Year 👏 Review 👏

Light

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How Our Eyes Perceive Light

Our eyes have Rods and Cones

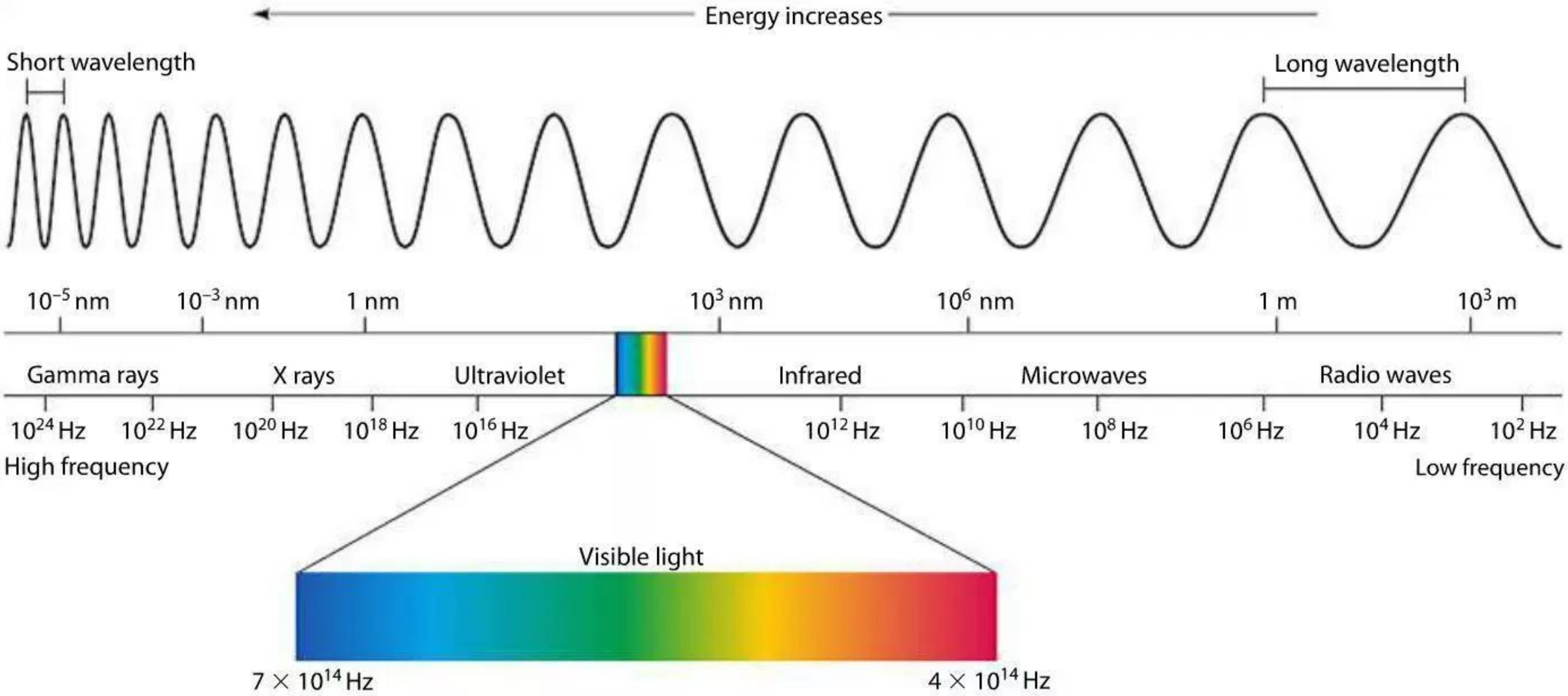
- Rods sensitive to low light
- Cones sensitive to color
  - They switch off based on how bright it is
- Color is our interpretation of *frequency*
  - Low frequency is more red
  - Higher frequency is more violet
  - The human eye respond to frequencies from 430 THz to 770 THz
    - Above 770 THz is *Ultraviolet*
    - 430 THz is *Infrared*

Our eyes don't perceive all colors equally

- In low light our eyes see cyan best
- In high light levels our eyes see yellow-green best

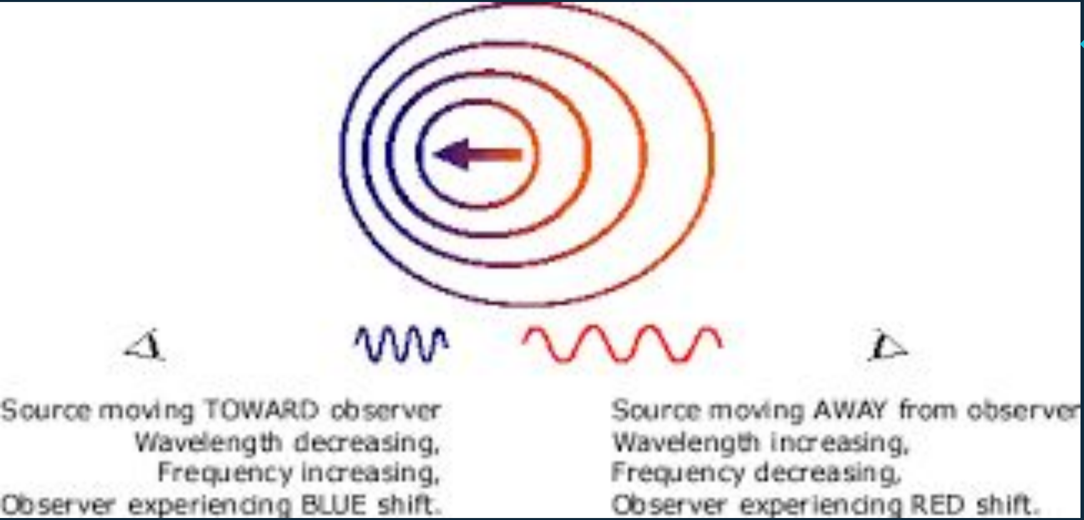
The Electromagnetic Spectrum

- The spectrum of radiation placed on a scale
  - shortest wavelength to longest wavelength
  - High frequency to low frequency.
- The Wave of light with the Lowest Frequencies have the Longest wavelength and vice versa.
  - Frequency measured in Hertz (Hz)
  - Wavelength measured in Meters(m)
  - Energy measured in electron volts(EV)


Energy increases
Short wavelength
Long wavelength
10⁻⁵ nm
10⁻³ nm
1 nm
10³ nm
10⁶ nm
1 m
10³ m
Gamma rays
X rays
Ultraviolet
Infrared
Microwaves
Radio waves
10²⁴ Hz
10²² Hz
10²⁰ Hz
10¹⁸ Hz
10¹⁶ Hz
10¹² Hz
10¹⁰ Hz
10⁸ Hz
10⁶ Hz
10⁴ Hz
10² Hz
High frequency
Low frequency
Visible light
7 × 10¹⁴ Hz
4 × 10¹⁴ Hz

Doppler Effect for Light

- Light moving away from the viewer will be red-shifted (lower frequency)
- Light moving toward the viewer will be blue-shifted(higher frequency)



- Doppler Effect used to determine movement of Stars

How Light Hits Matter

- When Lights hits any type of matter it forces the electrons in the matter to vibrate
- The way that the material reacts to the light is dependent on the frequency of the light wave and the natural frequency of the matter.

Opaque/Transparent Materials

- If the frequency of the light matches the natural frequency of the electrons the atoms start to vibrate and heat up.
- It prevents the light from passing through

For instance Visible light passing through glass but gamma rays heating up glass

And visible light heating up an object but x-rays passing through solid objects

Speed of Light

- Speed of light really hard to measure
  - Michelson experiment yielded accurate results

Speed of Light: 299,792,458 m/s in a vacuum

- (Rounded to 300,000,000 m/s)
- Fastest possible speed in the universe
- Light slower in other media (air, water)

Index of Refraction

Index(n) =

speed of light in a vacuum

____

speed of light in material

- Index will always be ≥ 1(vacuum is fastest)

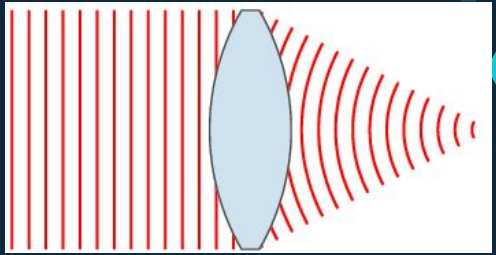
Refraction

- Refraction
  - Bends wavefronts
  - Can focus light
  - Lenses
  - Snell's law:
  - $\sin(\theta_1)*n_1=\sin(\theta_2)*n_2$
    - N is the index of refraction
      - low index of refraction-> high index of refraction: light travels closer to straight
    - Θ is the angle from normal
  - Happens on the borders of different media

Medium	n
Gases at 0°C, 1 atm	
Air	1.000293
Carbon dioxide	1.00045
Hydrogen	1.000139
Oxygen	1.000271
Liquids at 20°C	
Benzene	1.501
Carbon disulfide	1.628
Carbon tetrachloride	1.461
Ethanol	1.361
Glycerine	1.473
Water, fresh	1.333

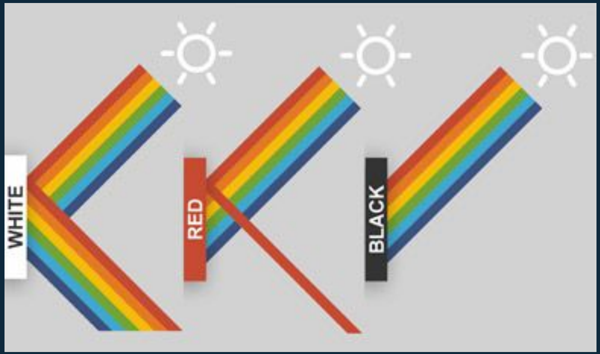
Solids at 20°C	
Diamond	2.419
Fluorite	1.434
Glass, crown	1.52
Glass, flint	1.66
Ice at 20°C	1.309
Polystyrene	1.49
Plexiglas	1.51
Quartz, crystalline	1.544
Quartz, fused	1.458
Sodium chloride	1.544
Zircon	1.923

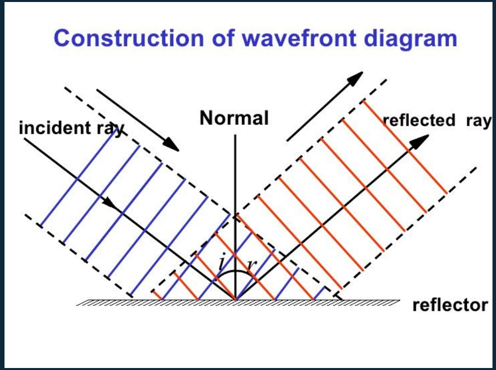
Figure 1: Indices of refraction for various materials.



Reflection

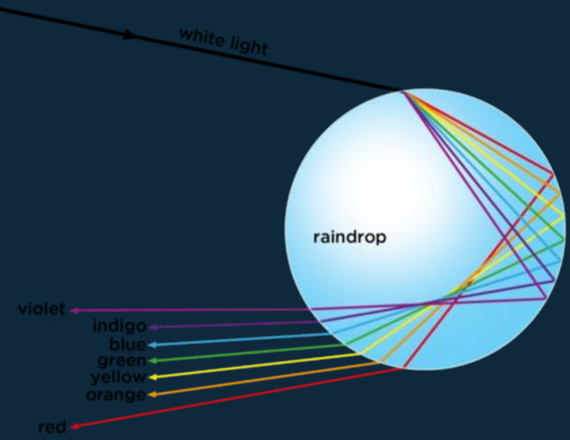
- Reflection
  - Changes direction of light
  - Total reflection: all light reflected, partial reflection: some light is transmitted
  - The color of light that an object reflects is the color you see
  - Can focus light

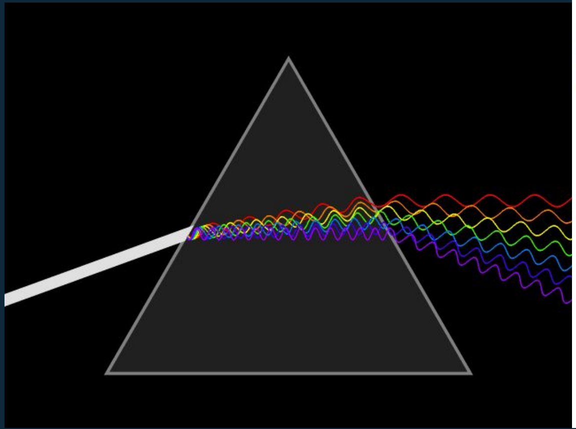


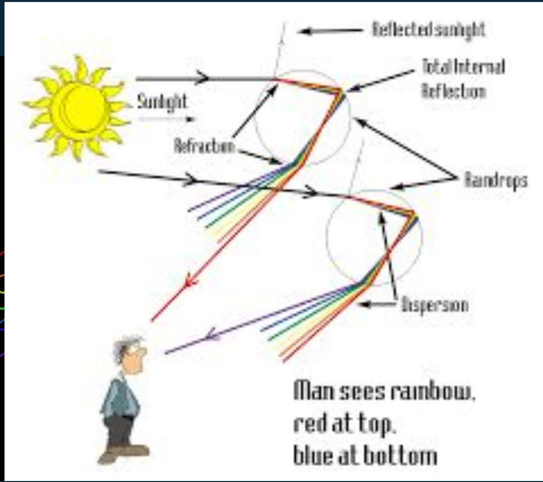


Dispersion

- Different frequencies of light are refracted differently in the same medium
- Bluer frequencies are refracted further than redder frequencies
- Makes prisms work
- Makes rainbows



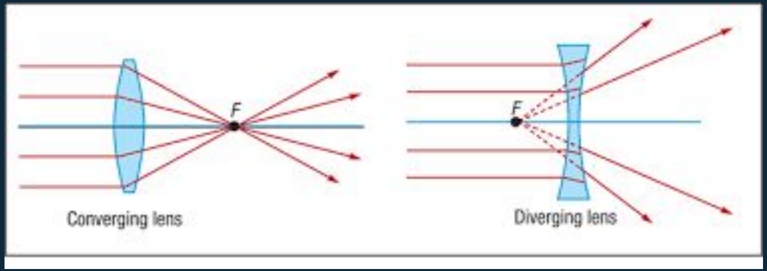




Diffraction

- Wave behavior exhibited at the edges of an opening
- Acts like a diverging lense
- Creates an interference pattern

Lenses



- Light gets refracted when it enters and leaves lenses
- There are two different types of lenses
  - **Converging lenses** with shine light to a point or **Diverging lenses** that diverge light away from a point
  - That point is called the **focal point**
  - The distance from the center of the lenses to the focal point is called the **focal length**
- Lenses are used to bend light to magnify images

Particle v. Wave.

Debates between Light being a wave vs. light being a particle have been going for a long time

- Double Slit experiment proved that light behaved like a wave because it interferes with itself
- Photoelectric effect ("ultraviolet catastrophe") problematic to wave model
  - High energy but low frequency light (red/infrared light) can't produce the photoelectric effect
  - Lower energy but higher frequency light(violet/ultraviolet) can produce the effect
    - Light can't be a wave
    - photons ("packets" of light)
    - Einstein proved that only 1 photon could be absorbed, meaning that frequency was important, not brightness

Particle v. Wave cont.

- Light: Wave or Particle wrong question to ask;
  - light isn't a wave or a particle
  - completely different
    - behaves like either
    - describing light as either is more helpful than correct