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.

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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

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Optical Theory

- Light
  - Invisible Light
  - Visible Light

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Understanding Light

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

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Understanding Light

- Two theories of light
  - Corpuscular theory
  - Electromagnetic wave theory
    - The Quantum Theory of Light

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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

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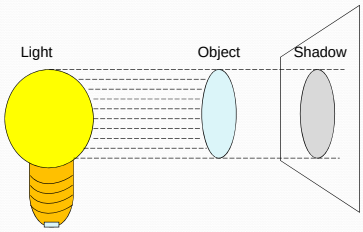
Understanding Light

- Corpuscular Theory
  Explains shadows



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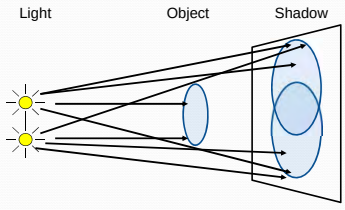
Indistinct Shadow

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



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Time for a Question

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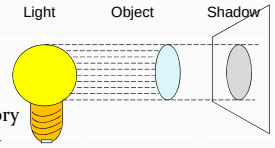
This illustration is explained by which light theory?



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

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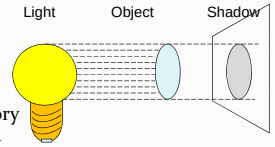
This illustration is explained by which light theory?



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

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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

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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

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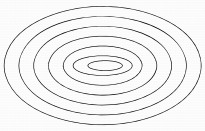
Electromagnetic Wave Theory

- 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.



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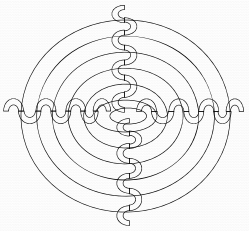
Electromagnetic Wave Theory

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



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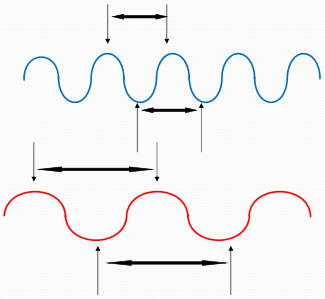
Wavelengths

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



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Frequency

- Number of vibrations of wavelength in 1 second

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Velocity

- Speed at which a wave travels forward

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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

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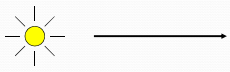
Rays, Pencil, Beam

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



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Rays, Pencil, Beam

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

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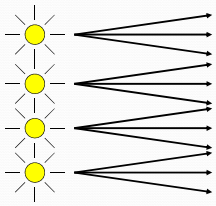
Rays, Pencil, Beam

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



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Wavelength & Color

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

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Time for a Question

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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

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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

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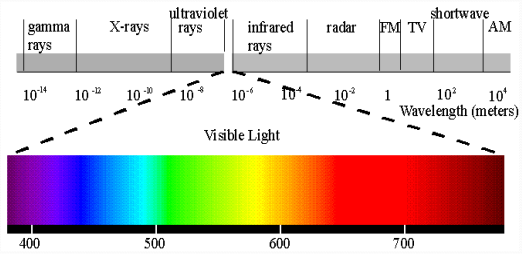
Electromagnetic Spectrum



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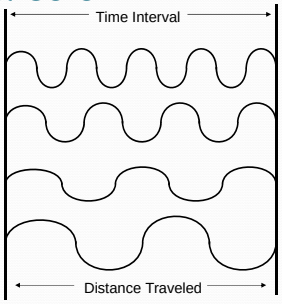
Wavelength & Color

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



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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

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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

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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

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Refraction and Reflection

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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.

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Index of Refraction

- Formula

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

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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

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Index of Refraction

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

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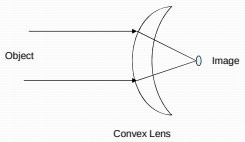
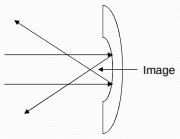
Real Images

- Light rays pass through a convex lens
  - They converge
- Light rays pass through a concave mirror
  - They converge



Convex Lens



Concave Mirror

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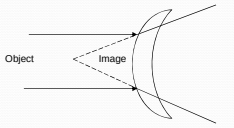
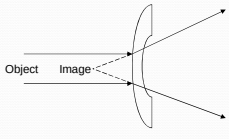
Virtual Images

- Light rays pass through a convex mirror
  - They diverge
- Light rays pass through a concave lens
  - They diverge



Convex Mirror



Concave Lens

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Time for a Question

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_____ 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

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_____ 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

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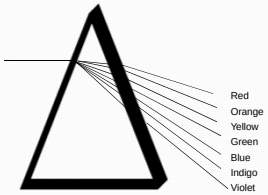
Dispersion

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



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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.

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Refraction

- The "bending" of light as it passes <u>obliquely</u> 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

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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

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Refraction

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

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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

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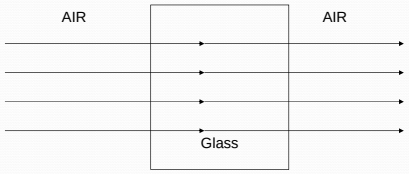
Refraction

- 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.



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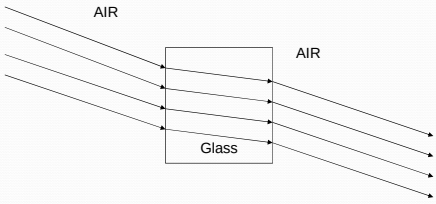
Refraction

- 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



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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"

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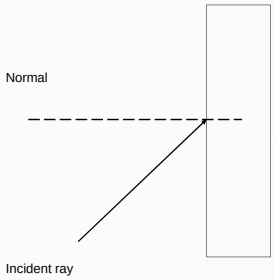
Terminology

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



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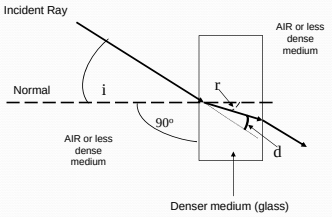
Refraction

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



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Time for a Question

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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

55

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

a) angle of refraction
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d) angle of deviation

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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

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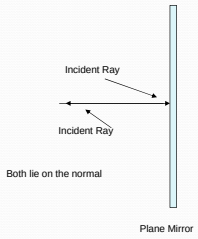
Reflection

- 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.



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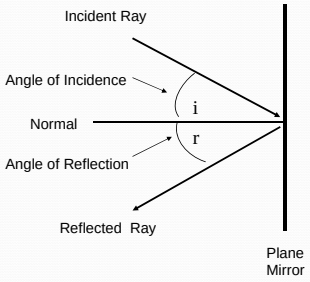
Reflection

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



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Light – Reflection - Interference

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

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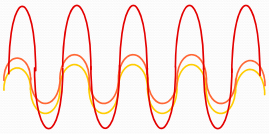
Light – Reflection - Interference

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



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