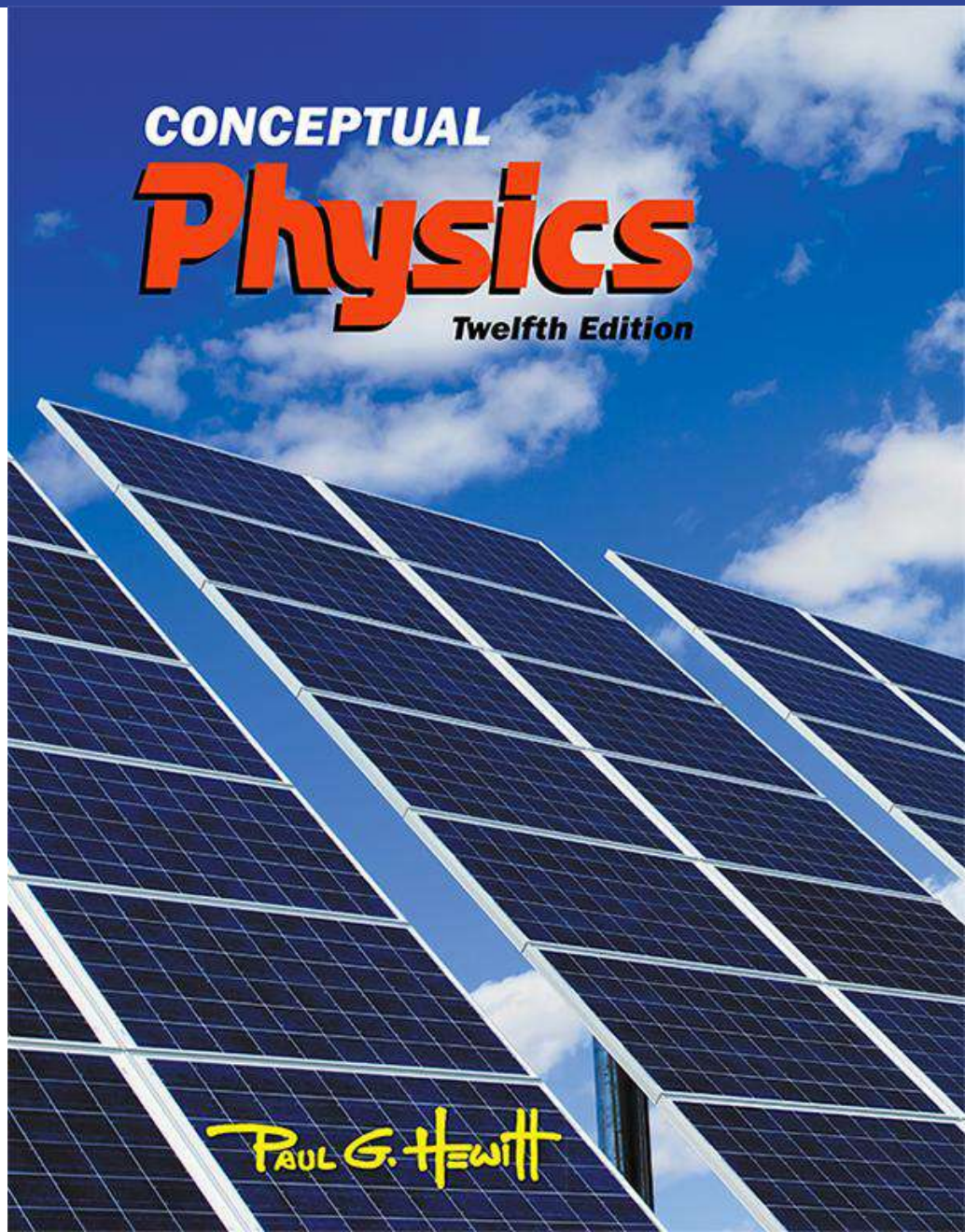
Lecture Outline

Properties of Light



This lecture will help you understand:

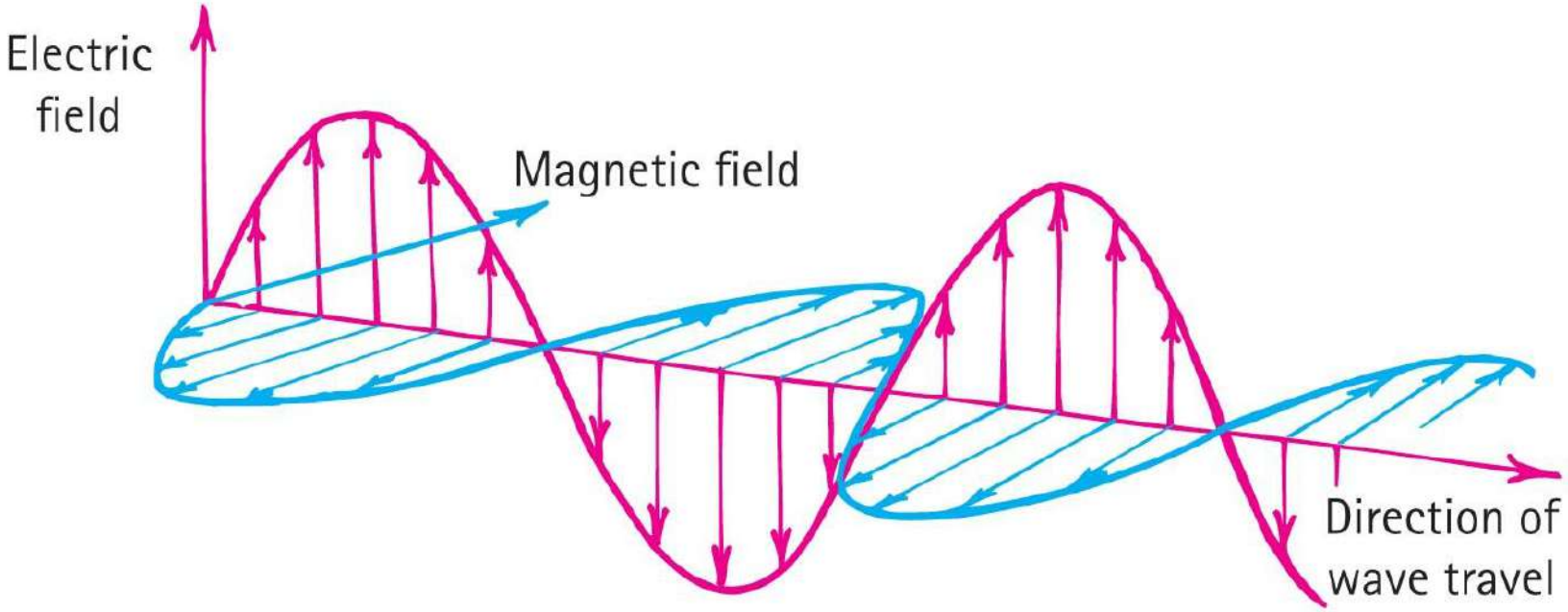
- Electromagnetic Waves
- The Electromagnetic Spectrum
- Transparent Materials
- Opaque Materials
- Seeing Light—The Eye

Electromagnetic Waves

- Light is the only thing we can see.
  - Originates from the accelerated motion of electrons
  - Electromagnetic phenomenon

Electromagnetic Waves, Continued

- Electromagnetic wave
  - Made up of vibrating electric and magnetic fields



Electromagnetic Waves
CHECK YOUR NEIGHBOR

If an electron vibrates up and down 1000 times each second, it generates an electromagnetic wave with a

A. period of 1000 s.
B. speed of 1000 m/s.
C. wavelength of 1000 m.
D. None of the above.

Electromagnetic Waves
CHECK YOUR ANSWER

If an electron vibrates up and down 1000 times each second, it generates an electromagnetic wave with a

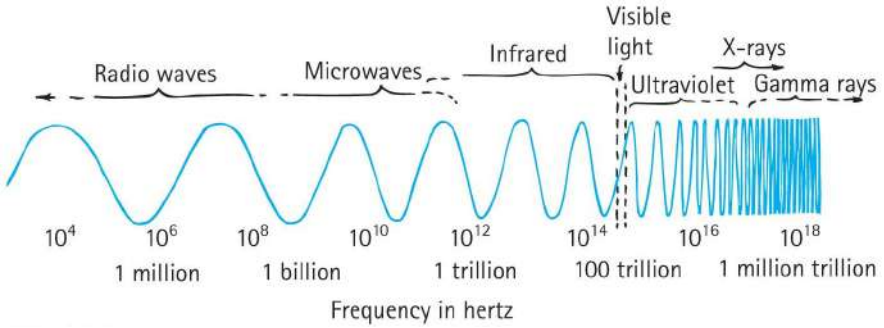
D. None of the above.

Explanation:

The vibrating electron would emit a wave with a *frequency* of 1000 Hz, which is not in the list above.

Electromagnetic Spectrum

- Electromagnetic spectrum
  - Classification of electromagnetic waves according to frequency
    - Lowest frequency of light we can see appears red.
    - Highest frequency of light we can see appears violet.
    - Higher frequency of light is ultraviolet—more energetic and causes sunburns.
    - Beyond are X-ray and gamma ray.



- No sharp boundary between regions

Electromagnetic Spectrum
CHECK YOUR NEIGHBOR

The electromagnetic spectrum spans waves ranging from lowest to highest frequencies. The smallest portion of the electromagnetic spectrum is that of

A. radio waves.
B. microwaves.
C. visible light.
D. gamma rays.

Electromagnetic Spectrum
CHECK YOUR ANSWER

The electromagnetic spectrum spans waves ranging from lowest to highest frequencies. The smallest portion of the electromagnetic spectrum is that of

C. visible light.

Electromagnetic Spectrum
CHECK YOUR NEIGHBOR, Continued

Which of these is fundamentally different from the others?

A. Sound waves
B. Light waves
C. Radio waves
D. X-rays

Electromagnetic Spectrum
CHECK YOUR ANSWER, Continued

Which of these is fundamentally different from the others?

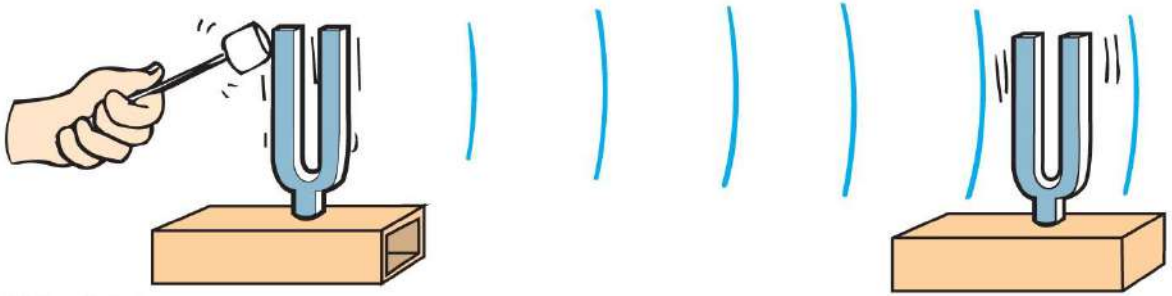
A. Sound waves

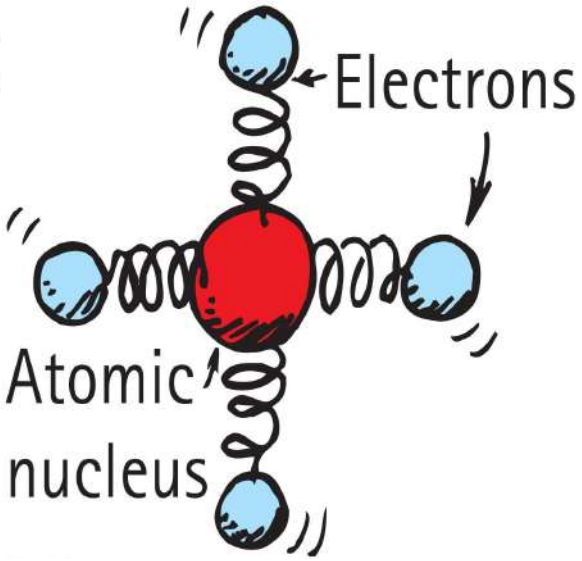
Explanation:

All are electromagnetic waves except sound, which is a mechanical wave.

Transparent Materials

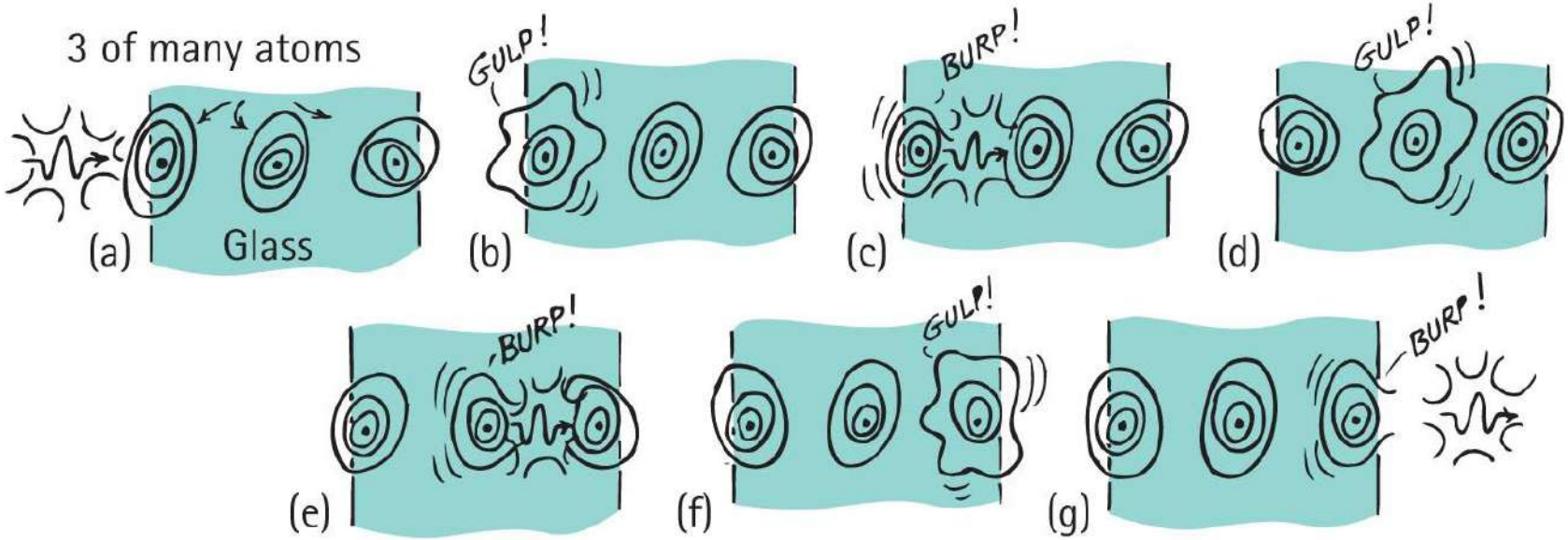
- Light is transmitted similarly to sound.
  - Both are vibrations due to a vibrating source.





Transparent Materials, Continued

- How light penetrates transparent material such as glass:

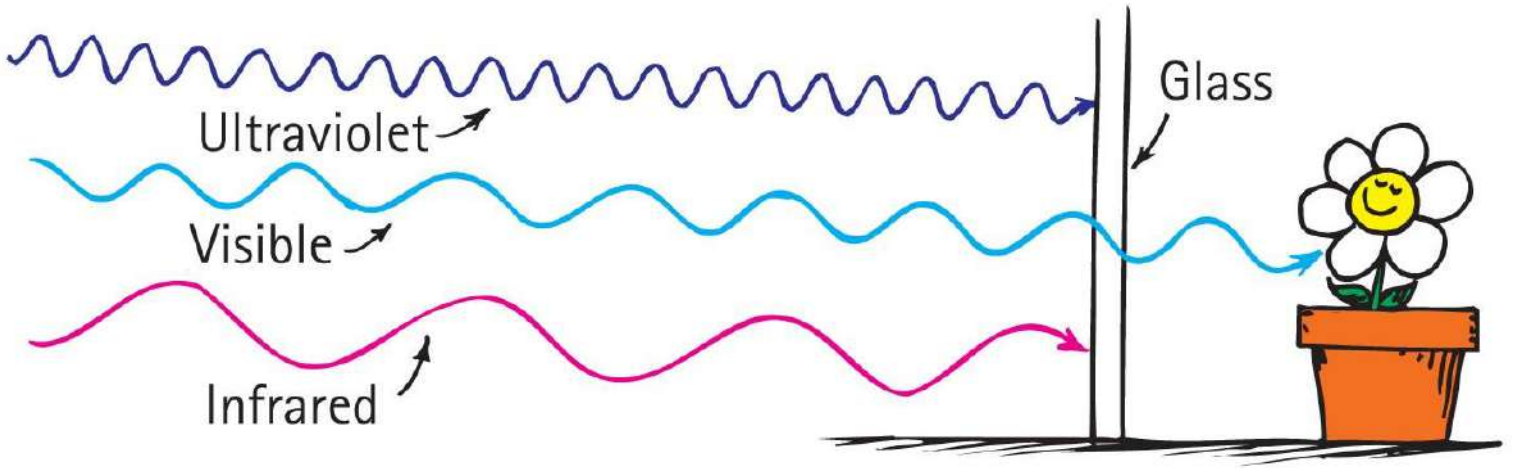


Transparent Materials, Continued-1

- How light penetrates transparent material such as glass (continued)
  - Electrons or molecules in the glass are forced into vibration.
  - Energy is momentarily absorbed and vibrates the electrons in the glass.
  - This vibrating electron either emits a photon (a corpsucle of light) or transfers the energy as heat.
- Time delay between absorption and re-emission of energy of vibrating electrons results in a lower average speed of light through a transparent material.

Transparent Materials, Continued-2

- In glass, infrared waves, with frequencies lower than those of visible light, cause not only the electrons but entire atoms or molecules to vibrate, increasing the temperature of the structure.
- So we see that glass is transparent to visible light, but not to ultraviolet and infrared light.



Transparent Materials, Continued-3

- Average speed of light through different materials
  - vacuum—*c* (300,000,000 m/s)
  - atmosphere—slightly less than *c* (but rounded off to *c*)
  - water—0.75 *c*
  - glass—0.67 *c*, depending on material
  - diamond—0.41 *c*

Transparent Materials
CHECK YOUR NEIGHBOR

Strictly speaking, the photons of light incident on glass are

A. also the ones that travel through and exit the other side.
B. not the ones that travel through and exit the other side.
C. absorbed and transformed to thermal energy.
D. diffracted.

Transparent Materials
CHECK YOUR ANSWER

Strictly speaking, the photons of light incident on glass are

B. not the ones that travel through and exit the other side.

Explanation:

Figure 26.8 illustrates this nicely. The light that exits the glass is not the same light that begins the process of absorption and re-emission.

Transparent Materials
CHECK YOUR NEIGHBOR, Continued

Compared with the frequency of illuminating light on a sheet of transparent plastic, the frequency of light that is transmitted

A. is slightly less.
B. is the same.
C. is slightly higher.
D. depends on the type of plastic.

Transparent Materials
CHECK YOUR ANSWER, Continued

Compared with the frequency of illuminating light on a sheet of transparent plastic, the frequency of light that is transmitted

B. is the same.

Explanation:

Speed of light in plastic may vary, but the frequency transmitted doesn't.

Transparent Materials
CHECK YOUR NEIGHBOR, Continued-1

The average speed of light is less in

A. air before entering glass.
B. glass.
C. air after emerging from glass.
D. None of the above.

Transparent Materials
CHECK YOUR ANSWER, Continued-1

The average speed of light is less in

B. glass.

Opaque Materials

- Most things around us are **opaque**—they absorb light without re-emitting it.
  - Books, desks, chairs, and people are opaque.
- Vibrations given by light to their atoms and molecules are turned into random kinetic energy—into internal energy.
  - These materials become slightly warmer.

Opaque Materials, Continued

- Metals
  - Light shining on metal forces free electrons in the metal into vibrations that emit their own light as reflection.

Opaque Materials, Continued-1

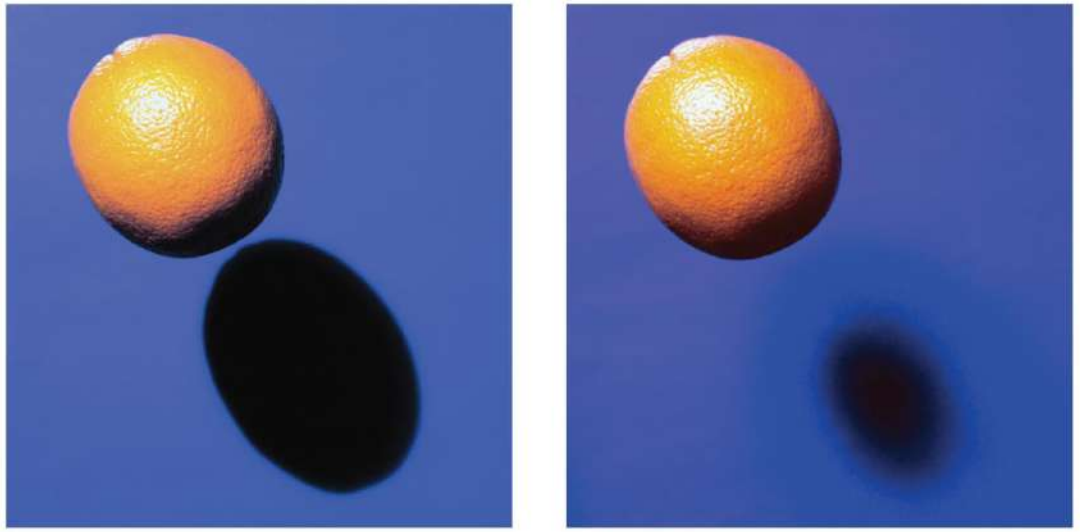
- Light incident on
  - dry surfaces bounces directly to your eye.
  - wet surfaces bounces inside the transparent wet region, absorbing energy with each bounce, and reaches your eye darker than from a dry surface.

Opaque Materials, Continued-2

- Shadows
  - A thin beam of light is often called a *ray*.
  - When we stand in the sunlight, some of the light is stopped while other rays continue in a straight-line path.
  - We cast a **shadow**—a region where light rays do not reach.

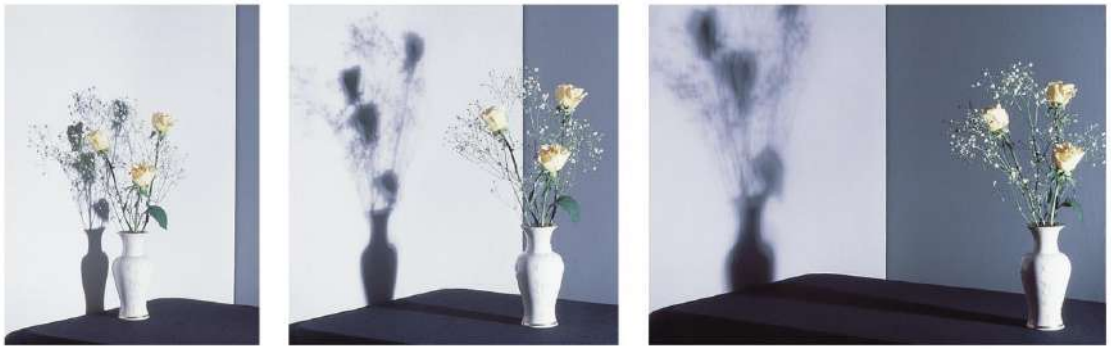
Opaque Materials, Continued-3

- Either a large, far-away light source or a small, nearby light source will produce a sharp shadow.
- A large, nearby light source produces a somewhat blurry shadow.



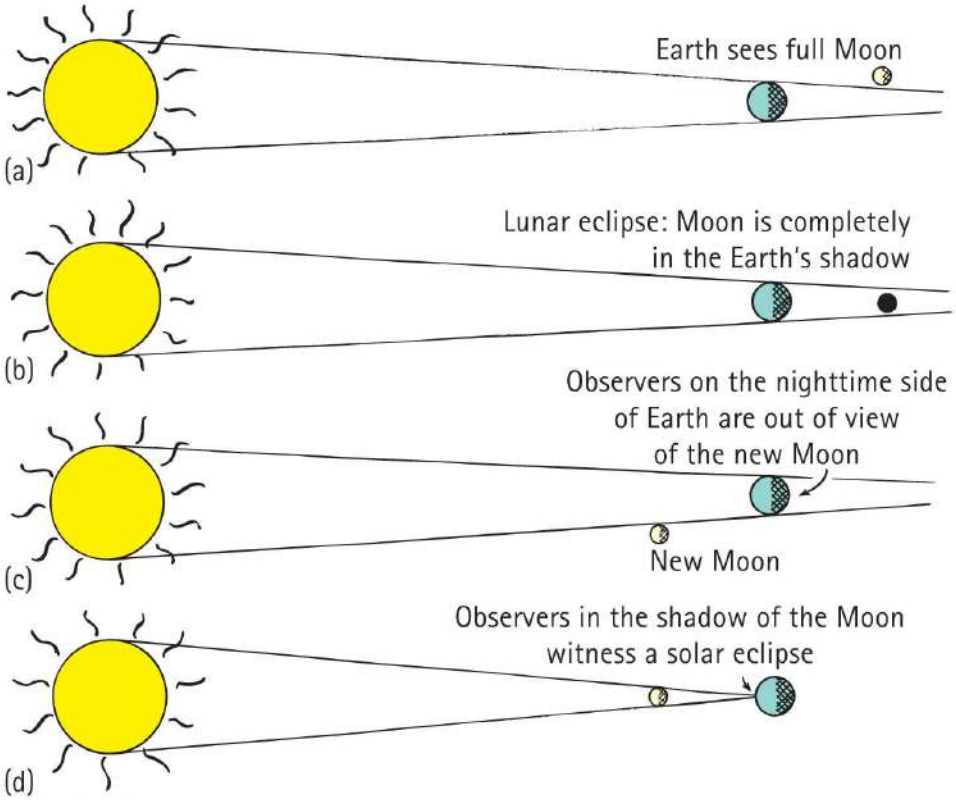
Opaque Materials, Continued-4

- There is usually a dark part on the inside and a lighter part around the edges of a shadow.
  - A total shadow is called an **umbra** and
  - A partial shadow is called a **penumbra.**
    - A penumbra appears where some of the light is blocked but where other light fills it in.
    - A penumbra also occurs where light from a broad source is only partially blocked.



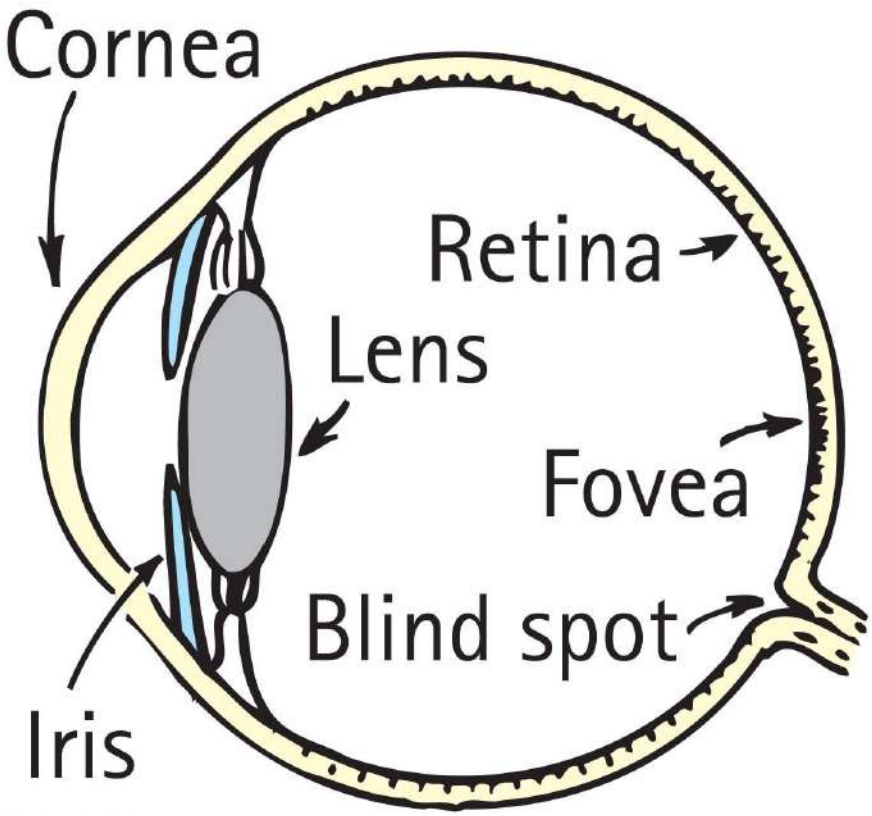
Opaque Materials, Continued-5

- In a **solar eclipse,** because of the large size of the Sun, the rays taper to provide an umbra (total eclipse) and a surrounding penumbra (partial eclipse).
- In a **lunar eclipse,** the Moon passes completely into the shadow of Earth.



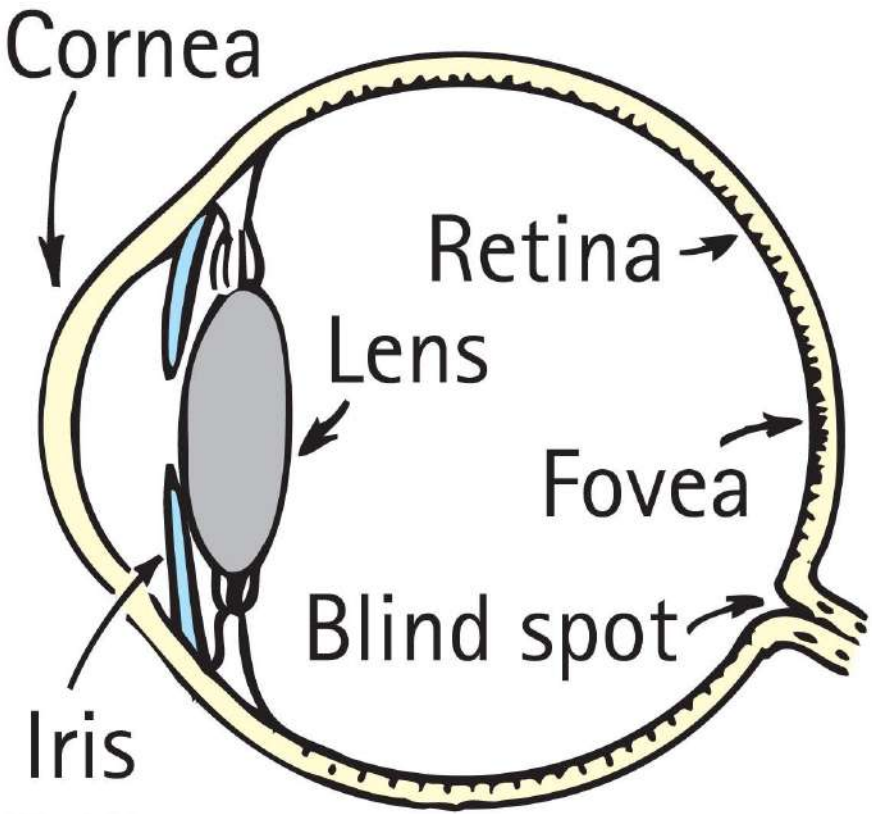
Seeing Light – The Eye

- Light is the only thing we see with the most remarkable optical instrument known—the eye.
- As light enters the eye, it moves through the transparent cover called the *cornea*, which does about 70% of the necessary bending of the light before it passes through an opening in the *iris* (colored part of the eye).



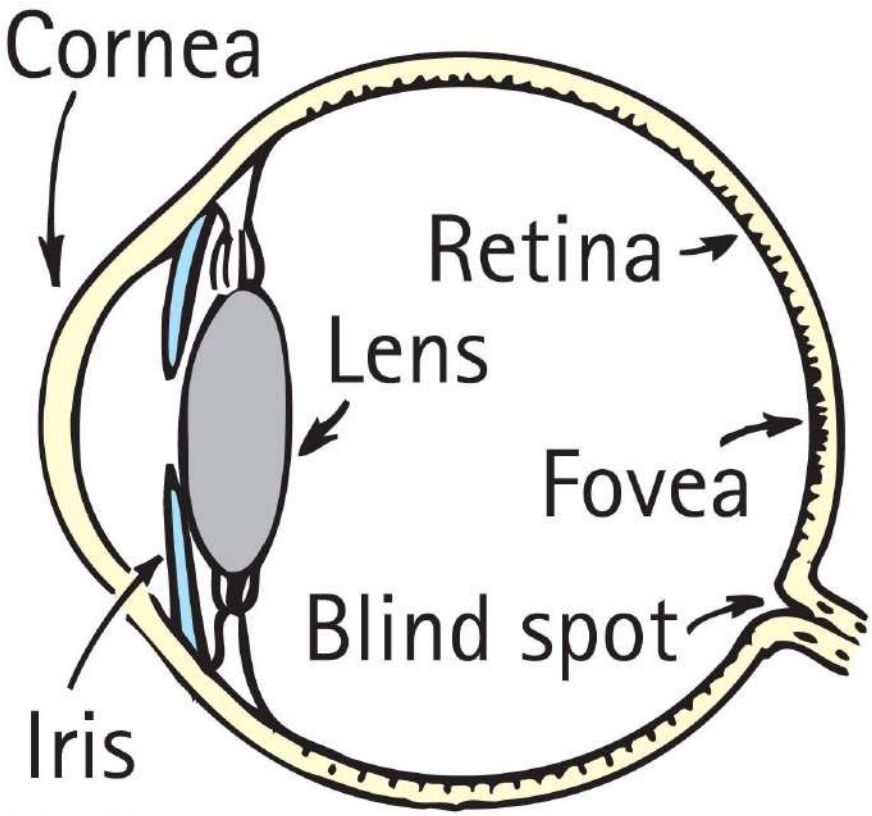
Seeing Light – The Eye, Continued

- The opening is called the *pupil*.
- The light then reaches the *crystalline lens,* which fine-tunes the focusing of light that passes through a gelatinous fluid called *vitreous humor*.
- Light then passes to the *retina,* which covers the back two-thirds of the eye and is responsible for the wide field of vision that we experience.



Seeing Light – The Eye, Continued-1

- For clear vision, light must focus directly on the retina.
- The retina is not uniform.
  - In the middle is the *macula,* and a small depression.
  - in the center is the *fovea,* the region of most distinct vision.
  - Behind the retina is the *optic nerve,* which transmits signals from the photoreceptor cells to the brain.
  - There is also a spot in the retina where optic nerves are connected; this is the blind spot.



Seeing Light – The Eye, Continued-2

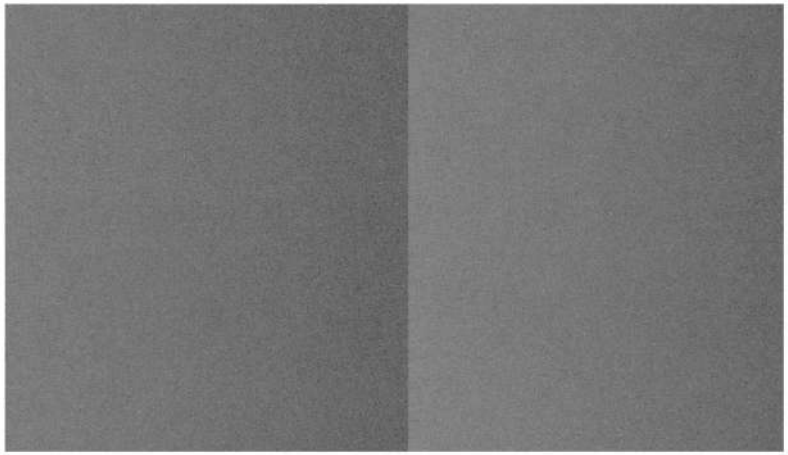
- The retina is composed of tiny antennae that resonate to the incoming light.
- Rods handle vision in low light.
  - They predominate toward the periphery of the retina.
- Cones handle color vision and detail.
  - They are denser toward the fovea.
  - There are three types of cones, stimulated by low, intermediate and high frequencies of light.

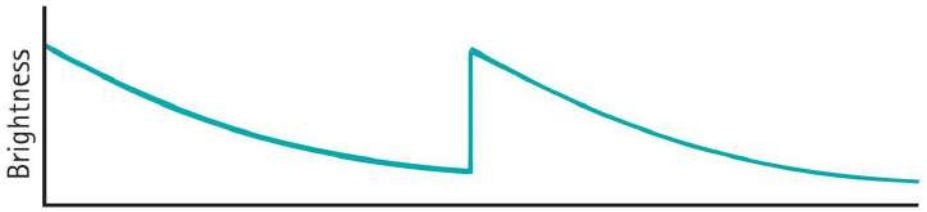
Seeing Light – The Eye, Continued-3

- Although our vision is poor from the corner of our eye, we are sensitive to anything moving there.

Seeing Light – The Eye, Continued-4

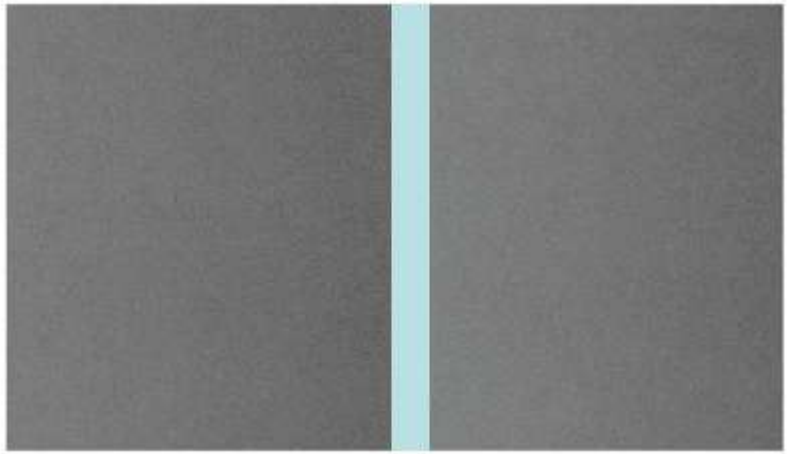
- The brightest light that the human eye can perceive without damage is some 500 million times brighter than the dimmest light that can be perceived.
- Lateral inhibition: We don't perceive the actual differences in brightness. The brightest places in our visual field are prevented from outshining the rest.

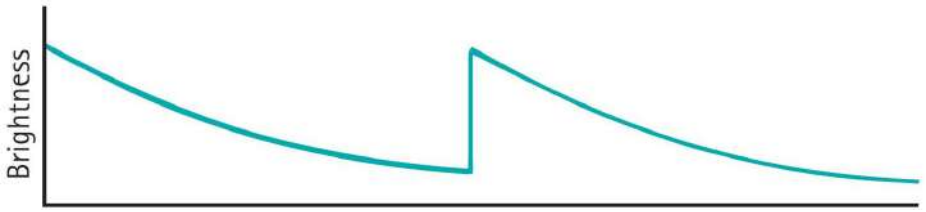




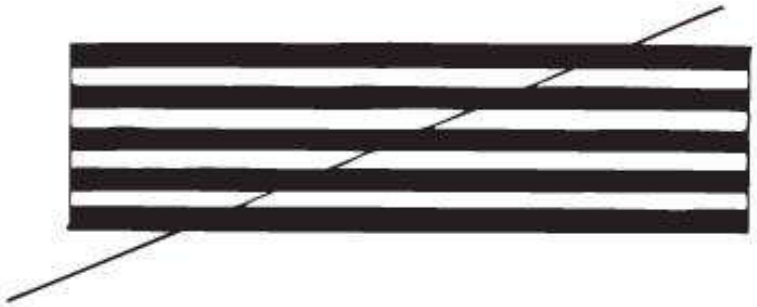
Seeing Light – The Eye, Continued-5

- The brightest light that the human eye can perceive without damage is some 500 million times brighter than the dimmest light that can be perceived.
- Lateral inhibition: We don't perceive the actual differences in brightness. The brightest places in our visual field are prevented from outshining the rest.





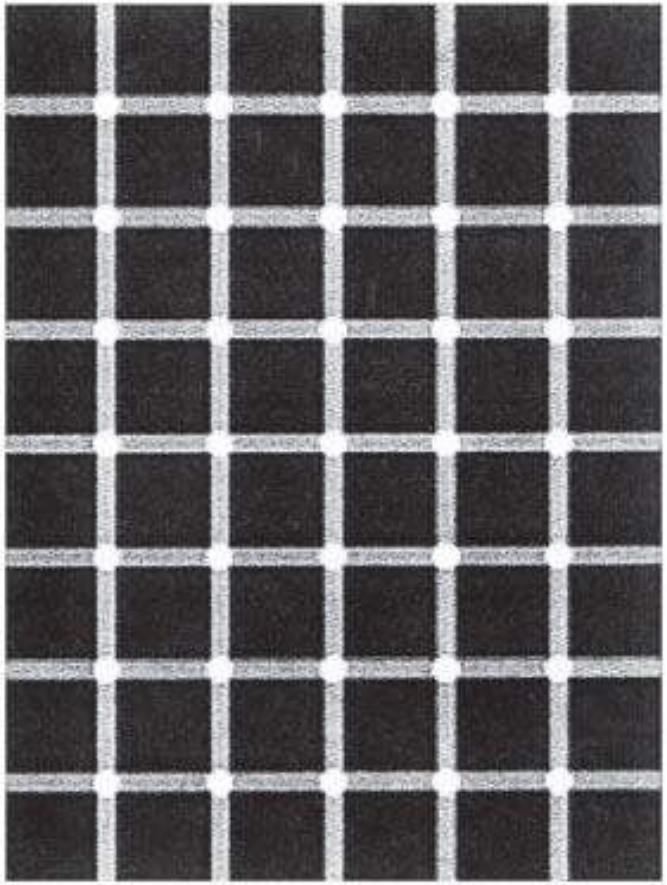
Seeing Light – The Eye, Continued-6



Is the slanted line really broken?

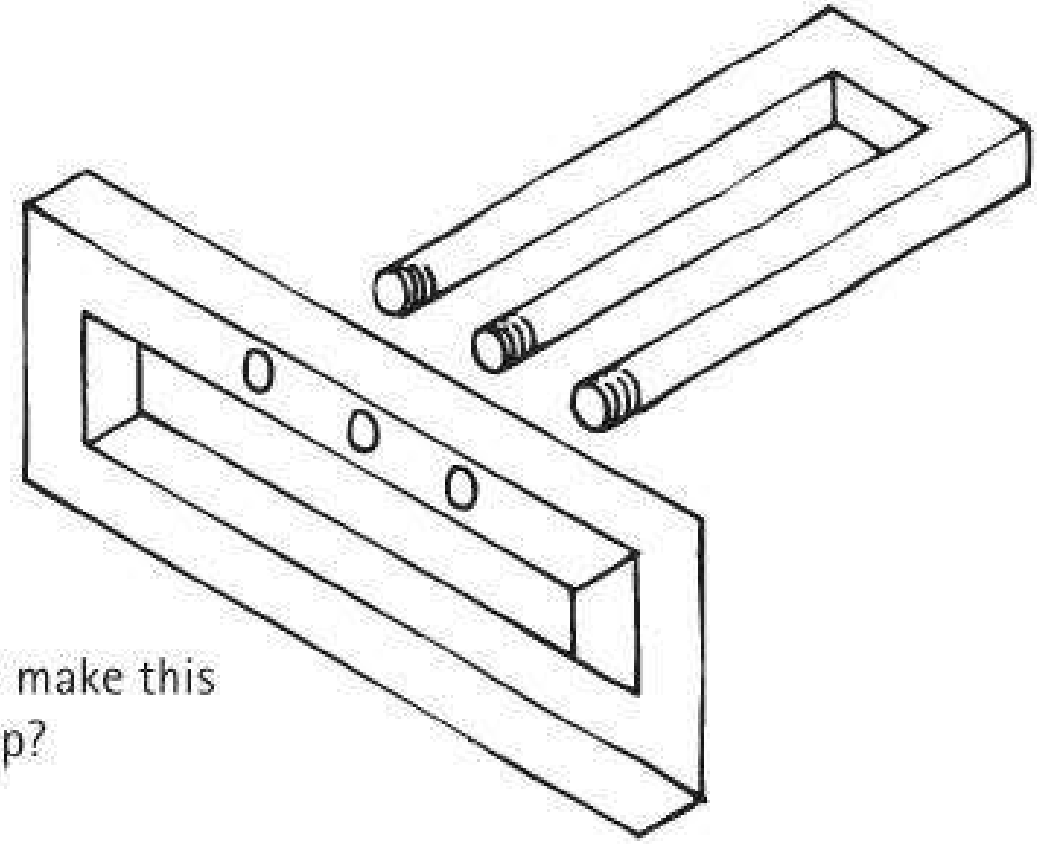
Are the dashes on the right really shorter?

Seeing Light – The Eye, Continued-7



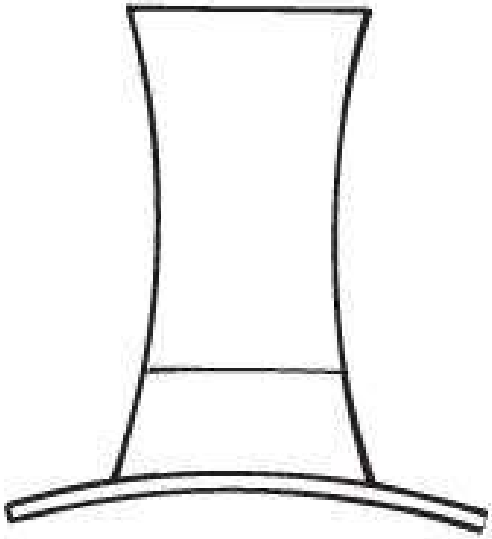
Can you count the black dots?

Seeing Light – The Eye, Continued-8

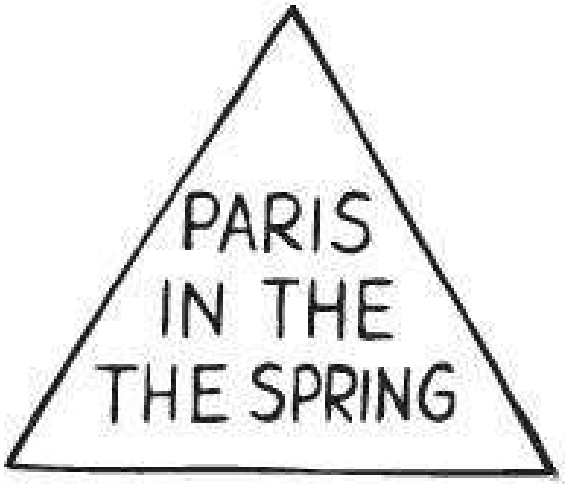


Could you make this in the shop?

Seeing Light – The Eye, Continued-9

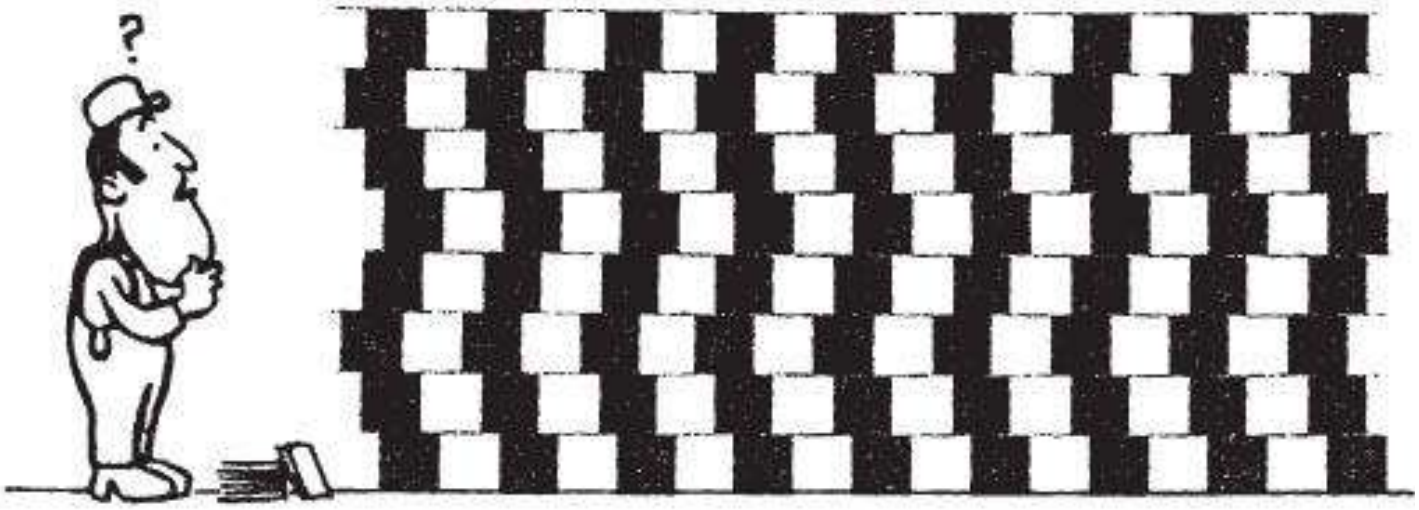


Is the hat taller than the brim is wide?



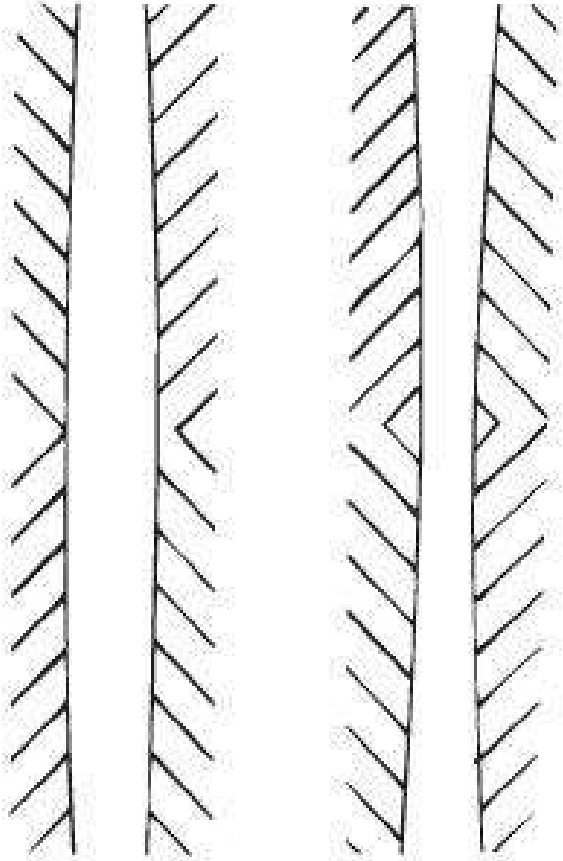
What does this sign read?

Seeing Light – The Eye, Continued-10



Are the rows of tiles really crooked?

Seeing Light – The Eye, Continued-11



Are the vertical lines parallel?