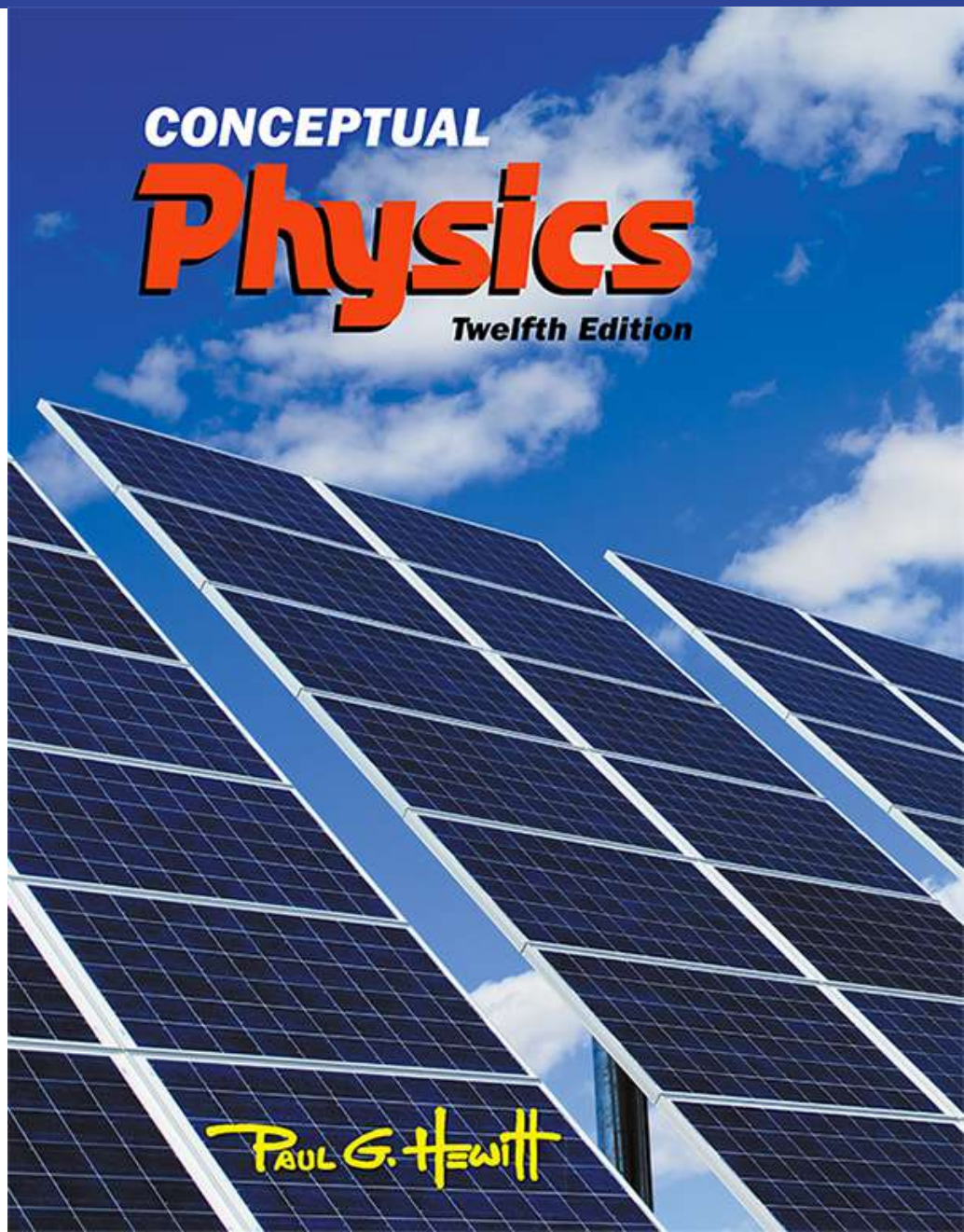
Lecture Outline

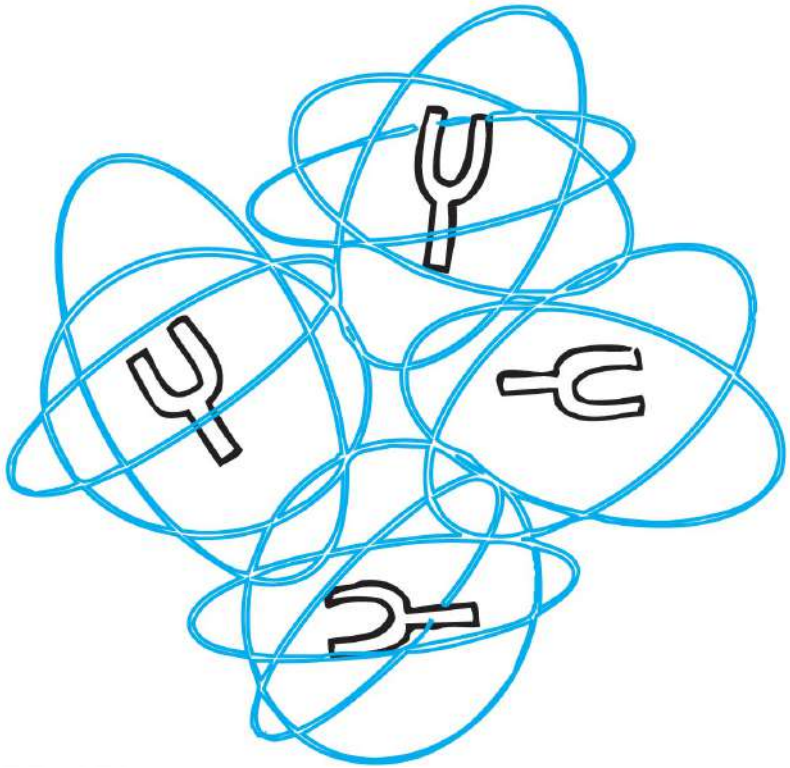
Chapter 28: Reflection and Refraction



Reflection

- We say light is *reflected* when it is returned into the medium from which it came—the process is **reflection.**

- When light illuminates a material, electrons in the atoms of the material move more energetically in response to the oscillating electric fields of the illuminating light.
- →The light sets the electrons into vibration.
- The energized electrons re-emit the electromagnetic waves (light), which is what you see.



Classwork

1. How does incident light that falls on an object affect the motion of electrons in the atoms of the object?

2. What do the electrons affected by illumination do when they are made to vibrate with greater energy?

Principle of Least Time

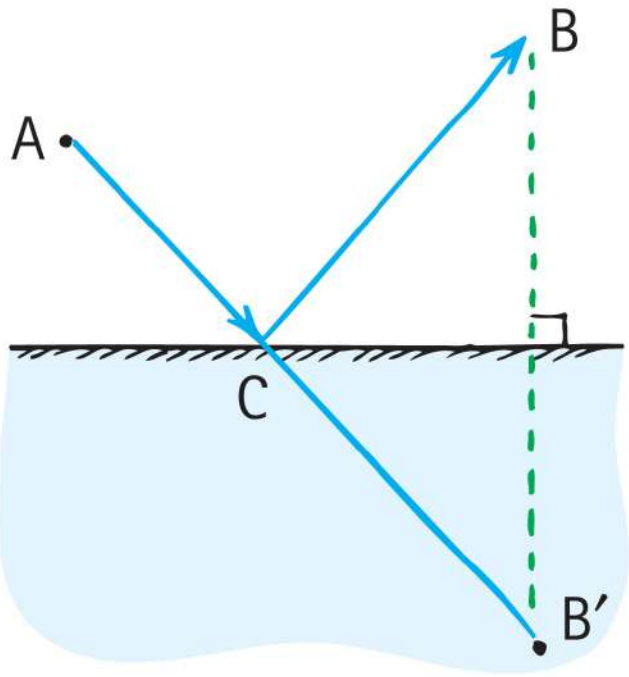
- Pierre de Fermat
- (1607-1665)
- French lawyer
- Polyglot
- Mathematical genius

- The idea that light takes the quickest path in going from one place to another is called **Fermat's principle of least time.**

Principle of Least Time, Continued

- Finding the shortest time for light to go from A to B by reflecting off the mirror

- Construct, on the opposite side of the mirror, an artificial point, which is the same distance "through" and below the mirror as the point B is above the mirror.
- The shortest distance between A and this artificial point is a straight line.
- This straight line intersects the mirror at a point C, the precise point of reflection for least time from A to B.



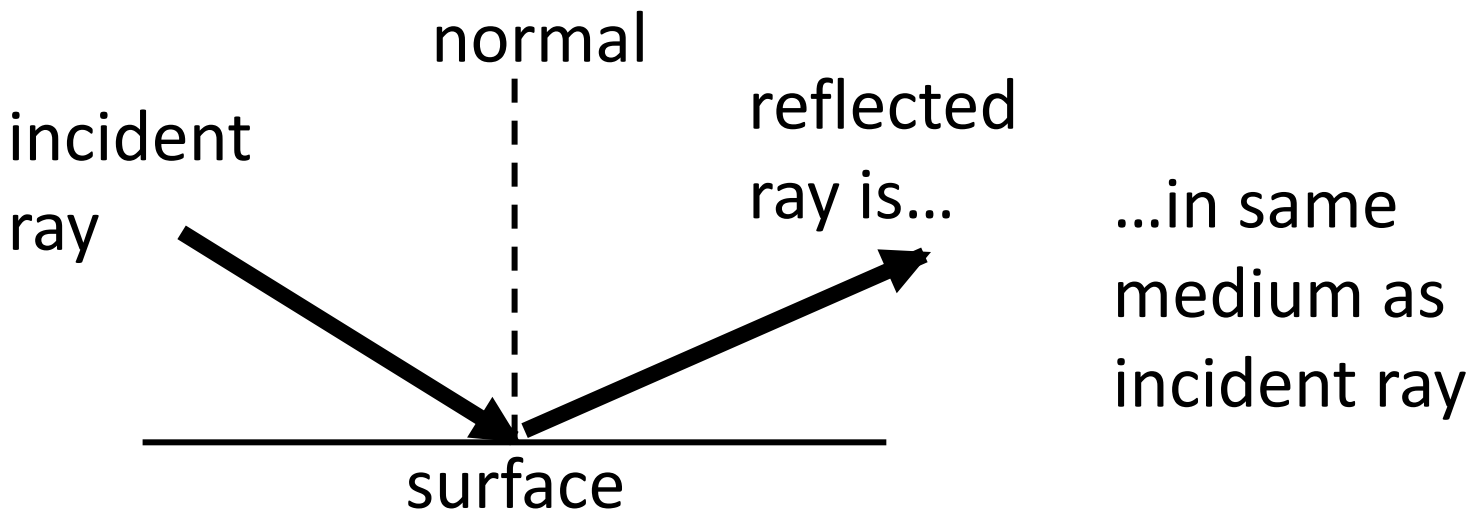
- **Light takes the path of least time.**

Classwork

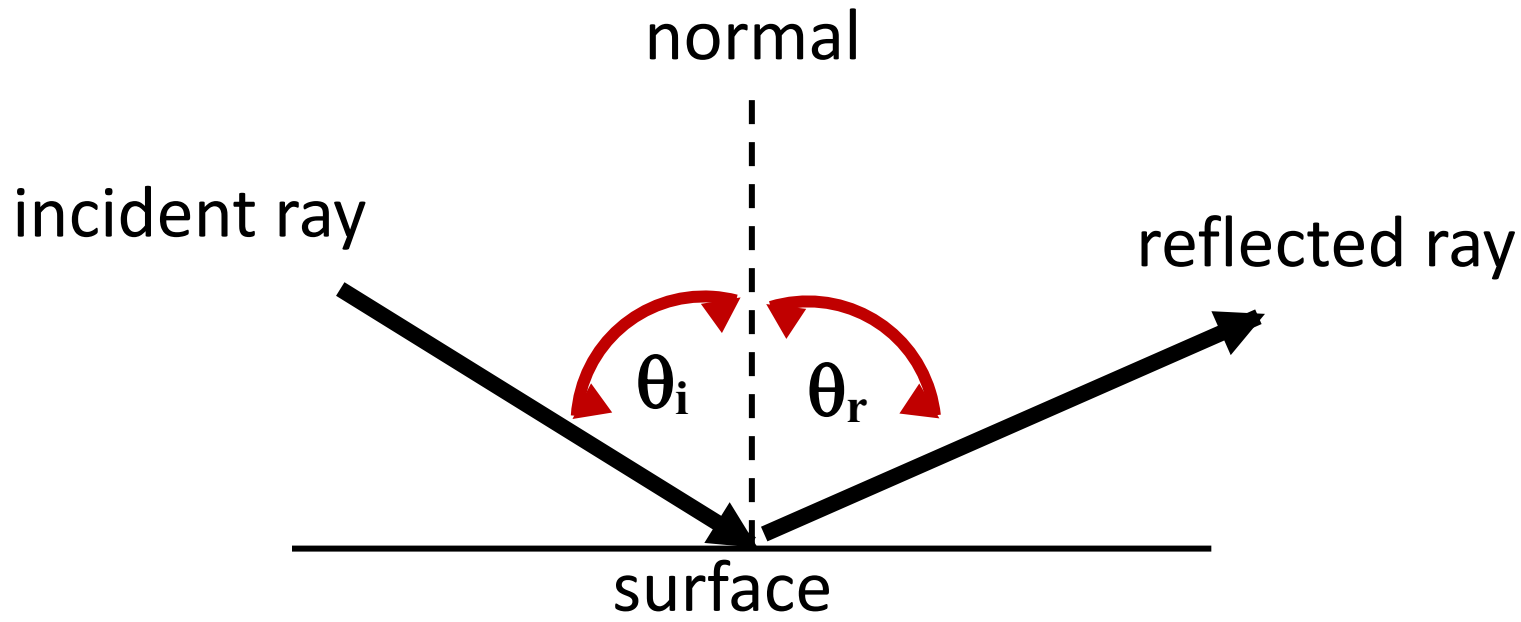
3. What is Fermat's principle of least time?

Reflection

- Direction of light wave is shown by an arrow, or ray.
- The *normal* (perpendicular)
  - Imaginary line perpendicular to the plane of the reflecting surface; usually drawn as dashed line



Reflected light does not enter the medium of surface

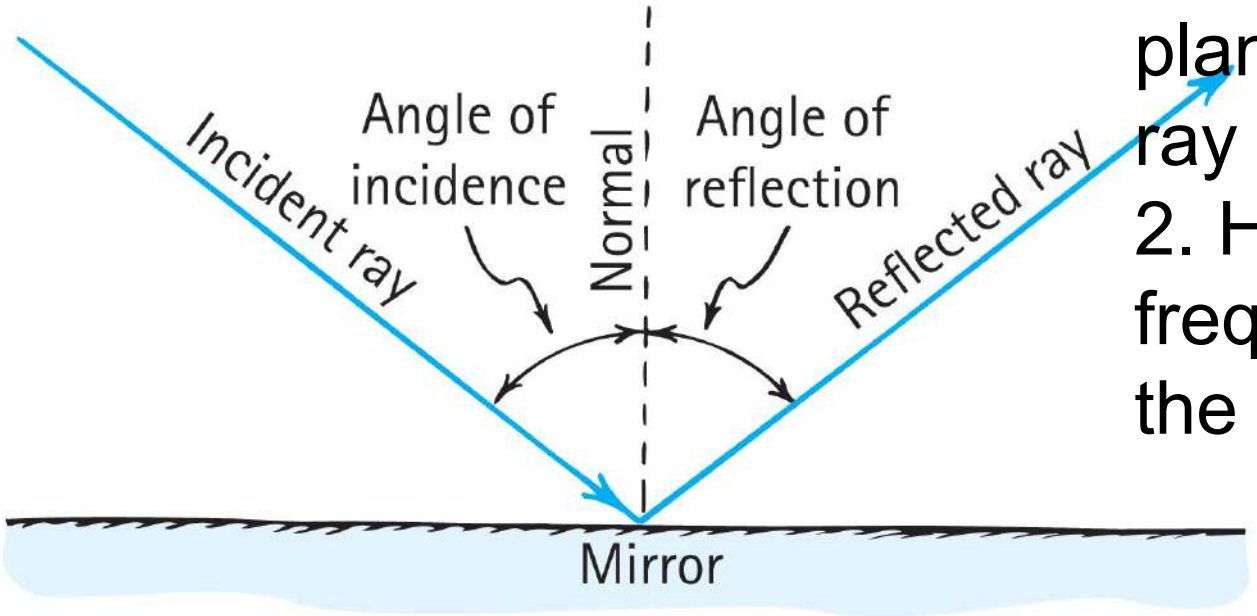


- **Angle of incidence ,θ_i**

  Angle between incoming ray and the normal
- **Angle of reflection, θ_r**
  - Angle made by the reflected ray and the normal

- Law of reflection
  - Angle of reflection equals angle of incidence

$$\theta_r = \theta_i$$



The reflected ray:
1. lies in the same plane as the incident ray and normal
2. Has the same frequency (color) as the incident ray.

This law is true for all waves: light, sound, earthquake, water, gravitational…

Classwork

4. Cite the law of reflection.

Law of Reflection
CHECK YOUR NEIGHBOR

The law of reflection applies to

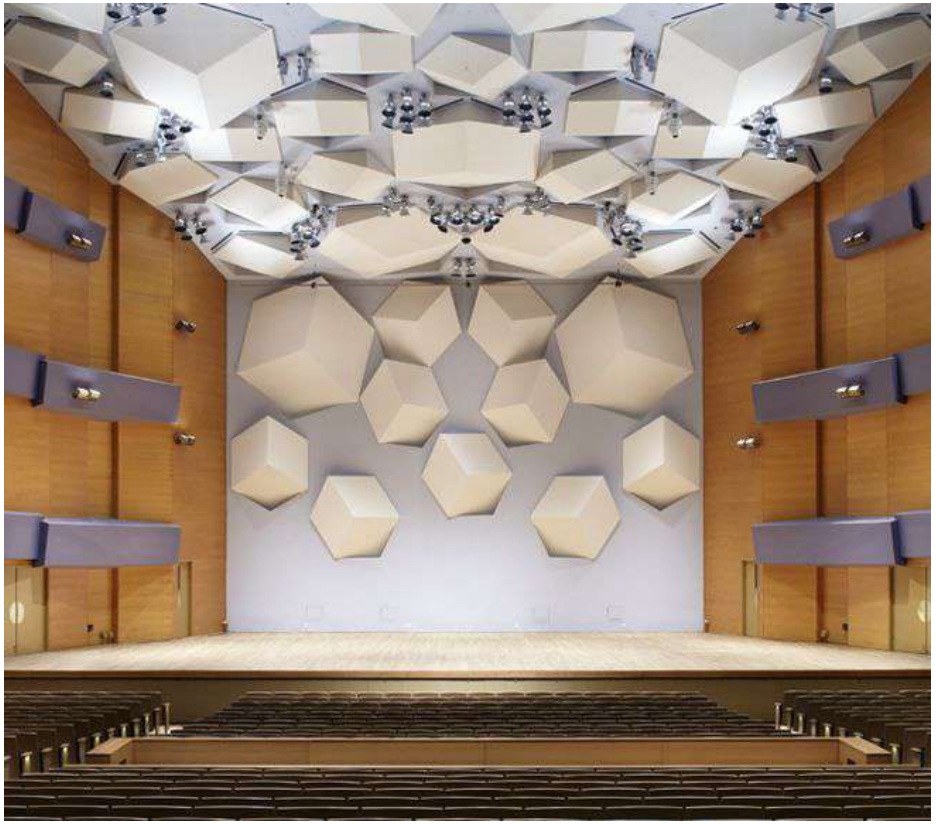
A. light.
B. sound.
C. Both A and B.
D. None of the above.

Law of Reflection
CHECK YOUR ANSWER

The law of reflection applies to

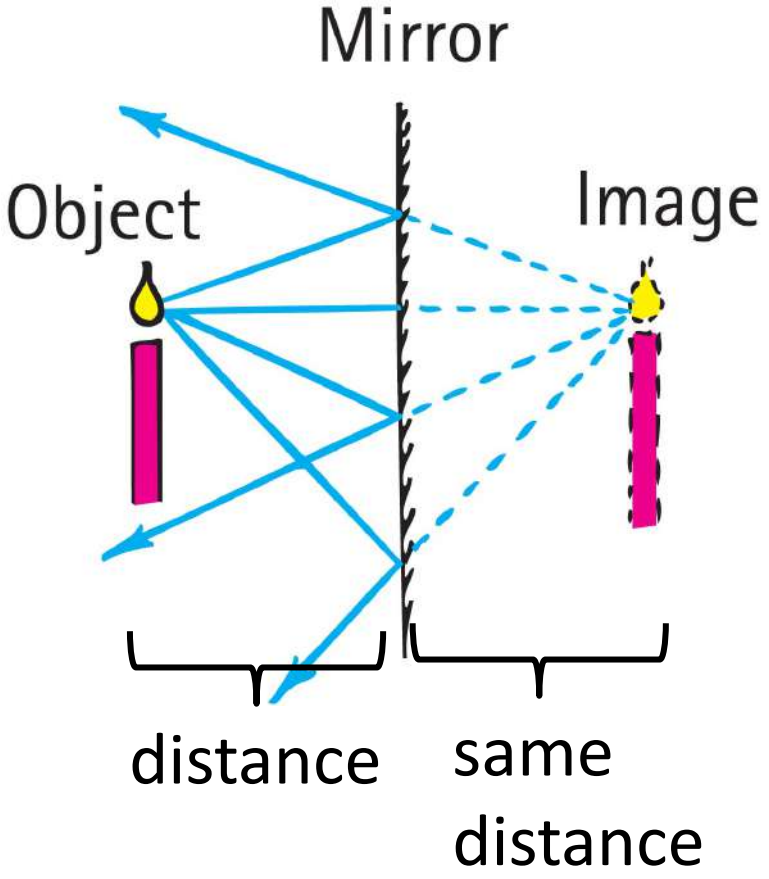
C. Both A and B.

Use light to aim sound:



Reflection from a *plane* (flat) mirror

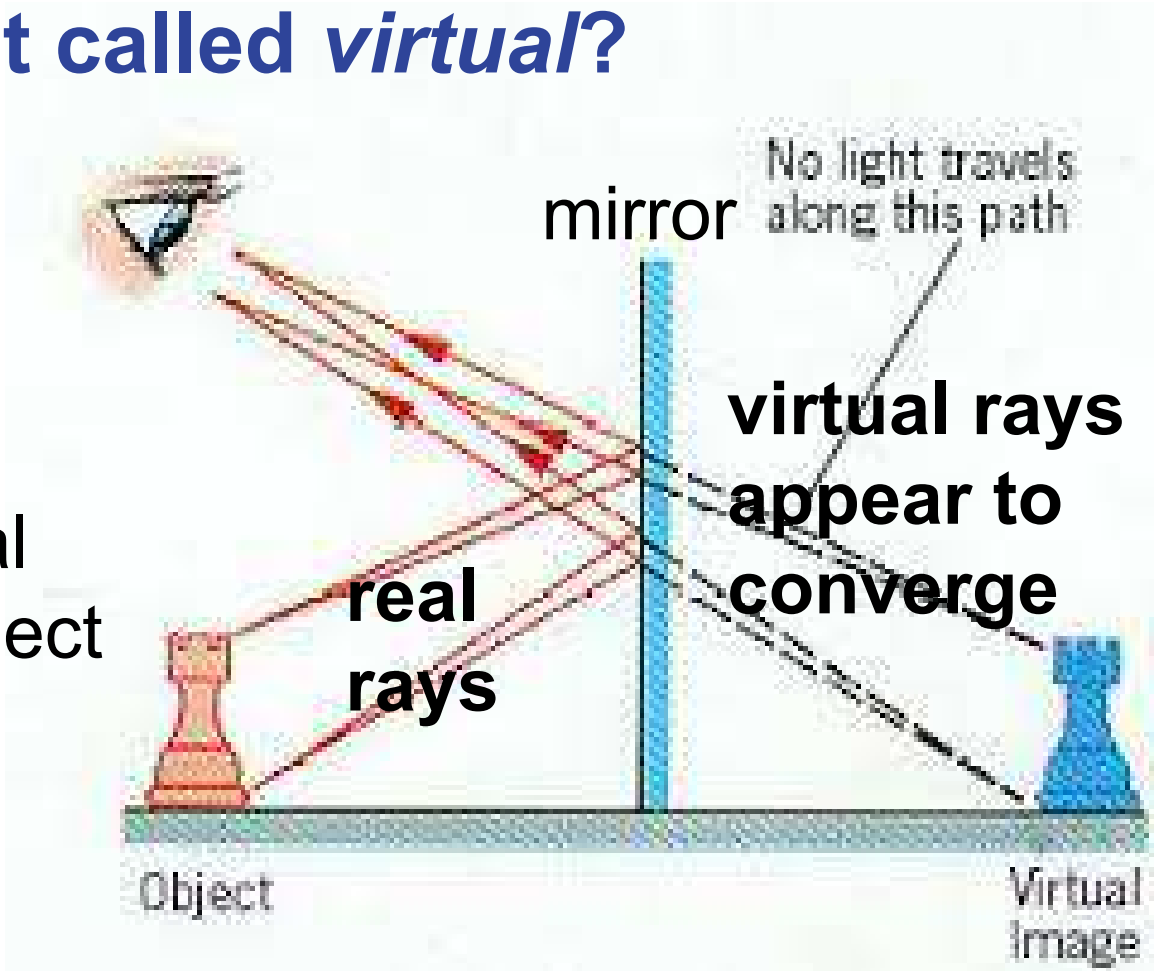
- Virtual image:
  - same size as object,
  - formed behind a mirror,
  - at the position where the extended (virtual) reflected rays converge.
  - as far behind the mirror as object is in front of mirror.



Classwork

5. Relative to the distance of an object in front of a plane mirror, how far behind the mirror is the image?

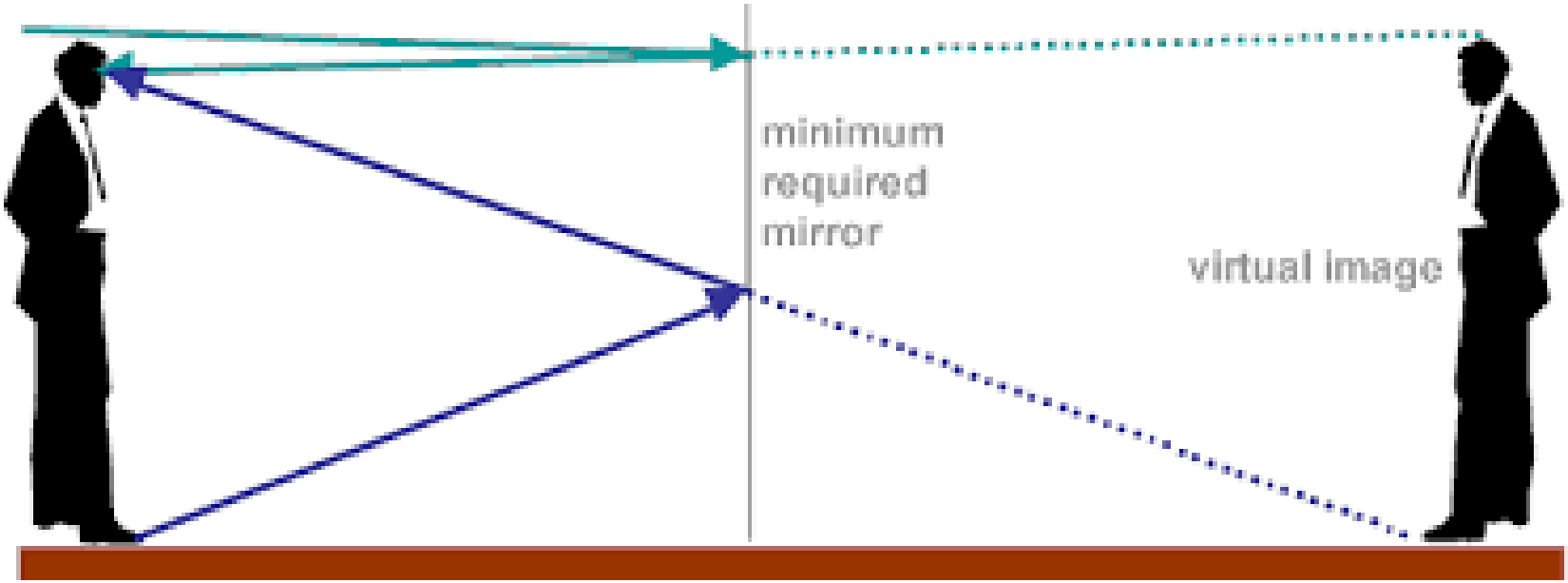
Why is it called *virtual*?



Virtual images cannot be projected

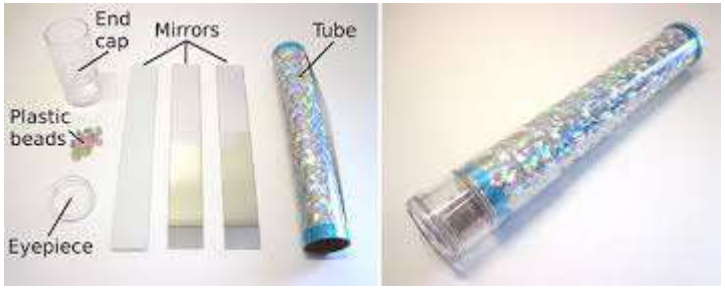
They form from real rays that diverge, but appear to converge.

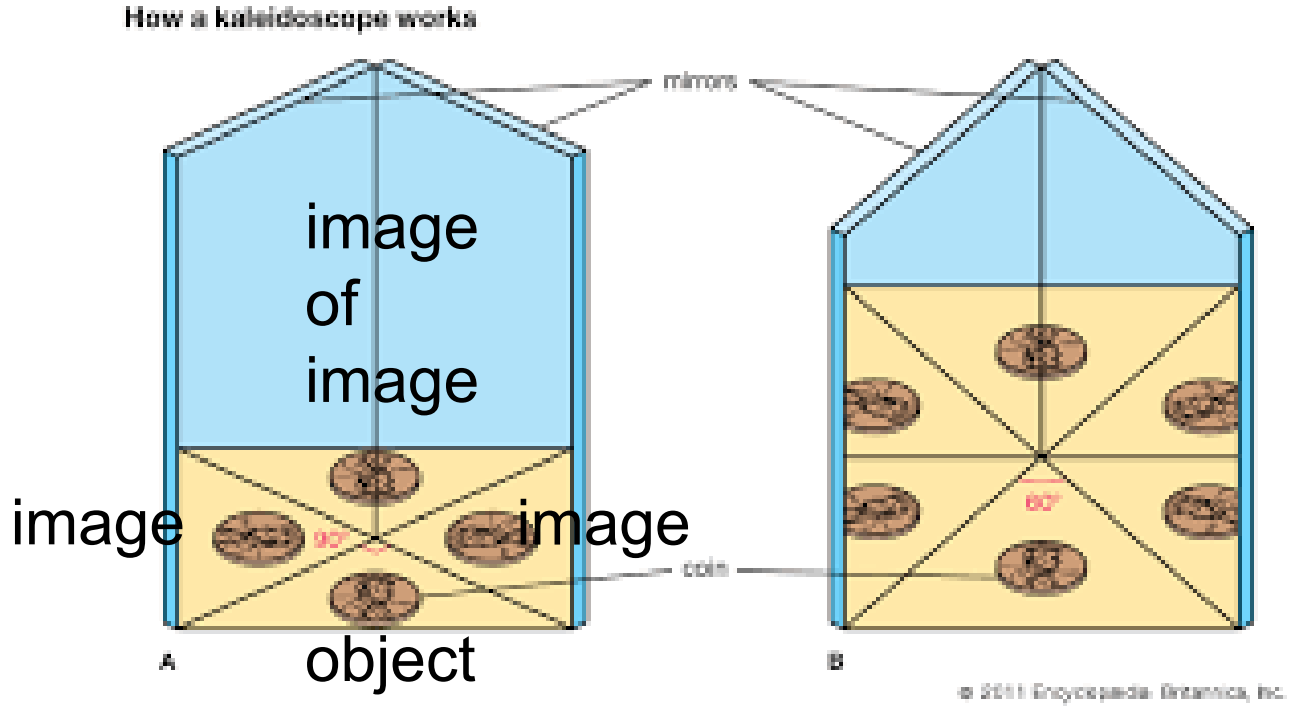
Your mirror only needs to be half of the object's size!



Kaleidoscope

Kaleidoscopes make reflections of reflections

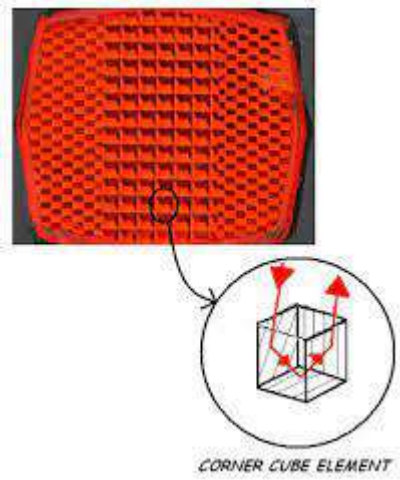


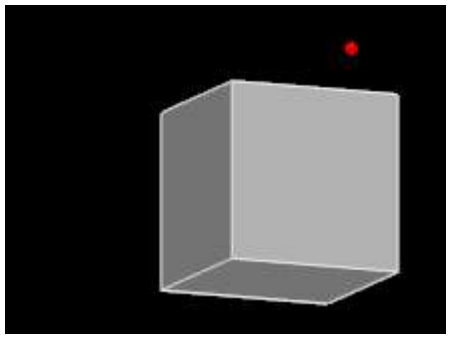


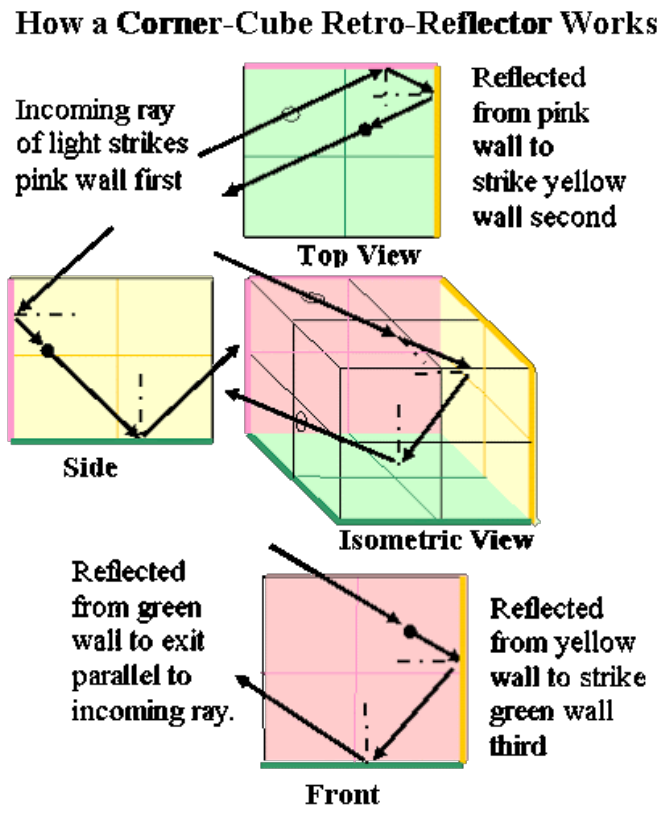
Corner reflector

Use 3 mirrors

Reflected ray is same direction as incident.

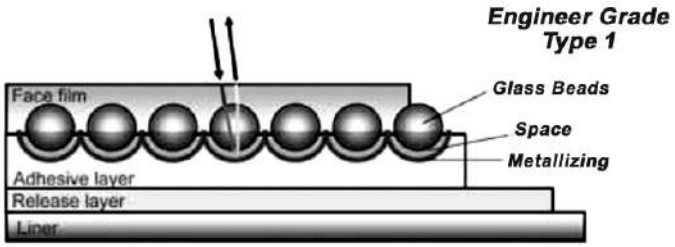


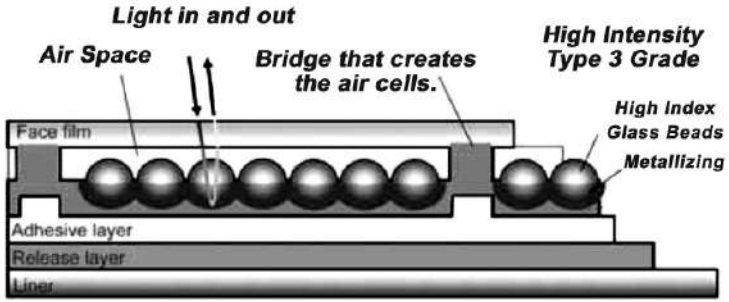


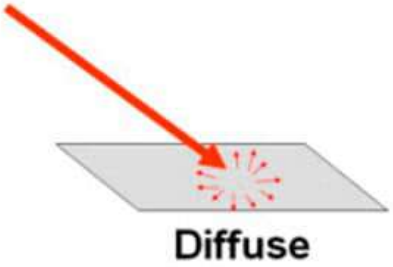


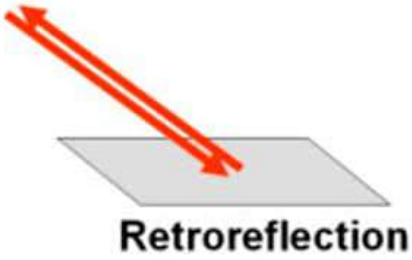
Retroreflection:

Reflection off the back of a tiny sphere:



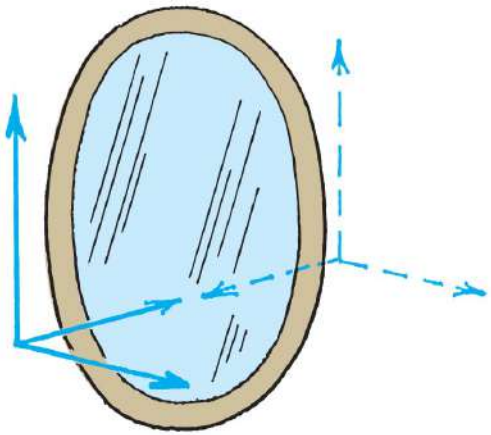






Law of Reflection, Continued-2

- Plane mirror
  - Note: the only axis reversed in an image is the front-back axis.

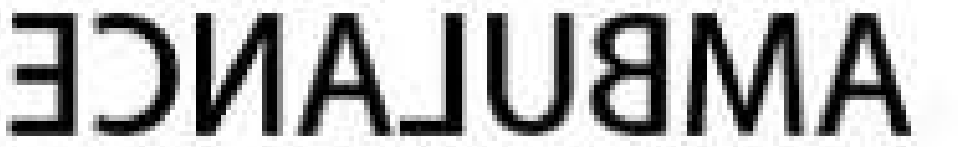


- What you see in a mirror is not the same as what we see:

Reversed letters

Which looks right in your rear view mirror?

AMBULANCE

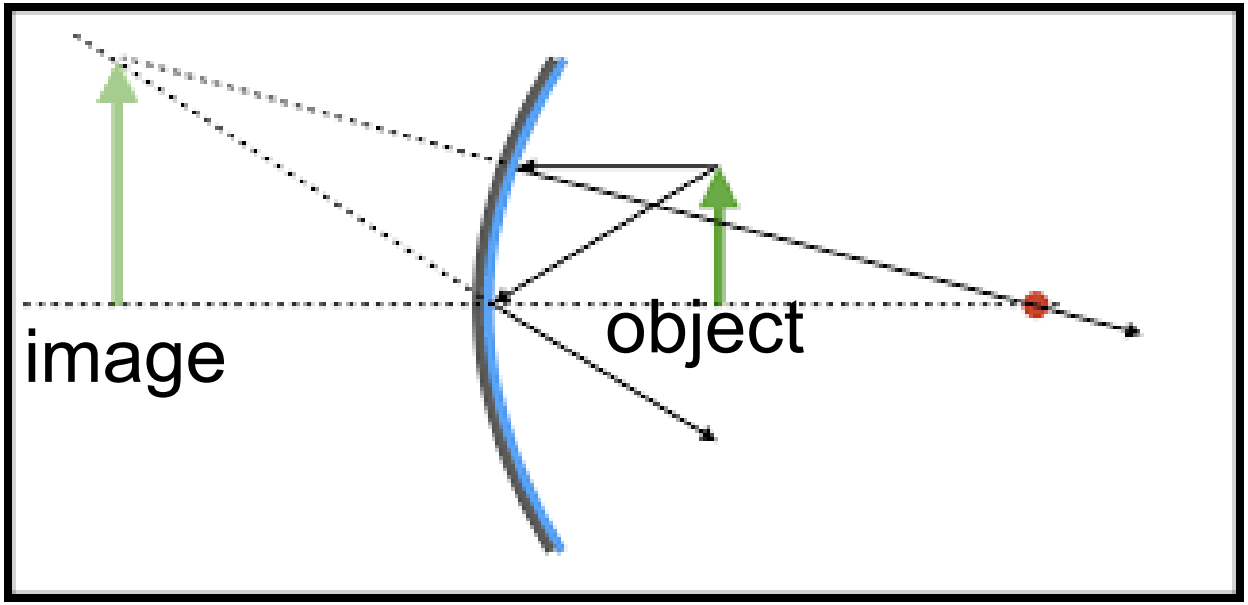


Curved mirrors

- Shape of mirror forms a different virtual image.
  - *Convex* mirror (curves outward): virtual image is smaller and closer to the mirror than the object.
  - Concave mirror (curves inward): virtual image is larger and farther away than the object.

Magnifying mirror

A concave mirror can produce a virtual image that is larger than the object

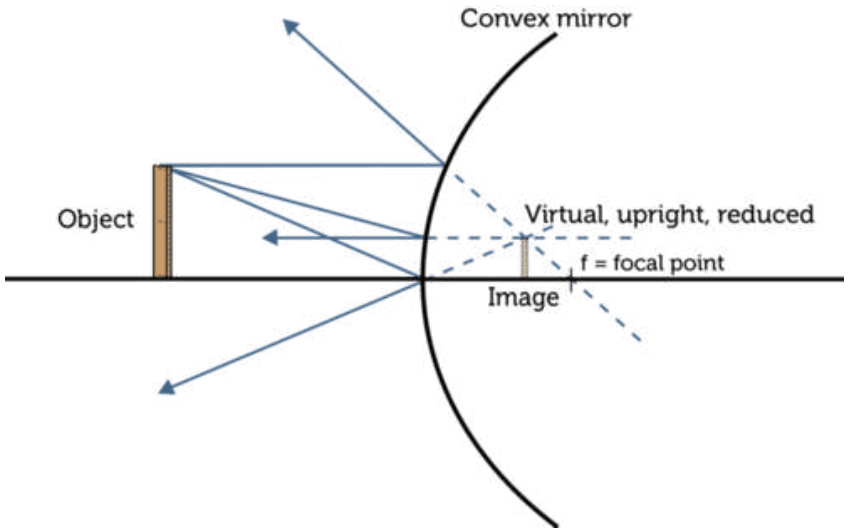


Security mirror

It's a convex mirror.

Virtual mages are smaller.

So you can fit more in.



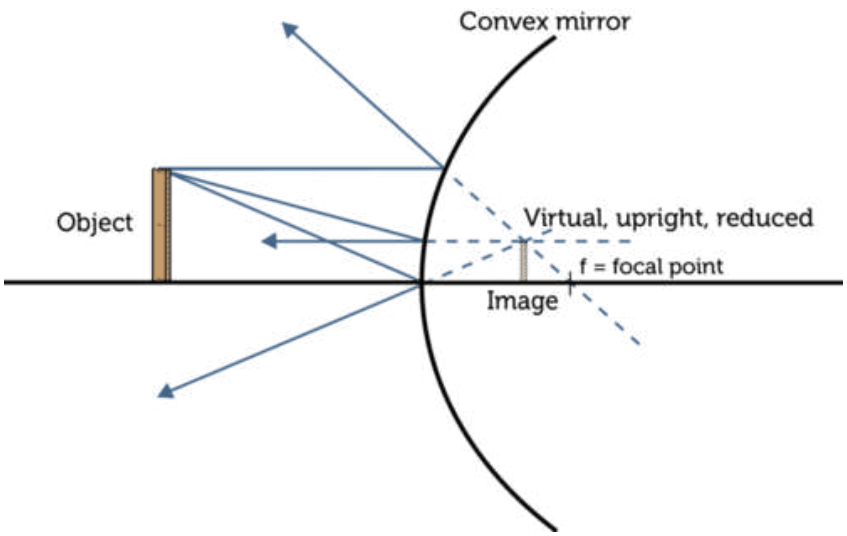
Images in mirror are closer than they….

If an image is smaller, you assume it is further away.

Plane mirror images are same size as object.

Convex mirror images are smaller than object.

So you think that they are further away…



Law of Reflection
CHECK YOUR NEIGHBOR, Continued

Light reflecting from a smooth surface undergoes a change in

A. frequency.
B. speed.
C. wavelength.
D. None of the above.

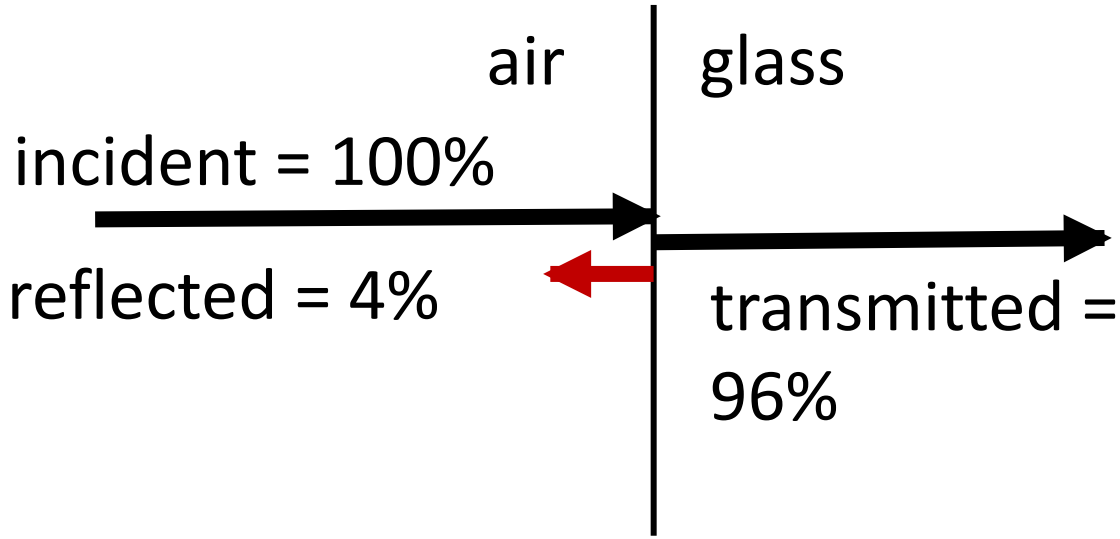
Law of Reflection
CHECK YOUR ANSWER, Continued

Light reflecting from a smooth surface undergoes a change in

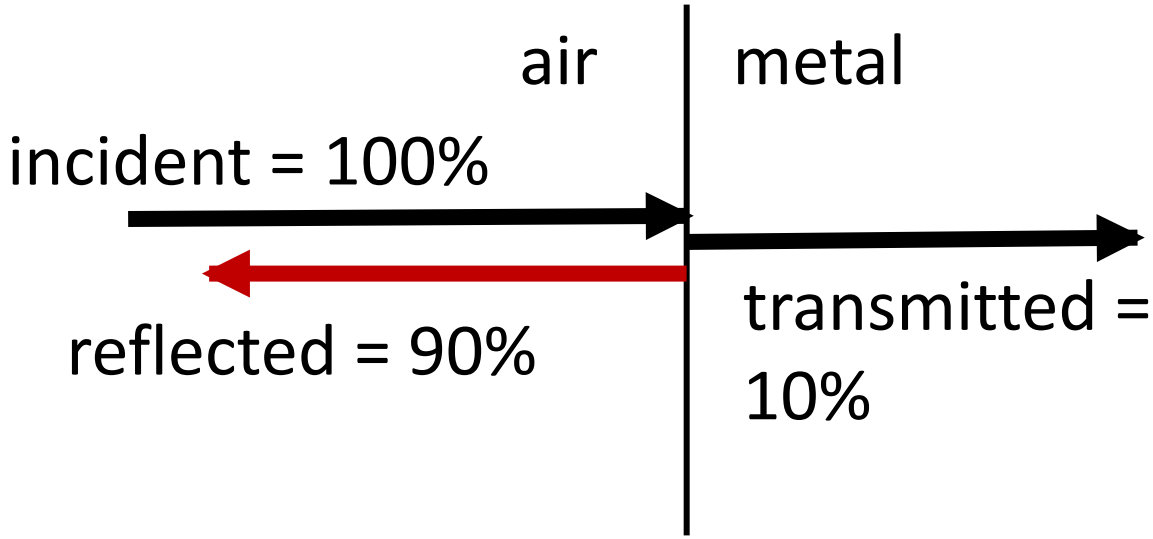
D. None of the above.

How much light reflects?

- Clear glass:



- Polished metals:



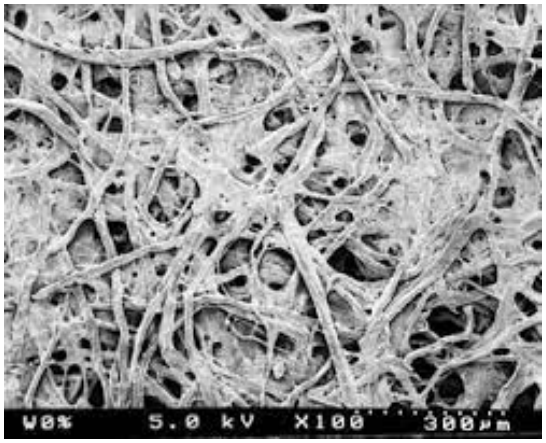
- Classwork

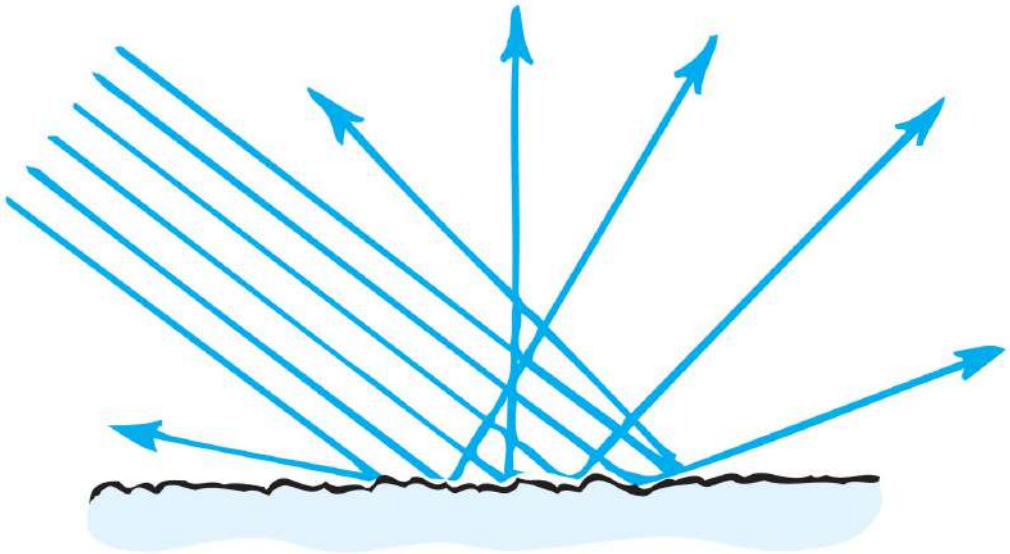
6. What fraction of the light shining straight at a piece of clear glass is reflected from the first surface?

Diffuse refection

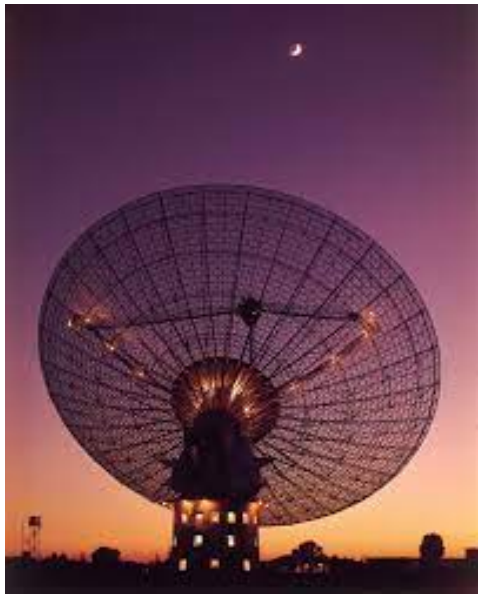
- When light strikes a rough or irregular surface and reflects in many directions
- Law of reflection is obeyed at each surface
- Occurs when the sizes of the surface irregularities are large compared to the wavelength of light

- paper:





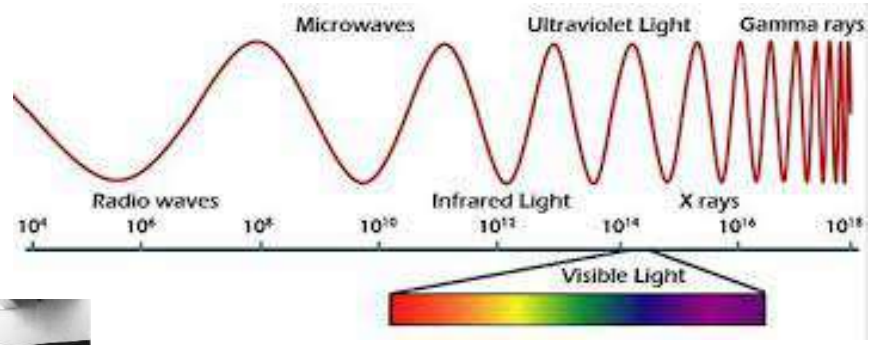
Radio telescopes

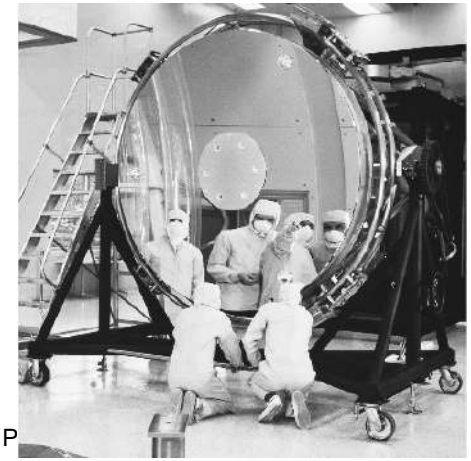


The mesh looks very smooth *to a radio wave.* The irregularities are small compared to wavelength of radio waves.

→ polished for radio

→ not polished for visible





The Hubble telescope is for visible light. The irregularities must be small so the irregularities are not big compared to the short wavelength that visible light has.

7. Can a surface be considered polished for some waves and not for others? Give an example.

Law of Reflection
CHECK YOUR NEIGHBOR, Continued-1

Diffuse reflection occurs when the sizes of surface irregularities are

A. small compared with the wavelength of reflected radiation.
B. large compared with the wavelength of reflected radiation.
C. Both A and B.
D. None of the above.

Law of Reflection
CHECK YOUR ANSWER, Continued-1

Diffuse reflection occurs when the sizes of surface irregularities are

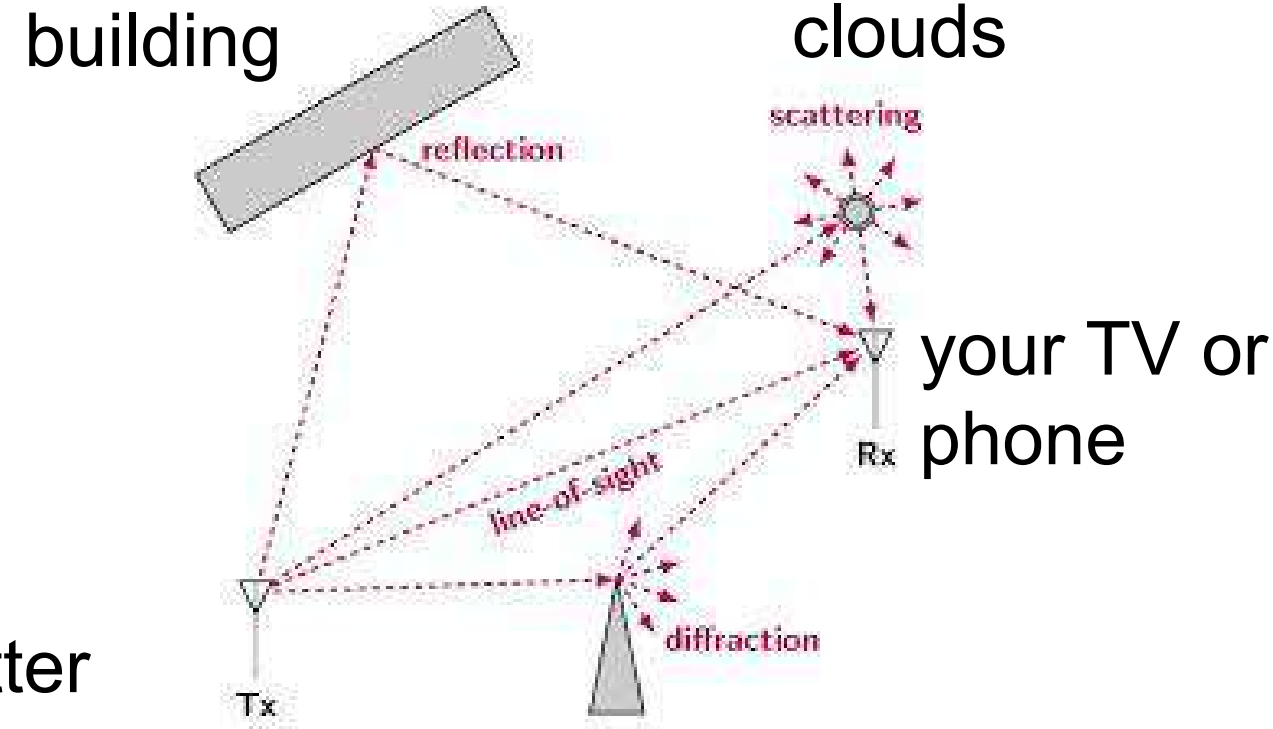
B. large compared with the wavelength of reflected radiation.

Explanation:

Diffuse reflection occurs for rougher surfaces.

Ghost images of signals:

An undesirable circumstance is the ghost image that occurs on a TV set when TV signals bounce off buildings and other obstructions.



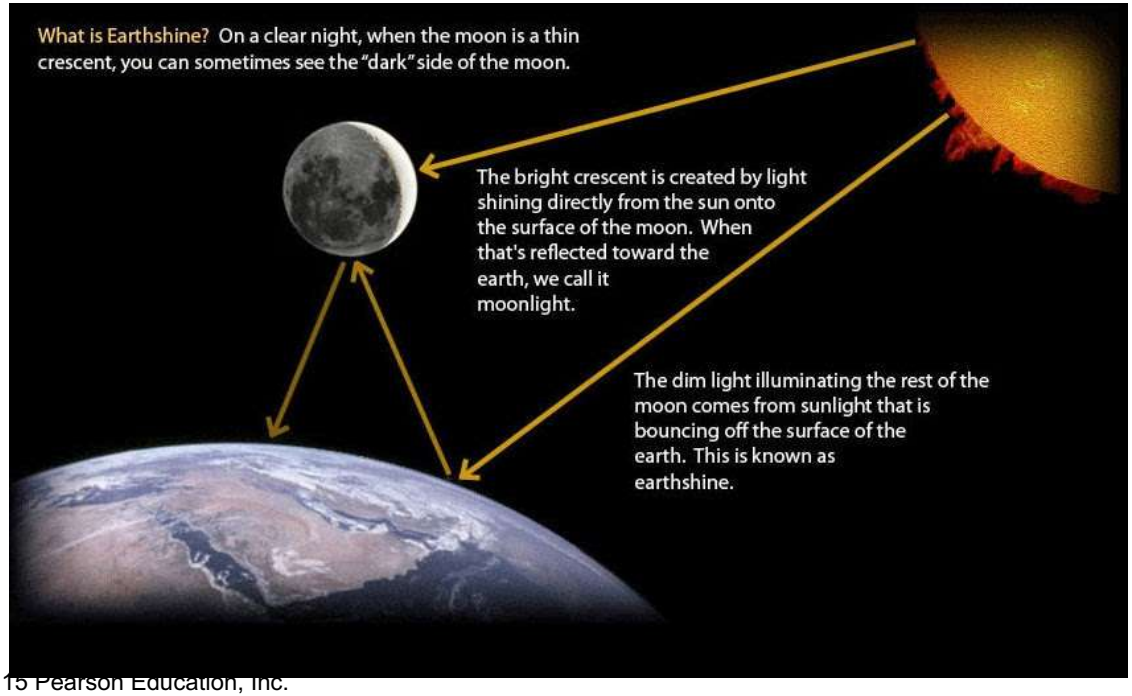
Law of Reflection, Continued-5

- Different road surfaces determine amount of diffuse reflection

– Rough road surface—because of diffuse reflection, see road ahead of car at night.
– Wet road surface is smooth—because of less diffuse, reflection, difficult to see.

Earthshine:

During a crescent moon, light reflected from Earth lights up the rest of the Moon. This is called *earthshine*.



Submit classwork now.

Old style periscope

Two mirrors making an image of an image: