The Basics of Light Refraction & Reflection

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Course Description

- This course will introduce the basics of light. Included in discuss will be two light theories, the principles of refraction (the bending of light) and the principles of reflection.

Learning objectives/outcomes

- At the completion of this course, the participant should be able to:

- Discuss the differences of the Corpuscular Theory and the Electromagnetic Wave Theory
- Have a better understanding of wavelengths
- Explain refraction of light
- Explain reflection of light

Optical Theory

- Light
  - Invisible Light
  - Visible Light

Understanding Light

- Clinically
  - How we see
  - Transports visual impressions
- Technically
  - Form of radiant energy
  - Essential for life on earth

Understanding Light

- Two theories of light
  - Corpuscular theory
  - Electromagnetic wave theory

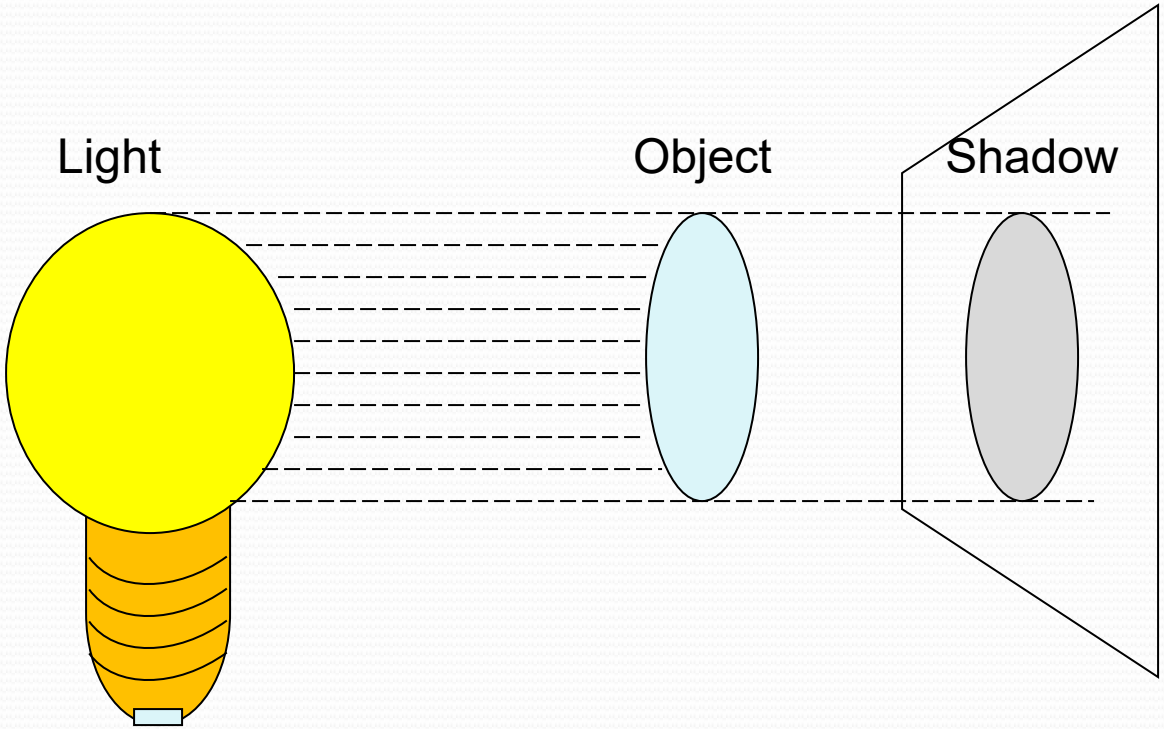
- The Quantum Theory of Light

Corpuscular Theory of Light

- Put forth by Pythagoras and followed by Sir Isaac Newton
  - Light consists of tiny particles of corpuscles, which are emitted by the light source and absorbed by the eye.
  - Explains how light can be used to create electrical energy
  - This theory is used to describe reflection
  - Can explain primary and secondary rainbows

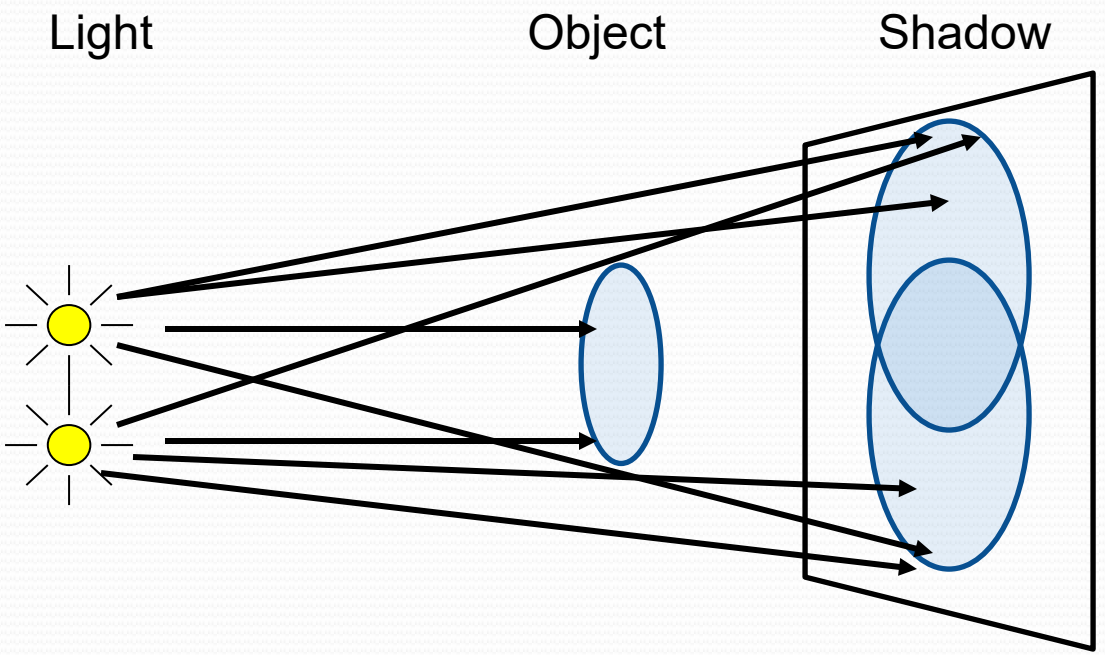
Understanding Light

- Corpuscular Theory
  Explains shadows



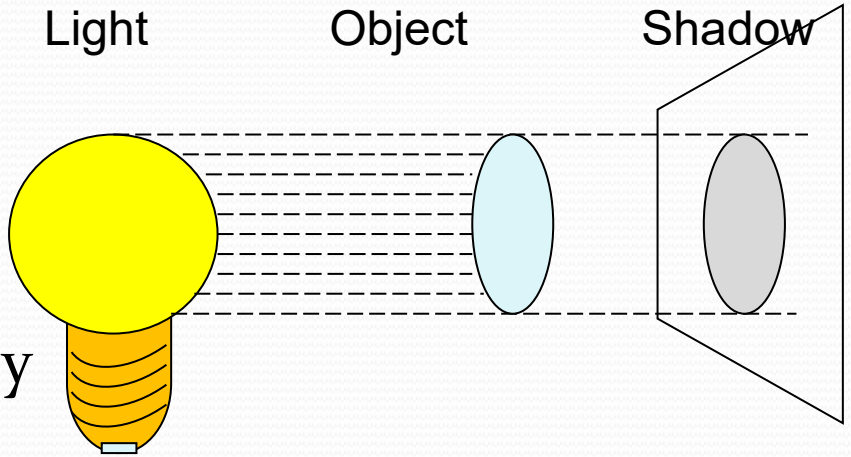
Indistinct Shadow

- If light from two separate sources fall on the same object, two shadows overlap resulting in an indistinct shadow



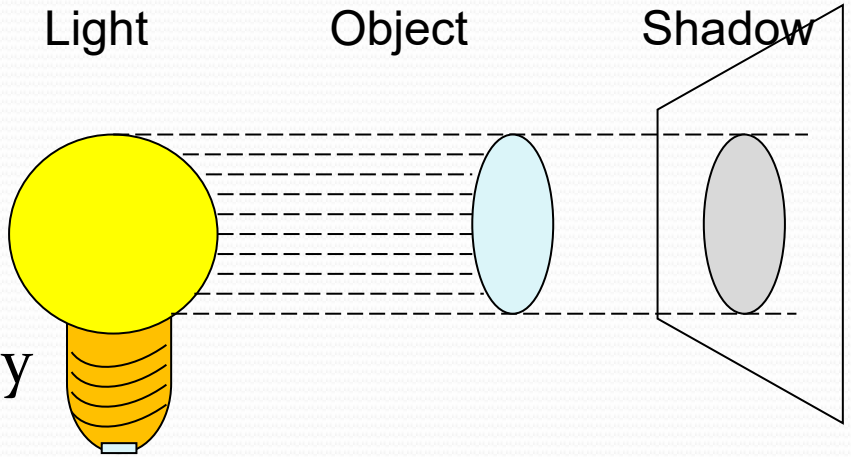
Time for a Question

This illustration is explained by which light theory?



a) Quantum theory
b) Particle theory
c) Corpuscular theory
d) Electromagnetic wave theory

This illustration is explained by which light theory?



a) Quantum theory
b) Particle theory
c) Corpuscular theory
d) Electromagnetic wave theory

Electromagnetic Wave Theory

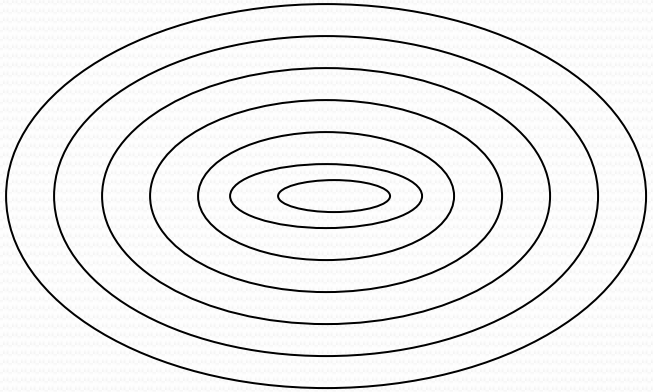
- 1678 - Hugens - Wave Theory
  - Theorized that light was a series of waves, moving outward from the source of light
  - Each color is a different wavelength
  - Supernumerary bows are explained
- 1864 – Maxwell – Electromagnetic Wave Theory
  - Improved on Hugens theory
  - Theorized that the vibrating particles in the waves were electric charges and the wave motion was magnetic motion
  - Very math intensive
  - Explains how light is generated
  - Explains that light is only one type of electromagnetic wave

Electromagnetic Wave Theory

- This is the theory that we use today to explain light
  - Electromagnetic Spectrum
    - Describes the range of wavelengths
      - Expressed in nanometers
    - Short end – Gamma rays, X-Rays, Ultraviolet
    - Long end – Infrared, Radar, Radio, TV
  - Visible light is only a small portion of the spectrum

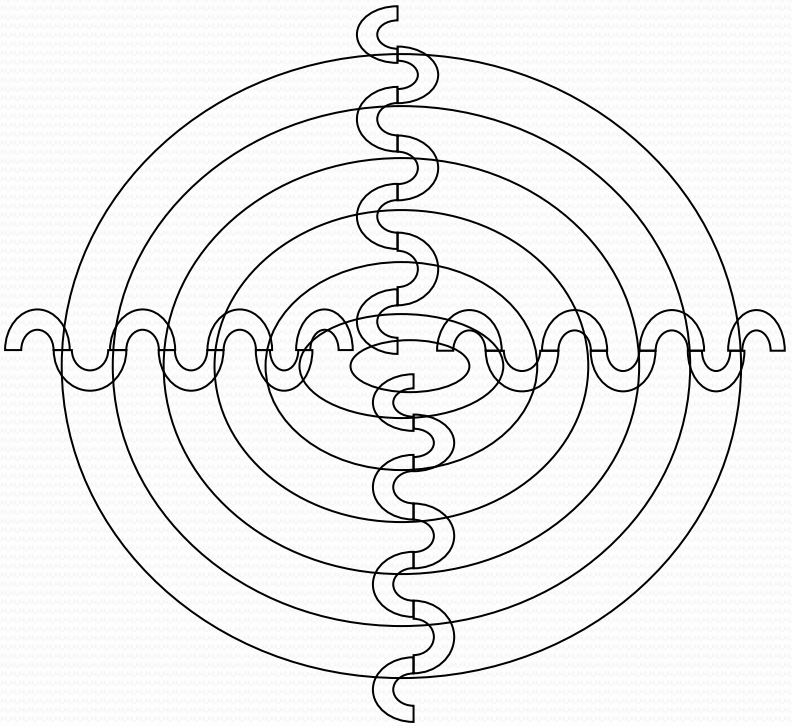
Electromagnetic Wave Theory

- Generally accepted theory used today.
- Waves move outward from the light source in concentric rings
  - Like waves created by a pebble tossed in a pond.



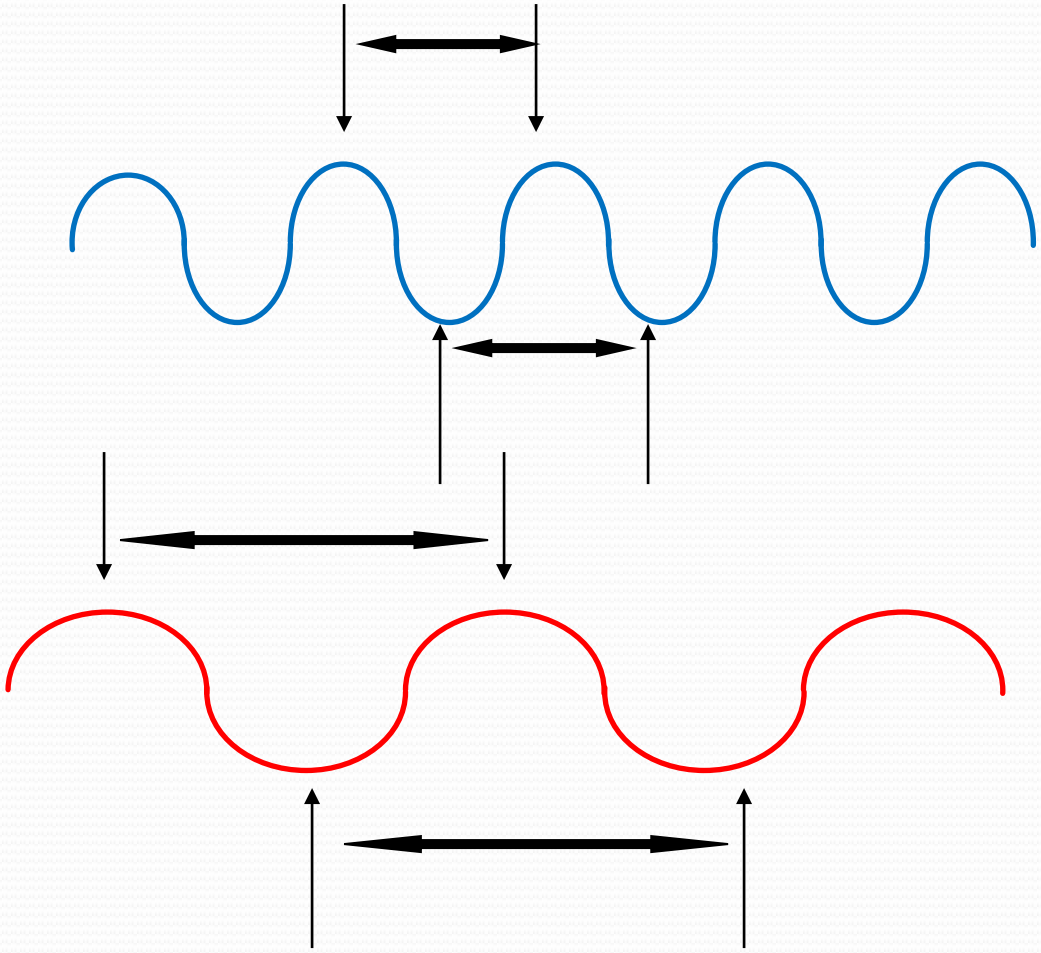
Electromagnetic Wave Theory

- Waves travel/vibrate up and down
- Travel outward from center
- Transverse motion



Wavelengths

- Distance between pulsations
- From crest to crest or trough to trough
- Measured in nanometers
- 0.000000001 m.



Frequency

- Number of vibrations of wavelength in 1 second

Velocity

- Speed at which a wave travels forward

Light

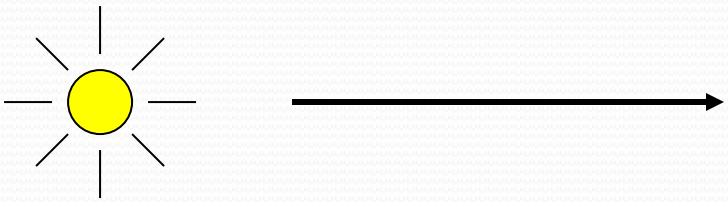
- Light diverges from a source in waves
- Velocity = Wavelength X Frequency

- The velocity of all EM radiation is the same in air

- Speed of light in air = 186,000 miles per second

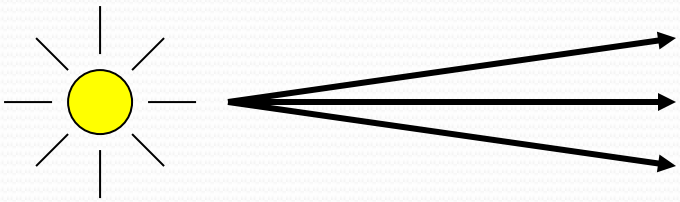
Rays, Pencil, Beam

- Ray – Single band of light from a single point on light source



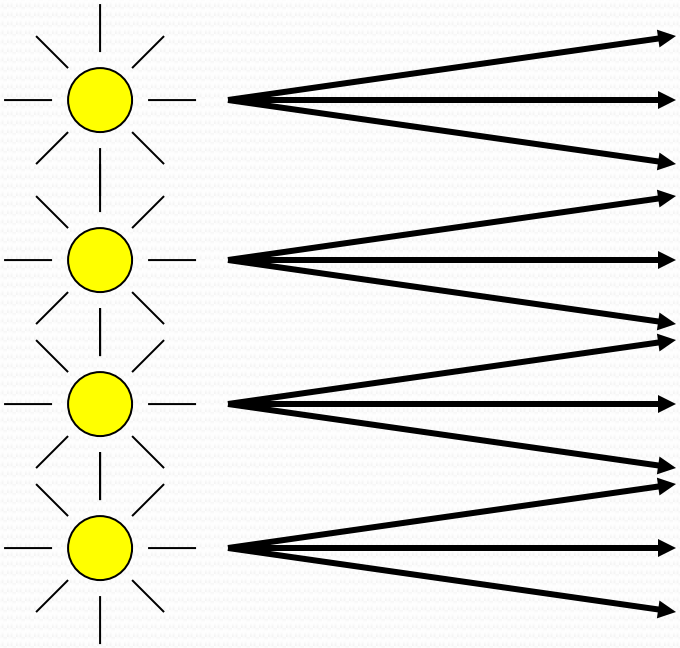
Rays, Pencil, Beam

- Pencil – Group of rays from a single point on light source



Rays, Pencil, Beam

- Beam = Group of pencils emanating from all points on light source.



Wavelength & Color

- Visible & Invisible Light
- Qualities of light
- Light is a combination of colors
  - Wavelenghts
- Spectrum

Time for a Question

What is the speed of light in air?

a) 186,000 miles per minute
b) 186,000 miles per second
c) 198,000 miles per minute
d) 198,000 miles per second

What is the speed of light in air?

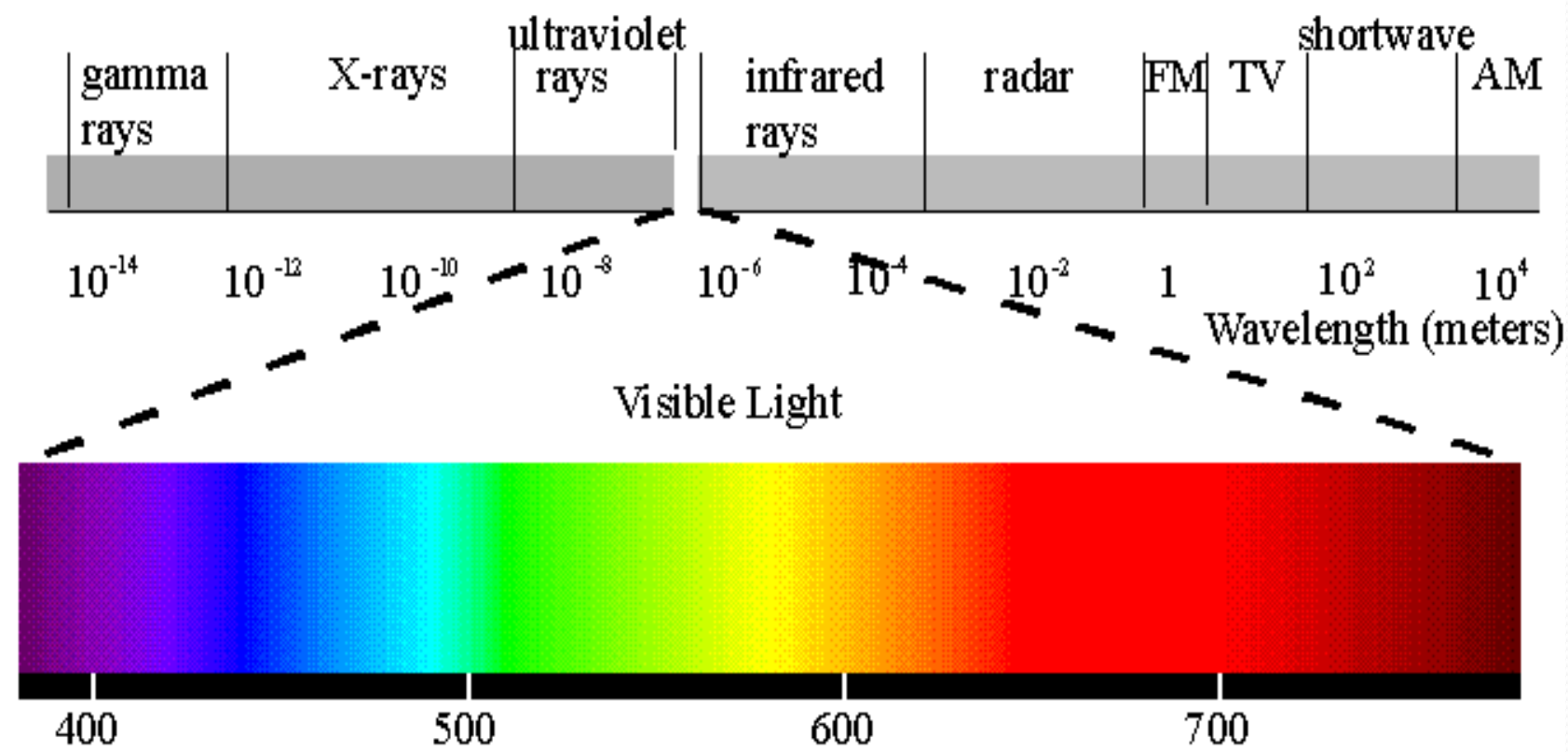
a) 186,000 miles per minute

b) 186,000 miles per second

c) 198,000 miles per minute

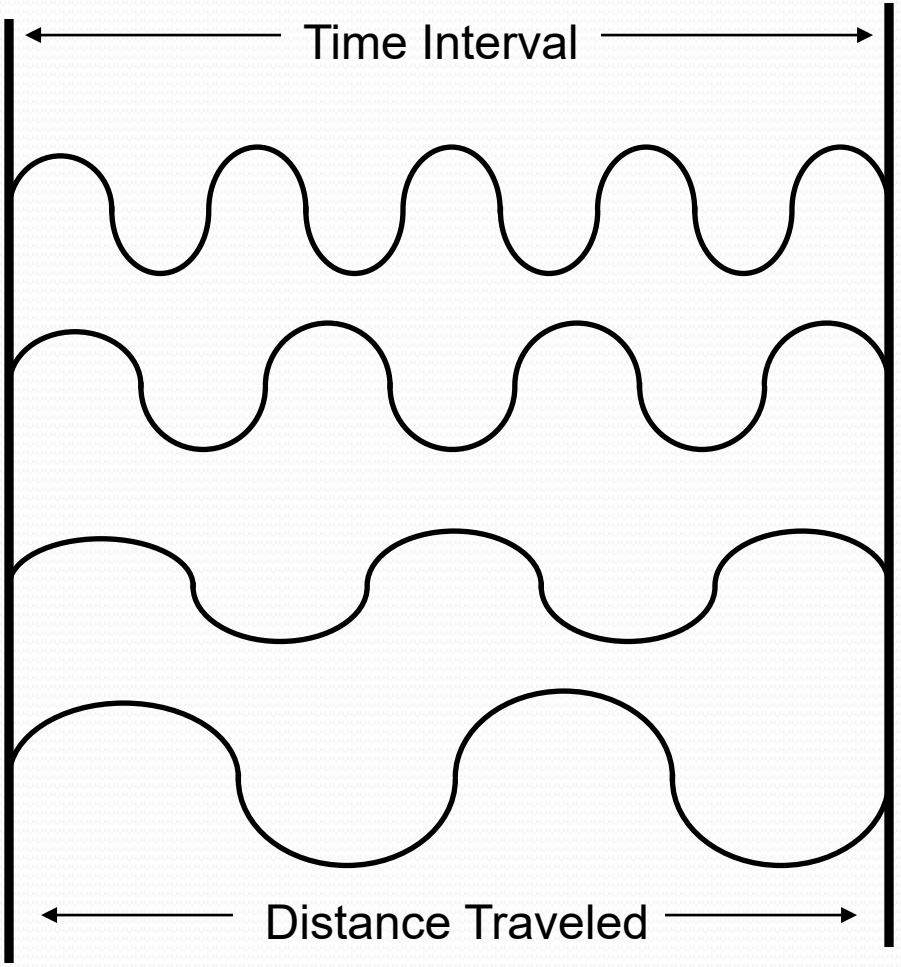
d) 198,000 miles per second

Electromagnetic Spectrum



Wavelength & Color

- Why don't we see colors in light?
- Time interval
- Distance



Electromagnetic Radiation

- Ultraviolet
  - UVC: 200 - 275 nm Ozone Layer
  - UVB: 275 - 330 nm Sunburn
  - UVA: 330 – 380/400 nm Ocular Hazard
- Visible Light
  - 380/400 - 750 ROY G BIV
- Infrared - Heat
  - 750 - 1,000,000 nm

Invisible Light

- Ultraviolet light is the high-energy invisible light that is divided into three categories
  - UV-A
    - 315 to 380 nm
  - UV-B
    - 280 to 315 nm
  - A & B
    - Can cause damage to the tissues of the body including the eye
  - UV-C
    - 190nm to 280 nm
    - Not thought to be of concern

High-Energy Visible Light

- HEV
  - Blue light
    - More accurately the blue and violet portion of the visible spectrum
  - Research is beginning to show to be a contributing factor to AMD
    - As we age, we produce fewer antioxidants and lose more melanin pigment in not just skin but retina as well
    - Lighter complexions, light eye colors, the greater exposure risk becomes

Refraction and Reflection

Index of Refraction

- When light travels through transparent substances other than air, it slows down

- Comparison of speed of light through that substance compared to the speed of light in air is the index of refraction.

Index of Refraction

- Formula

$$n = \frac{\text{speed of light in air}}{\text{speed of light in the medium}}$$

Index of Refraction

- Let's use the formula

- Speed of light in the medium is 124,165
- So the formula is 186,000 divided by 124,165

- n = 1.498

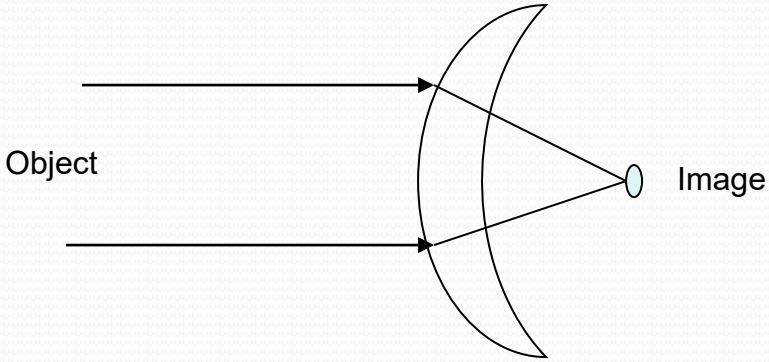
- Which is CR 39 plastic

Index of Refraction

$$\text{Speed of light in a medium} = \frac{\text{speed of light in air}}{n}$$

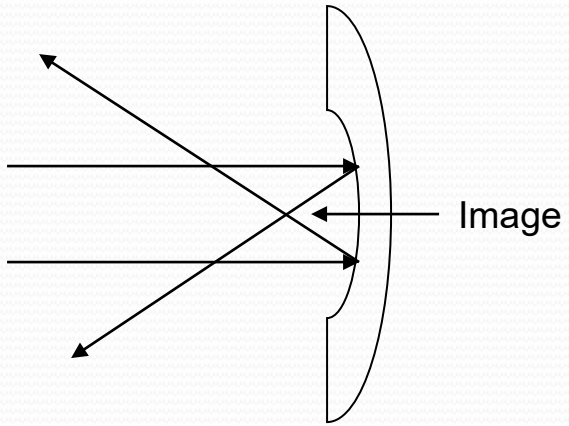
Real Images

- Light rays pass through a convex lens
  - They converge



Convex Lens

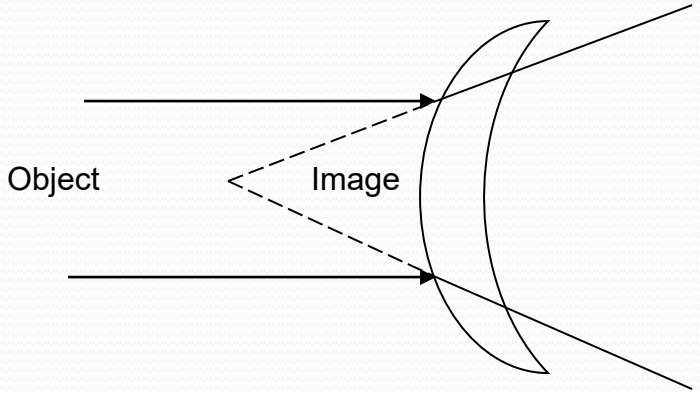
- Light rays pass through a concave mirror
  - They converge



Concave Mirror

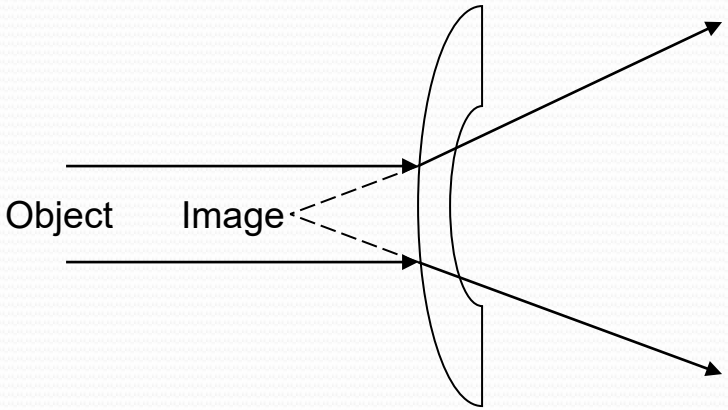
Virtual Images

- Light rays pass through a convex mirror
  - They diverge



Convex Mirror

- Light rays pass through a concave lens
  - They diverge



Concave Lens

Time for a Question

_____ images are formed when light rays pass through an optical medium and _____ (come together) to a point.

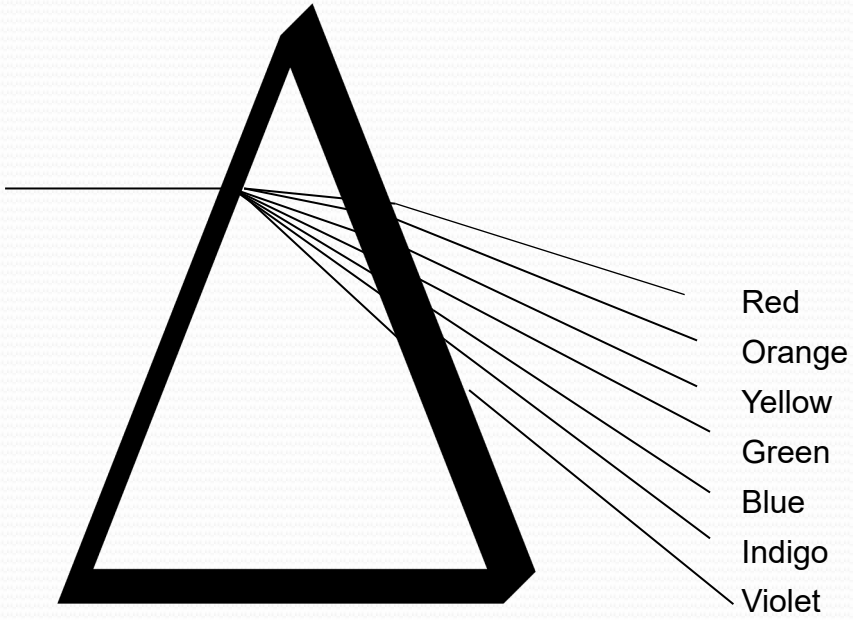
a) Real, converge
b) Real, diverge
c) Virtual, converge
d) Virtual, diverge

_____ images are formed when light rays pass through an optical medium and _____ (come together) to a point.

a) Real, converge
b) Real, diverge
c) Virtual, converge
d) Virtual, diverge

Dispersion

- Red is the longest wavelength
  - travels fastest
  - bends less
- Violet is the shortest wavelength
  - travels slowest
  - bend most



How Light Interacts With An Object

- Several things can happen
  - Object may transmit most or part of the light
    - Transparent
    - If no light transmits, the object is opaque
  - Light may be reflected
    - Depends on how much light is reflected and wavelenghts
  - Light may be absorbed
    - Heat is generated
  - When light falls on an object, pressure is exerted on the object.

Refraction

- The “bending” of light as it passes obliquely between two different refractive mediums

- A beam of light that enters a refractive medium perpendicularly is not refracted, but merely slowed down and the path of the beam is unchanged

Refraction

- Index of refraction
  - Number comparison
  - Speed of light through a medium compared to speed of light in air.
- Speed of light in air is 1.0

Refraction

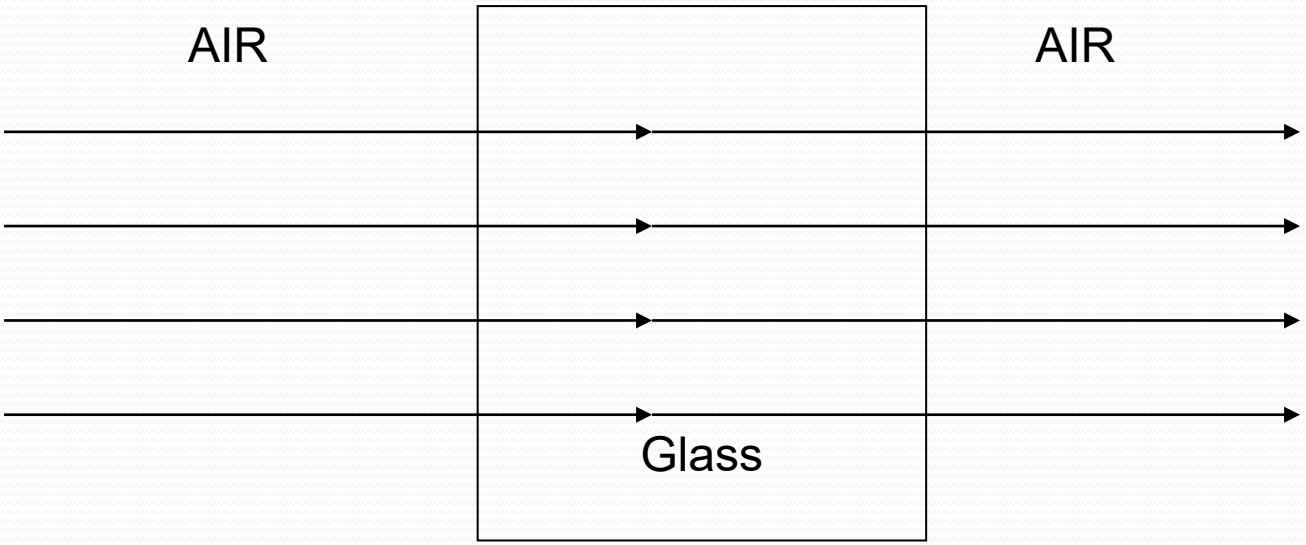
- Formula for determining speed of light in a medium
- n = Index of refraction
- $n = \frac{\text{Speed of light in Air}}{\text{Speed of light in a Medium}}$

Index of Refraction

- Amount of refraction/bending is dependent on speed.
  - Ray slowed more = bent more
  - Ray slowed less = bent less
  - Higher index of refraction = bent more

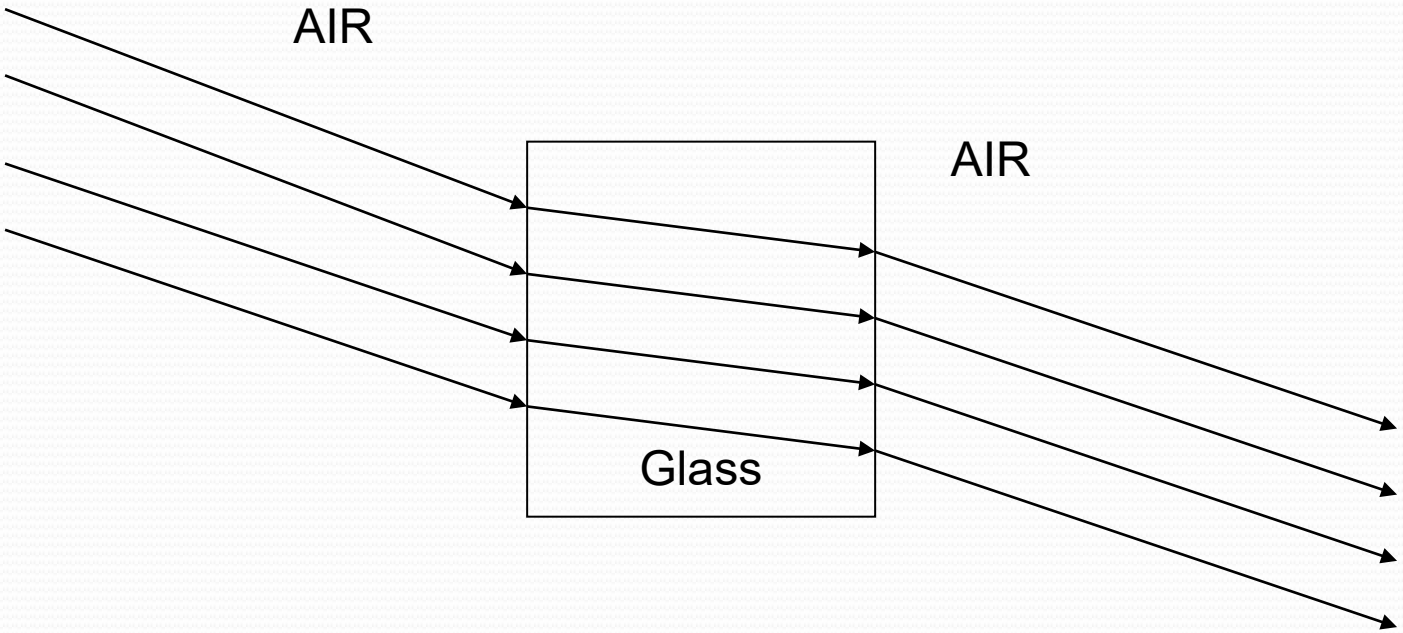
Refraction

- When a beam of light moving through air strikes a parallel piece of optical medium, two different things can happen. If the light strikes the surface at a perpendicular angle, it will merely be slowed down, and will travel through the medium on its original path.



Refraction

- If the light strikes the same surface at an oblique angle, it will be slowed down, bent, and will emerge slightly deviated from its original path

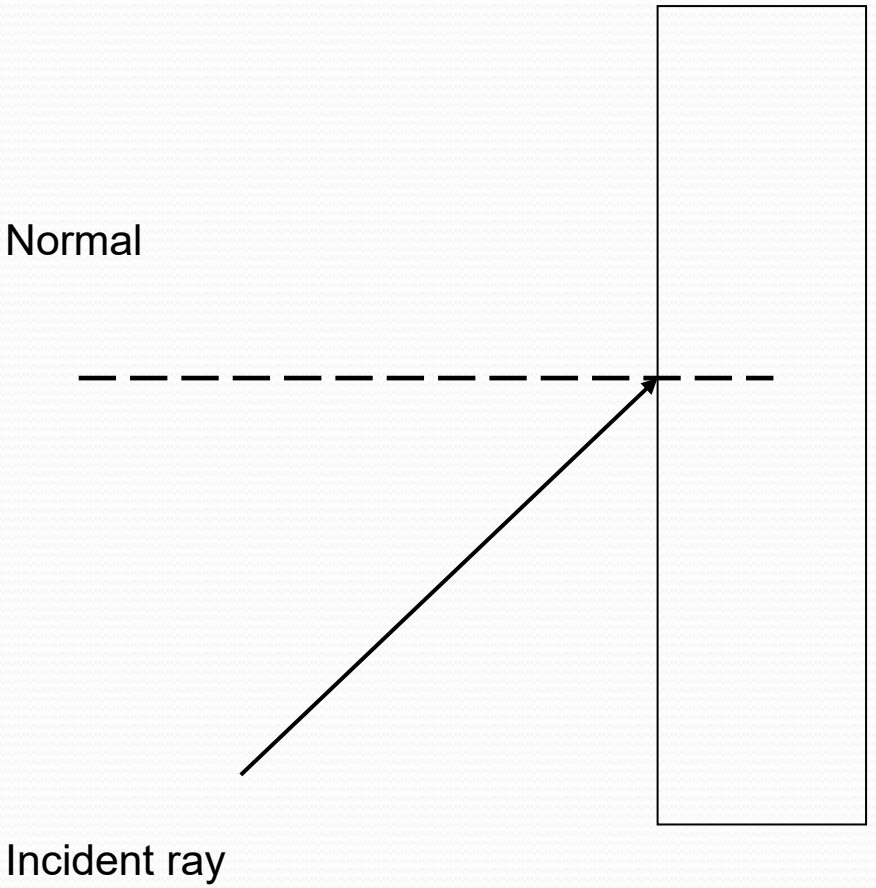


Refraction - Terminology

- Angle of incidence
  - The angle at which a ray strikes the surface and a line perpendicular to the surface, or “normal”
    - Designated by “i”
- Angle of refraction
  - The angle between the ray inside the glass and the line perpendicular to the surface.
    - Designated by “r”
- Angle of deviation
  - The angle from which the line would have extended with no deviation from where it actually extends
    - Designated by “d”

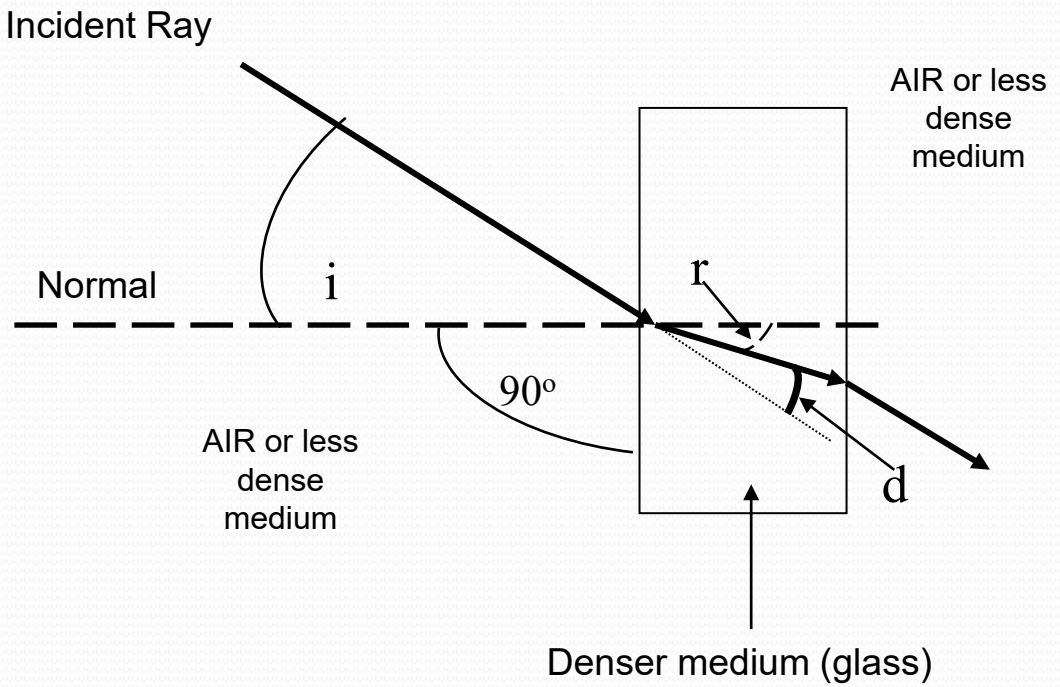
Terminology

- Normal
  - An imaginary line that is perpendicular to the refractive surface
  - At the point of incidence



Refraction

- Angle of incidence – i
- Angle of refraction – r
- Angle of deviation - d



Time for a Question

The angle at which a ray strikes the surface and a line perpendicular to the surface, or "normal" is the _____

a) angle of refraction
b) angle of incidence
c) angle of reflection
d) angle of deviation

The angle at which a ray strikes the surface and a line perpendicular to the surface, or "normal" is the _____

a) angle of refraction
b) angle of incidence
c) angle of reflection
d) angle of deviation

Snell's Law

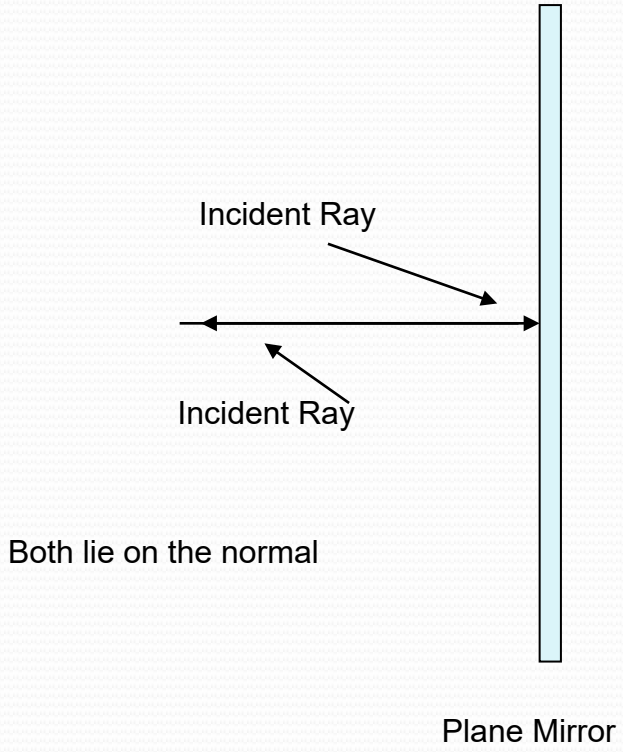
Variations of the formula

- $n_1 \sin i = n_2 \sin r$
- $n1 * \sin i1 = n2 * \sin i2$
- $n \sin i = n^1 \sin i^1$

Snell's Law: $\frac{\sin i}{\sin R} = n$ where n is a constant

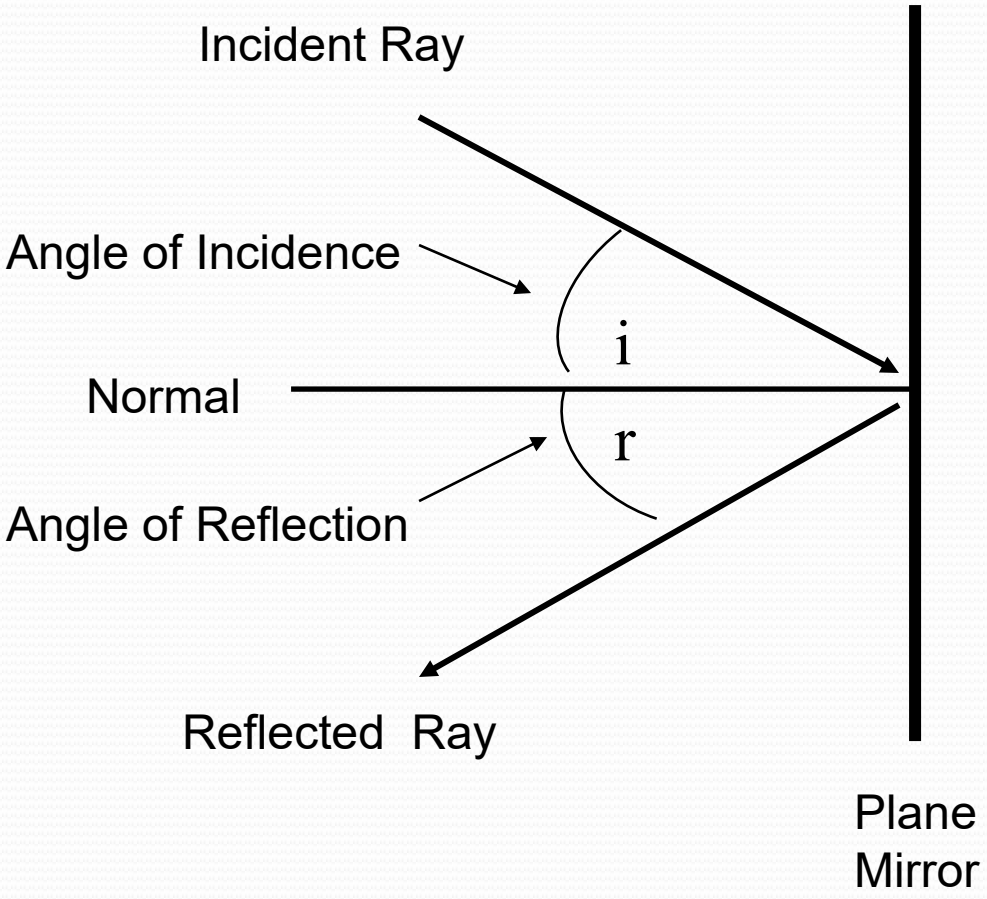
Reflection

- Unless interrupted, a single ray of light travels in a straight line
- If it strikes a reflective object, the ray of light bounces back
  - At a predictable angle
- If it strikes a surface at a perpendicular line, it is reflected back on itself.



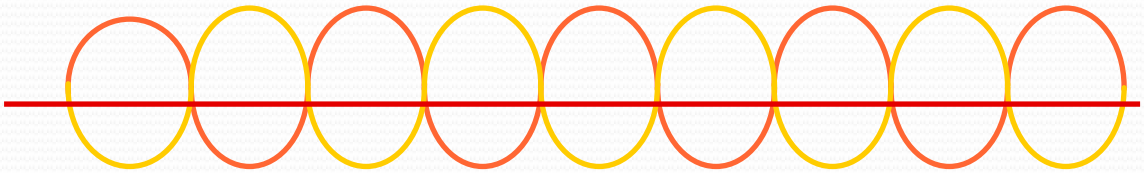
Reflection

- Both the Angle of Incidence and the Angle of Reflection are measured from the Normal.
- The Reflected Angle always equals the Reflected Angle



Light – Reflection - Interference

- Out of Phase
  - Canceling
  - Destructive
  - No Reflection
  - AR Coating



Light – Reflection - Interference

- In Phase
  - Compounding
  - Constructive
  - Reflection
  - Mirror Coating