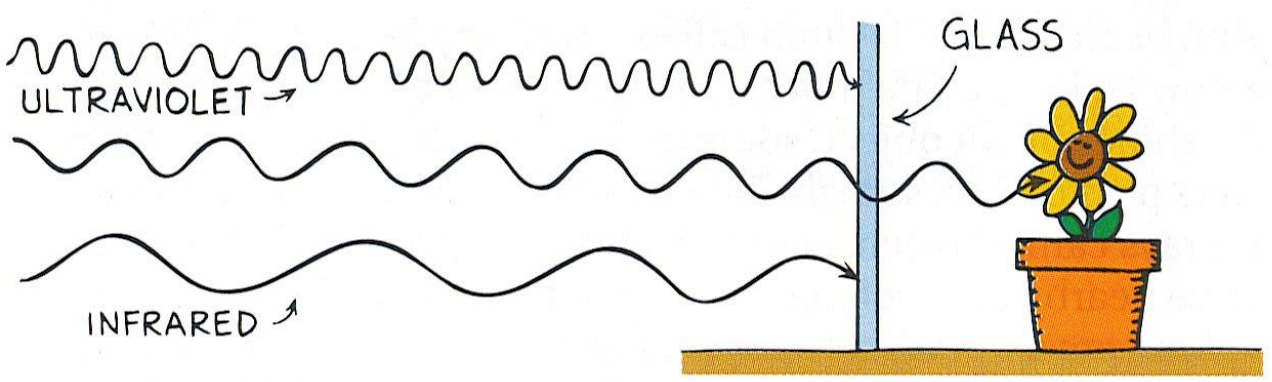
c. In **glass** it travels **0.67c**

d. In **diamond** is travels at **0.40c**

C. **Glass** blocks both **infrared** and **ultraviolet**, but is transparent to **visible light.**

1. **Ultraviolet** light creates resonance in glass and atoms hold onto energy for quite a long time and gives up **energy as heat.**

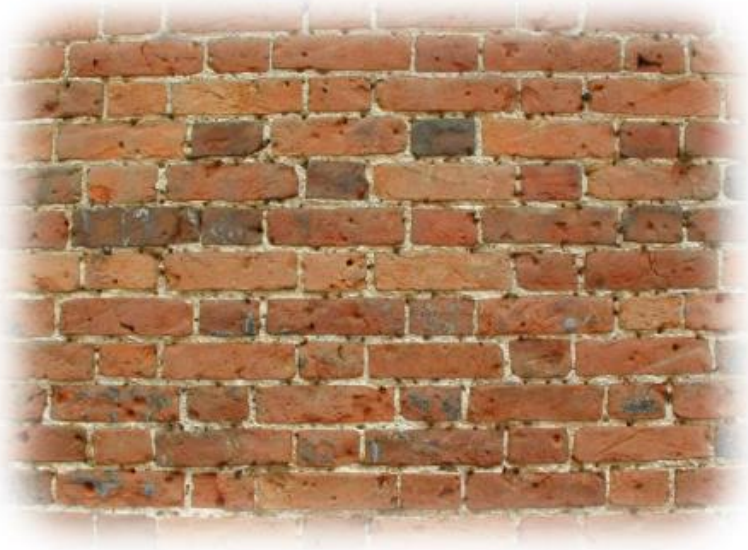
2. **Infrared** vibrate not only the electrons, but also the **entire structure** of the glass. This vibration **increases internal energy and makes it warmer.**



V. **Opaque** Materials (27.5)

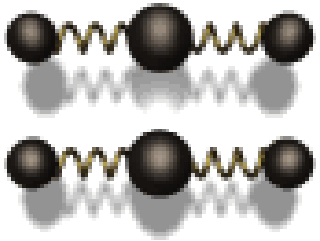
A. Most materials **absorb** light <u>without</u> **reemission** and allow **no** light through them (they are opaque)

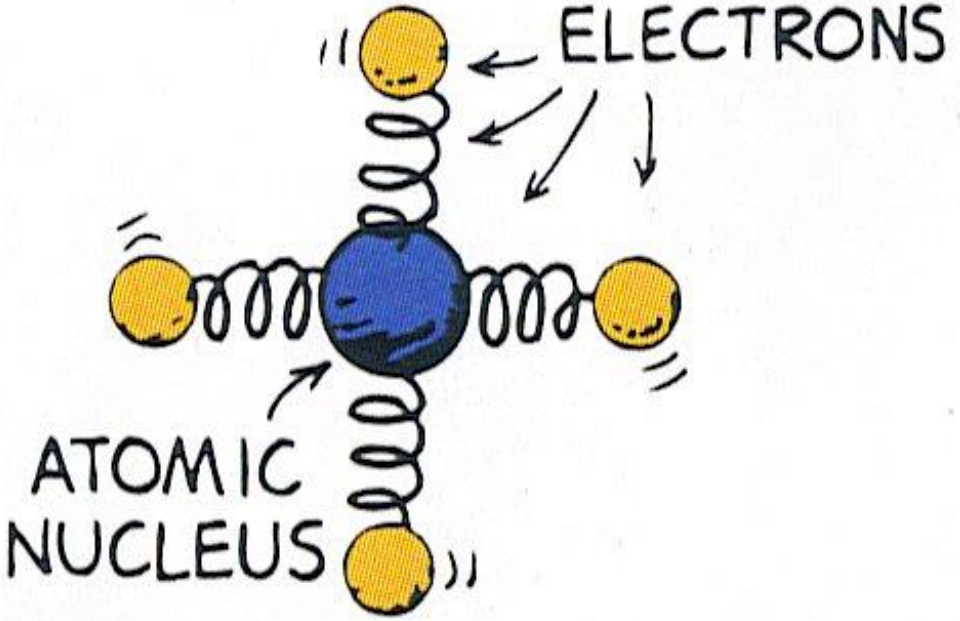
1. vibrations given by light to atoms and molecules turned into **random kinetic energy** (into <u>internal energy</u>)
2. The materials become slightly **warmer**



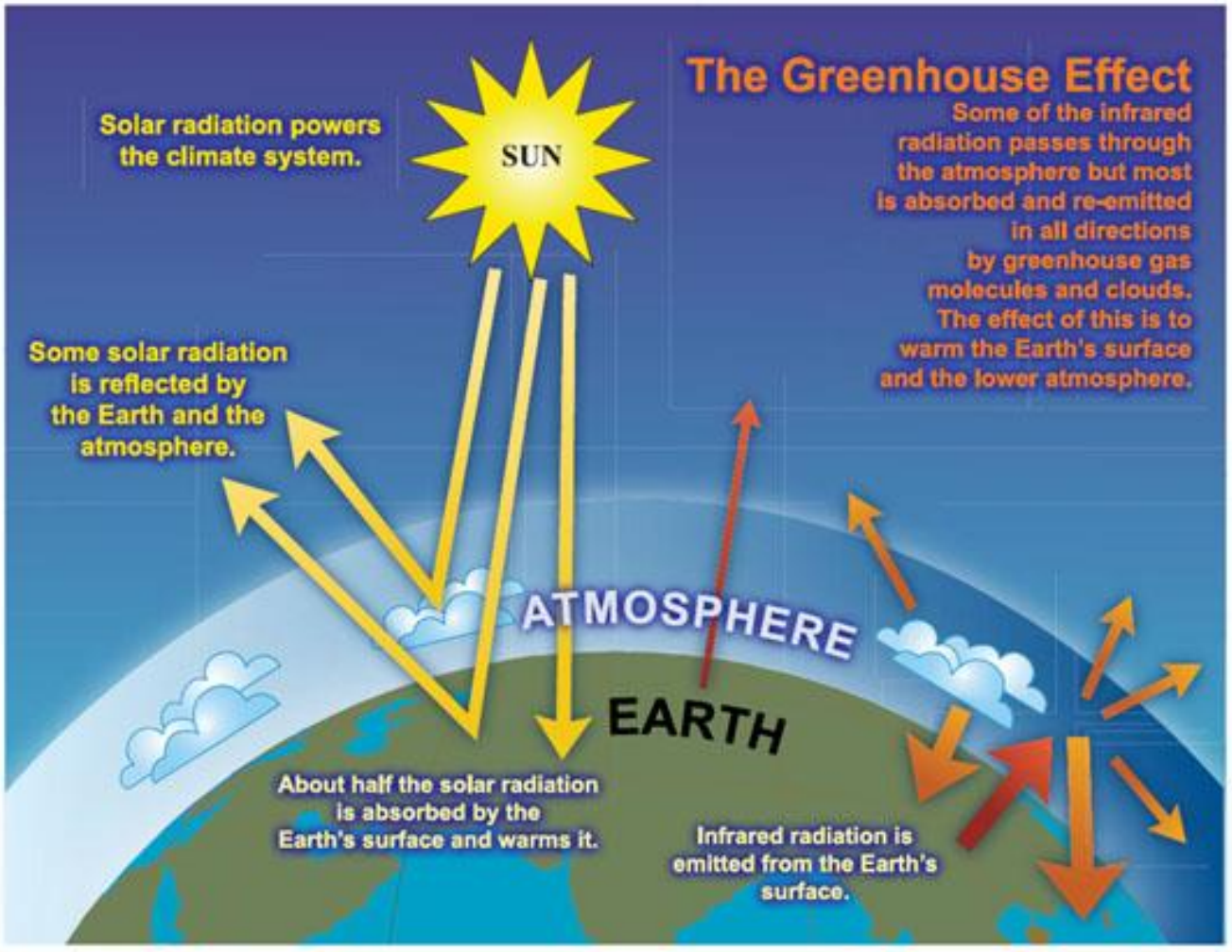
B. Metals have **outer electrons** that are <u>not</u> bound to any particular atom.

1. Makes metals **good conductors** of **electricity** and **heat.**
2. Light shines on metals causes outer electrons to vibrate, but energy does <u>not</u> "**spring**" from atom to atom but is **reemitted** as visible light (***reflected***).





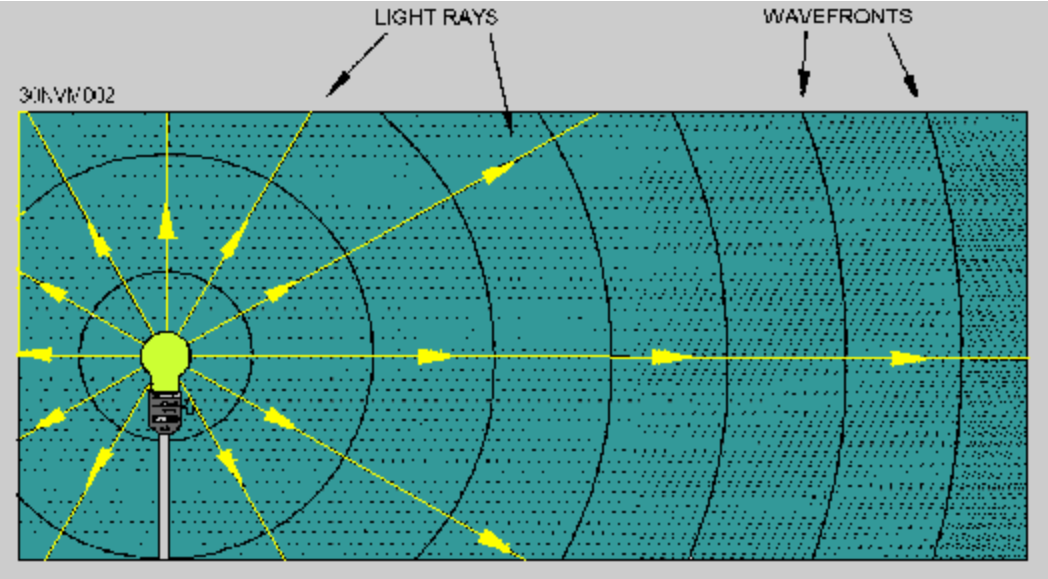
C. Our atmosphere is <u>transparent</u> to **visible** light and some **infrared**, but almost <u>opaque</u> to high-frequency **ultraviolet** waves



VI. Shadows (27.6)

A. A **thin beam of light** is called a **ray**

1. Any beam of light-no matter how wide-can be thought of as made of a bundle of rays
2. When light shines on object, some rays may be stopped where others pass on in a **straight-line path**

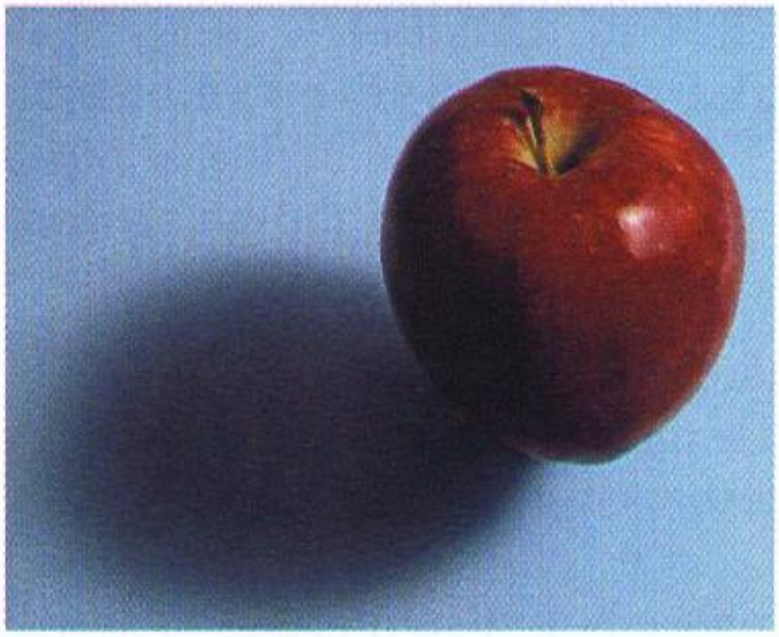


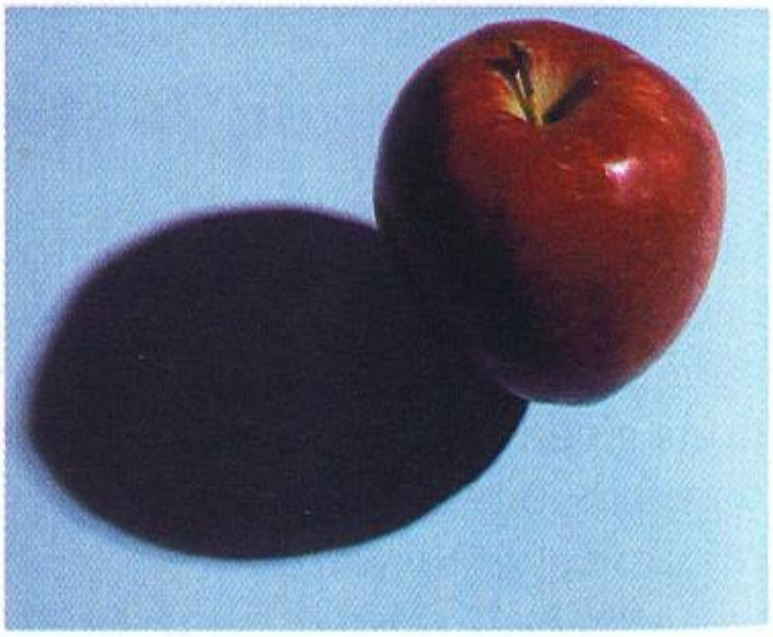
3. A **shadow** is formed where light rays cannot reach

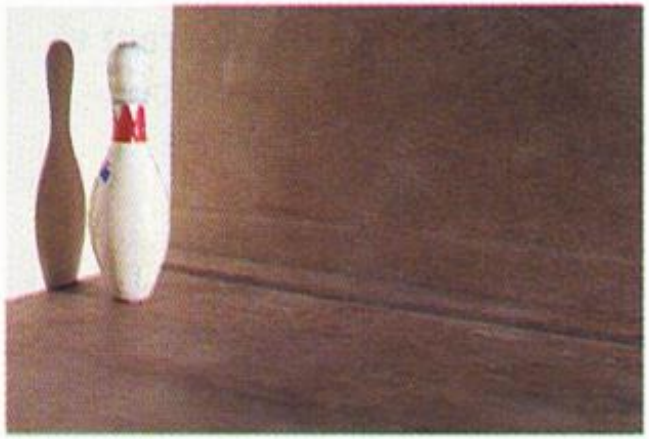
B. **Sharp shadows** are produced by **small light source** nearby or by **larger source** farther away

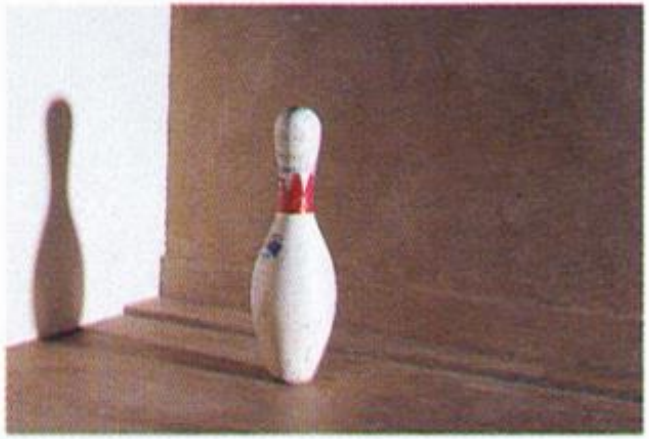
C. Most shadows are somewhat blurry

1. Total shadow called the **umbra**
2. partial shadow called **penumbra**







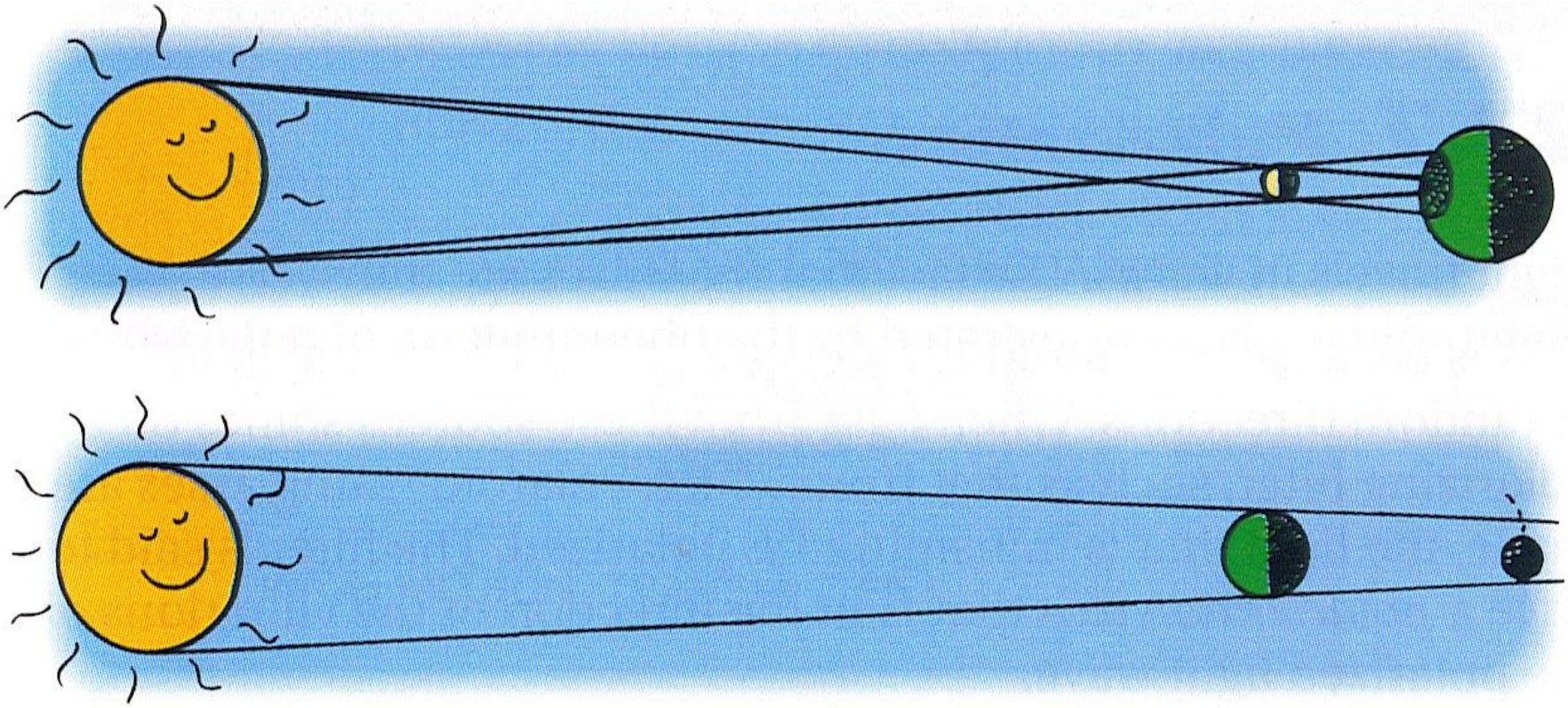


a. A **penumbra** appears where some light is blocked, but other light fill in

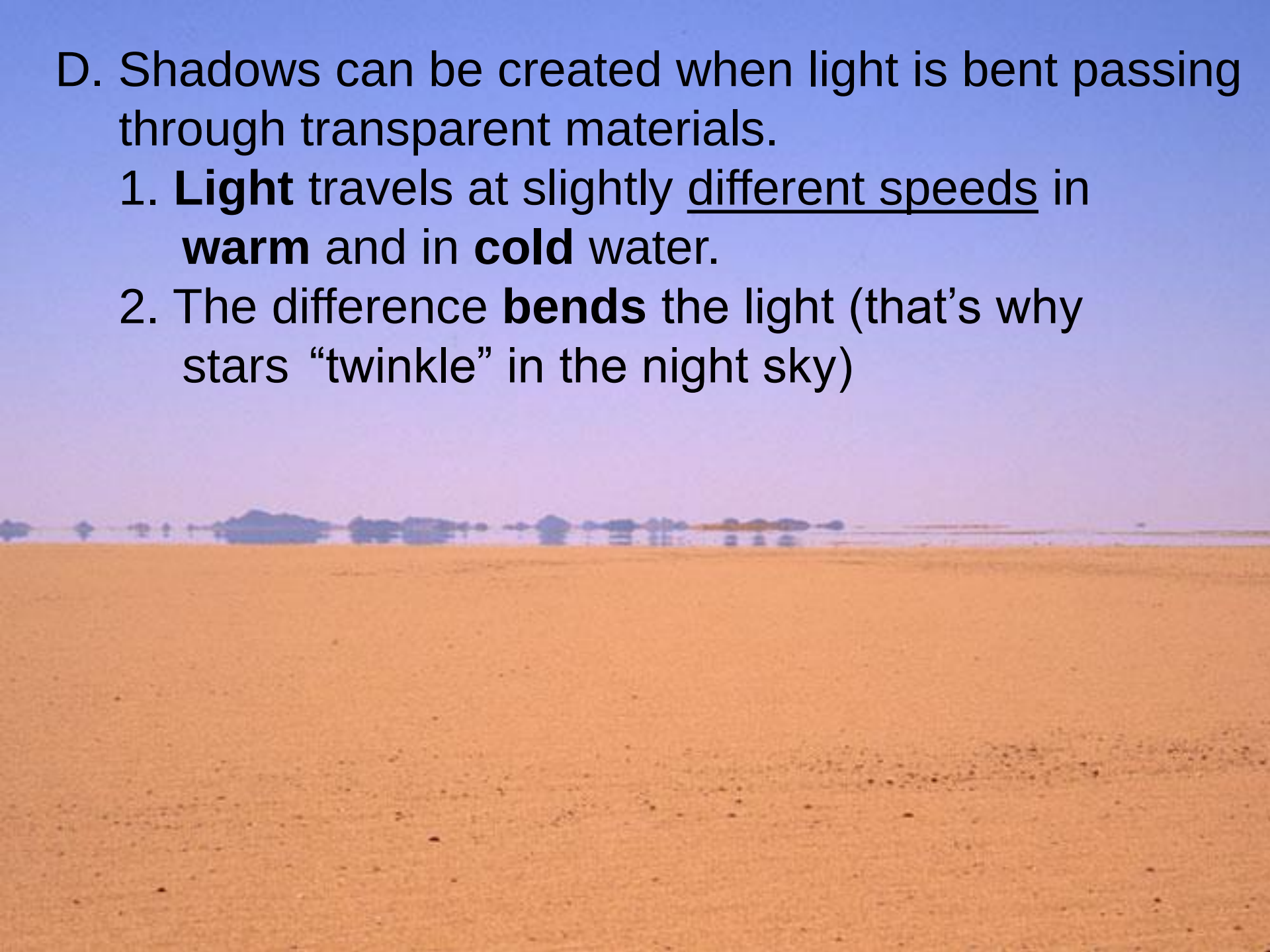
b. Occurs where light from a **broad** source is only **partially blocked**

c. Can be seen during **solar eclipse** (when moon passes between Earth and Sun)

d. **Lunar eclipse**- when Earth passes between Sun and the moon.



D. Shadows can be created when light is bent passing through transparent materials.
   1. **Light** travels at slightly <u>different speeds</u> in **warm** and in **cold** water.
   2. The difference **bends** the light (that's why stars "twinkle" in the night sky)

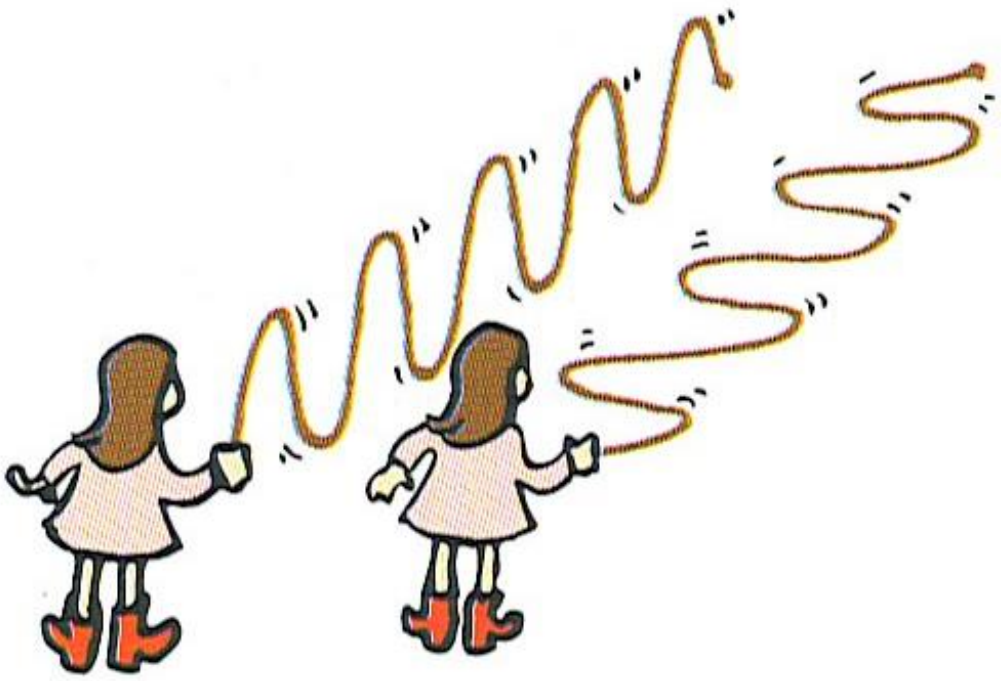


VII. Polarization (27.7)

A, **Light travels in waves** (**transverse** waves)

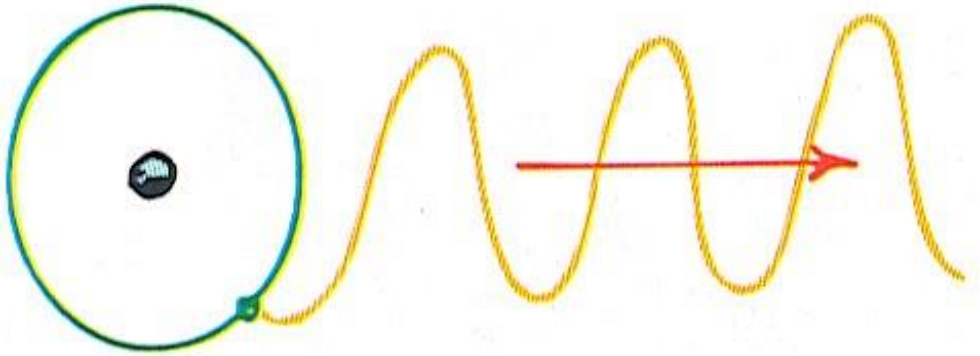
1. Demonstrated by phenomenon of **polarization**

2.**Transverse** waves have **vibrations** back and forth in one direction (wave said to be **polarized**)



B. Vibrating electrons can be vertical, horizontal or random

1. Creates vertical and horizontal polarized light
2. Candle light, light bulbs, and sun emit light that is **not polarized** (random vibration of electrons)

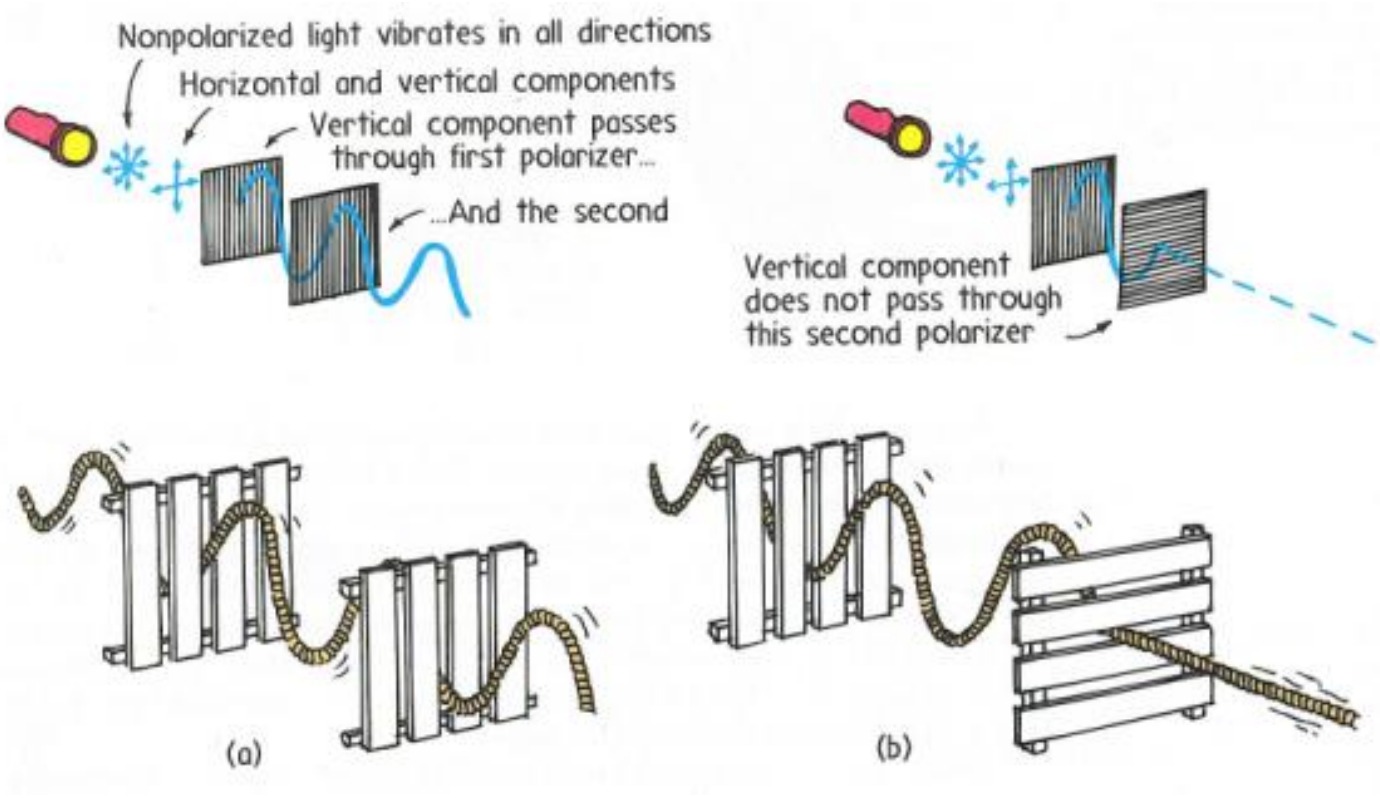


C. **Polarized filter**

1. Polarized sunglasses block out horizontal vibrating light

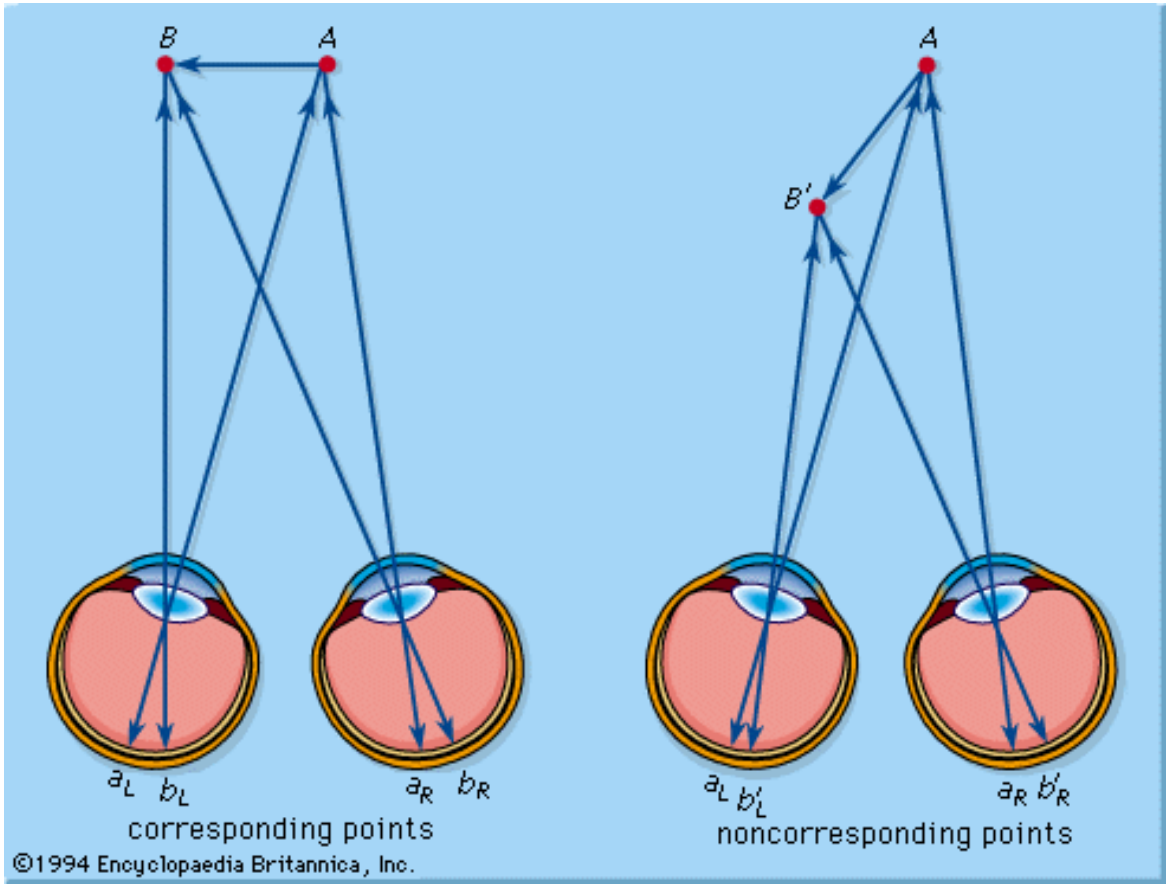
2. Light that reflects from nonmetallic surfaces such as glass, water, or roads, vibrates mainly in **plane** of the **reflecting surfaces**

3. So glare from a horizontal source is horizontally polarized (that's why polarized sunglasses block glare from horizontal surfaces)

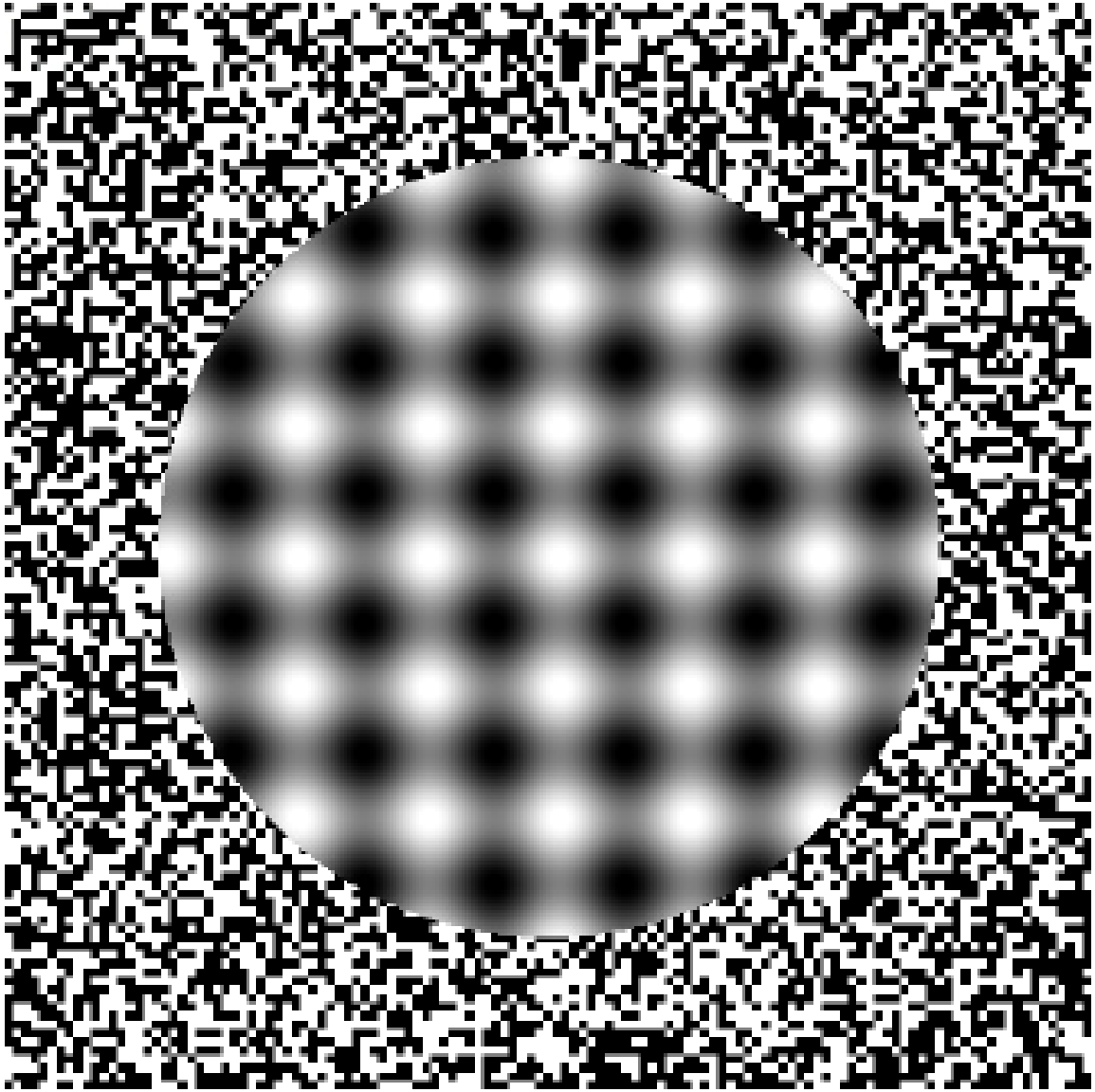


VIII. Polarized Light and 3-D Viewing (27.8)

A. Vision in **three dimensions** depends on fact that both eyes give impressions simultaneously, each eye viewing a scene from slightly different angle

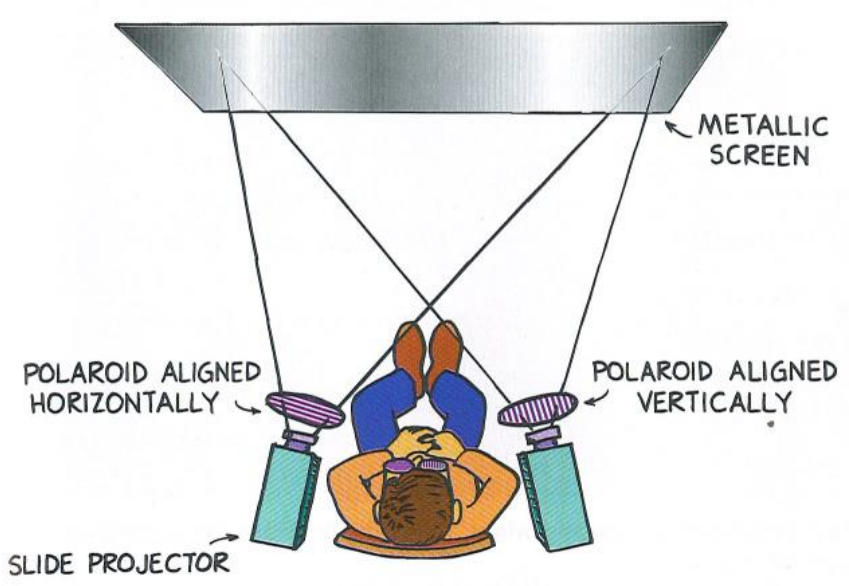


1. View by each eye is different
2. Combination of views in eye-brain gives **depth**



B. A pair of photographs or movie frames taken a short distance apart (about average eye spacing) can be seen in 3-D

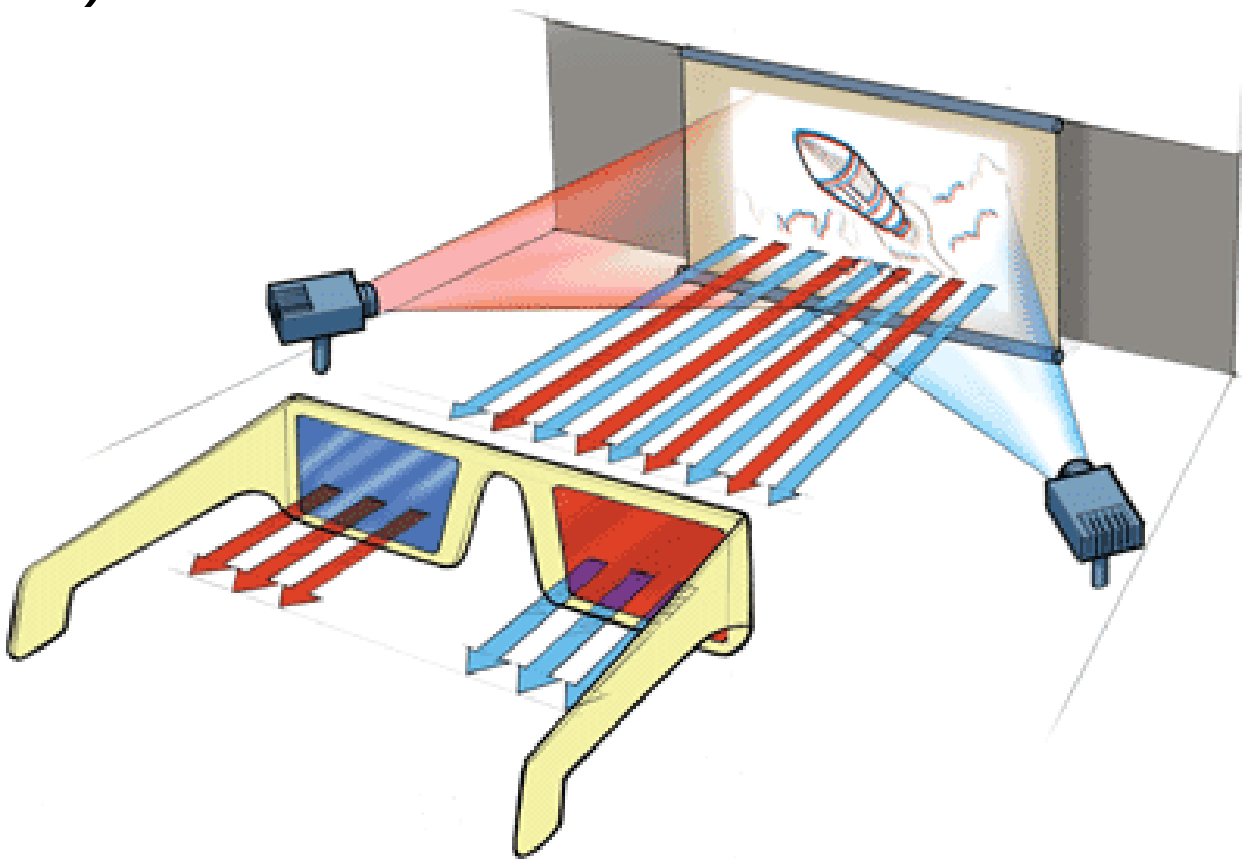
1. When left eye sees only the left view and right eye sees only the right view
2. Accomplish this with by projecting the **pair of views** through **polarization filters** onto a screen.



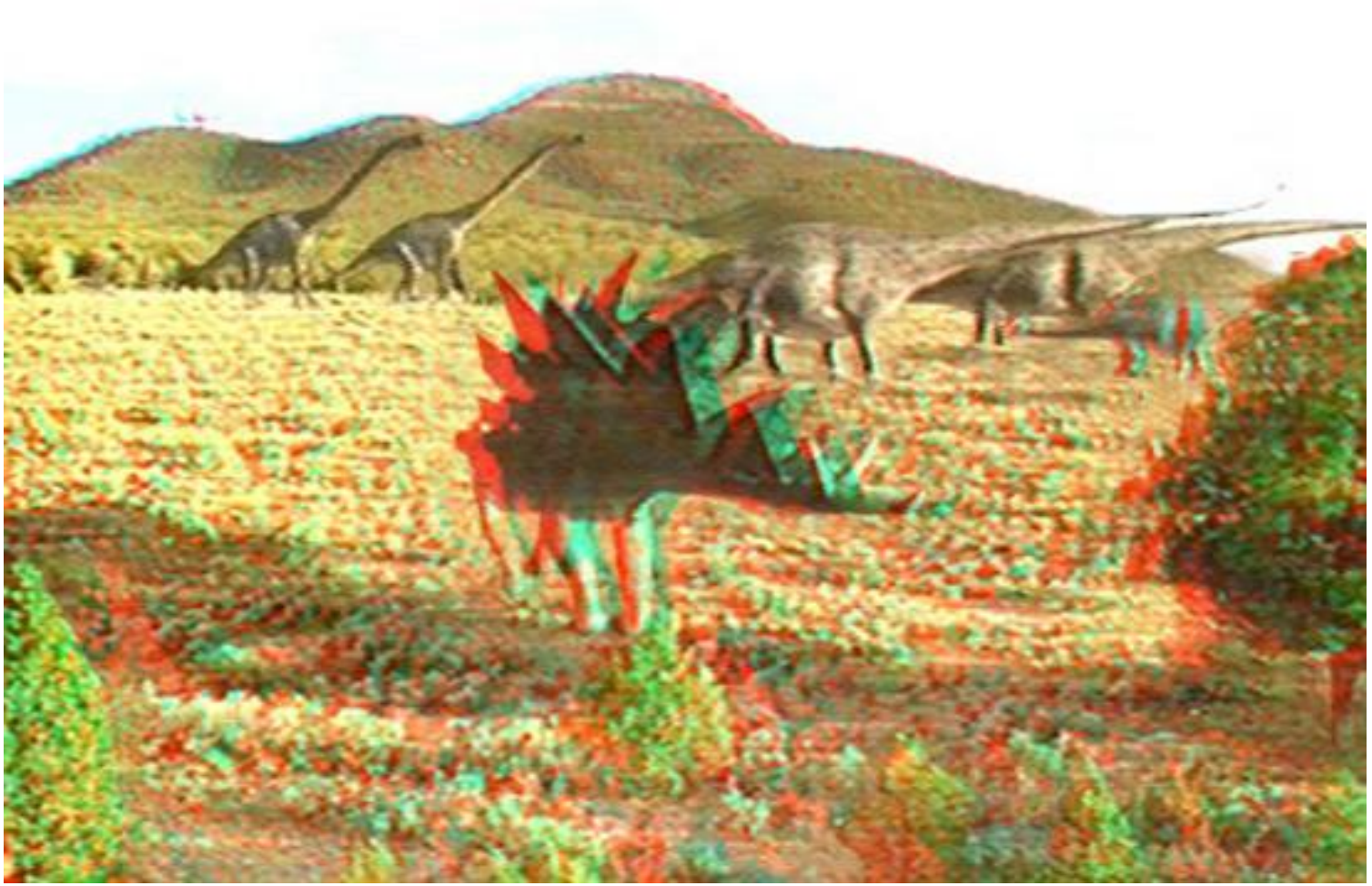
a. **Polarization axes** are at **right angles** to each other

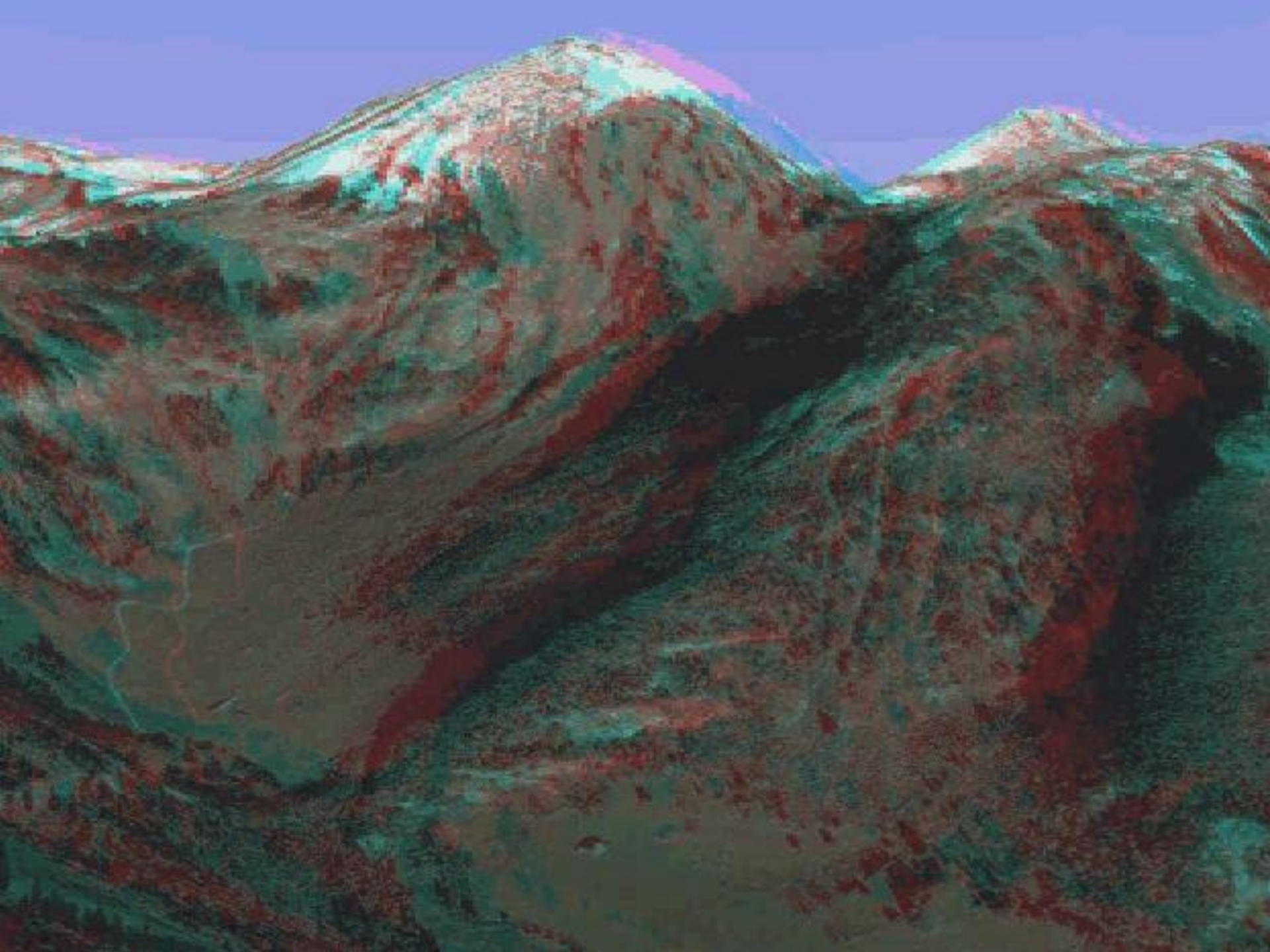
b. Overlapping pictures look **blurry** to the naked eye

c. Viewer wears polarized eyeglasses with the lens axes also at right angles (each eye sees a separate picture)



d. **Brain** interprets the two pictures as a single picture with a feeling of **depth**.





C. Stereograms- use this technique also