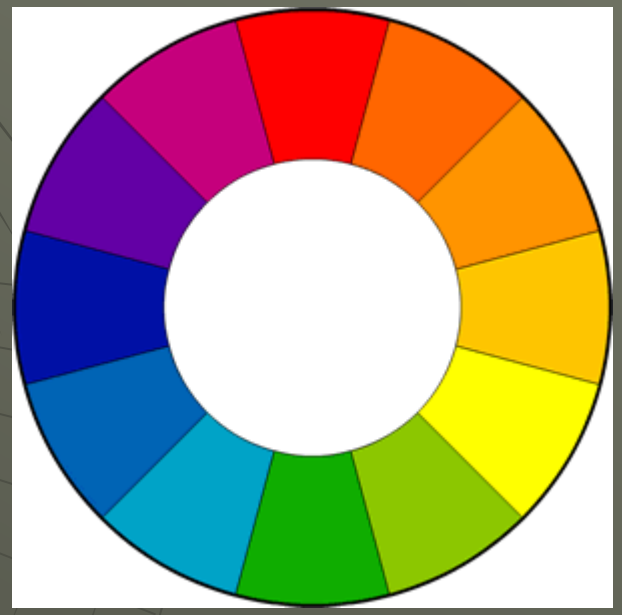
Nature of Light

- Objectives
  - What is light
  - What are the different forms

Light's Importance

- Light contributes 99% of all observations in Astronomy
- Light is a form of energy
- Light is electromagnetic radiation (get to later)
- We perceive certain light as "color"

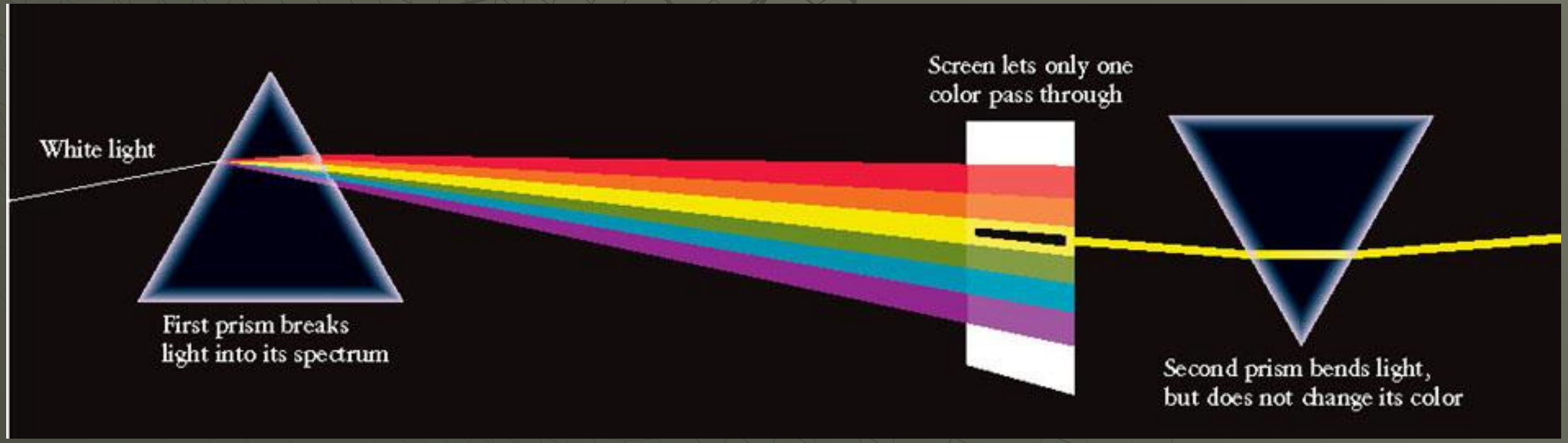


Newton

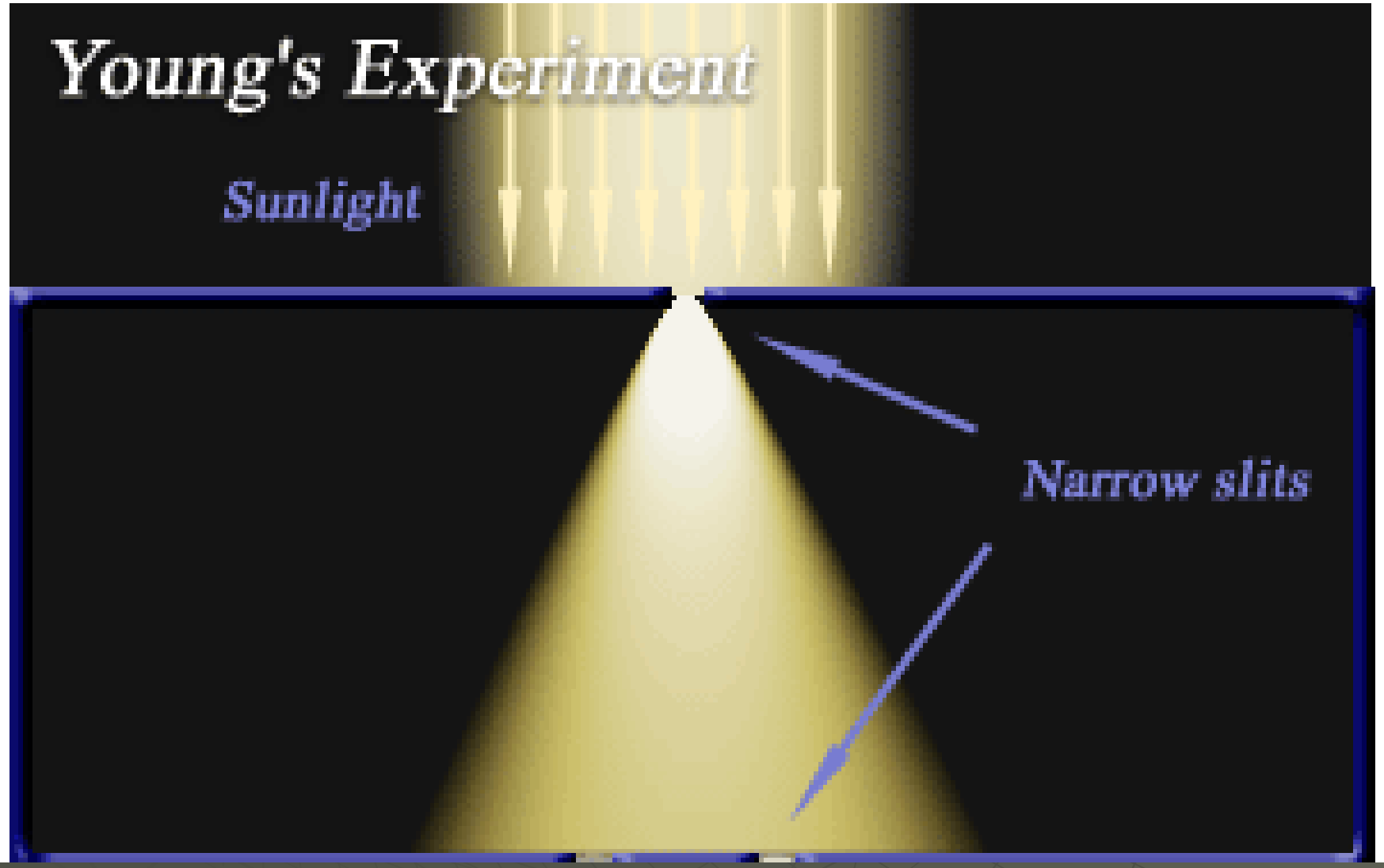
- He noticed that Sun light split into different colors through a prism
- Sun light contains all colors (white light)

Newton Round 2

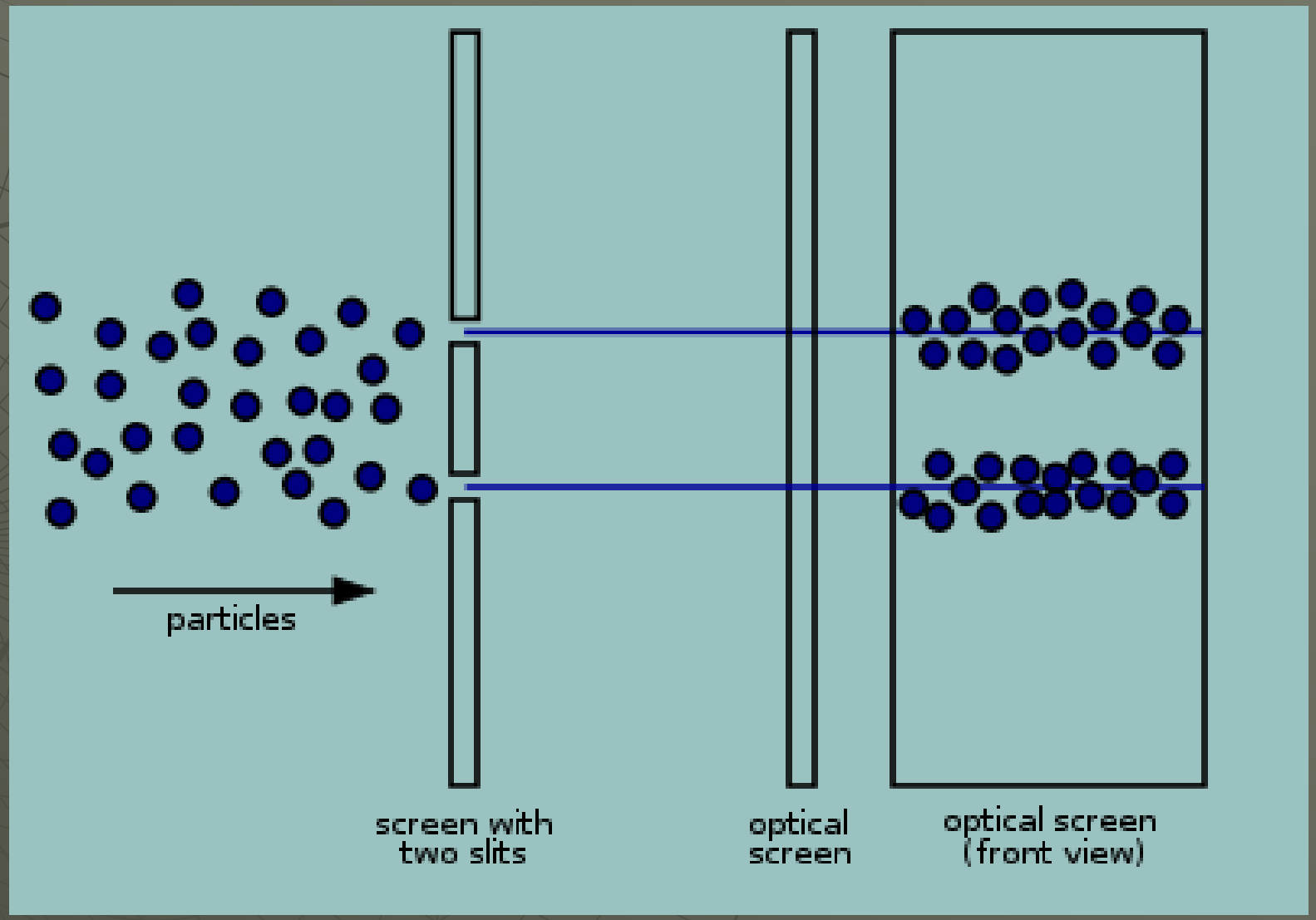
- Newton concluded that light is a particle!
  - Laser at a wall looks like a point.
- But wait, Another guy proposed that light could be a wave
  - Like water



Young Single Slit Experiment

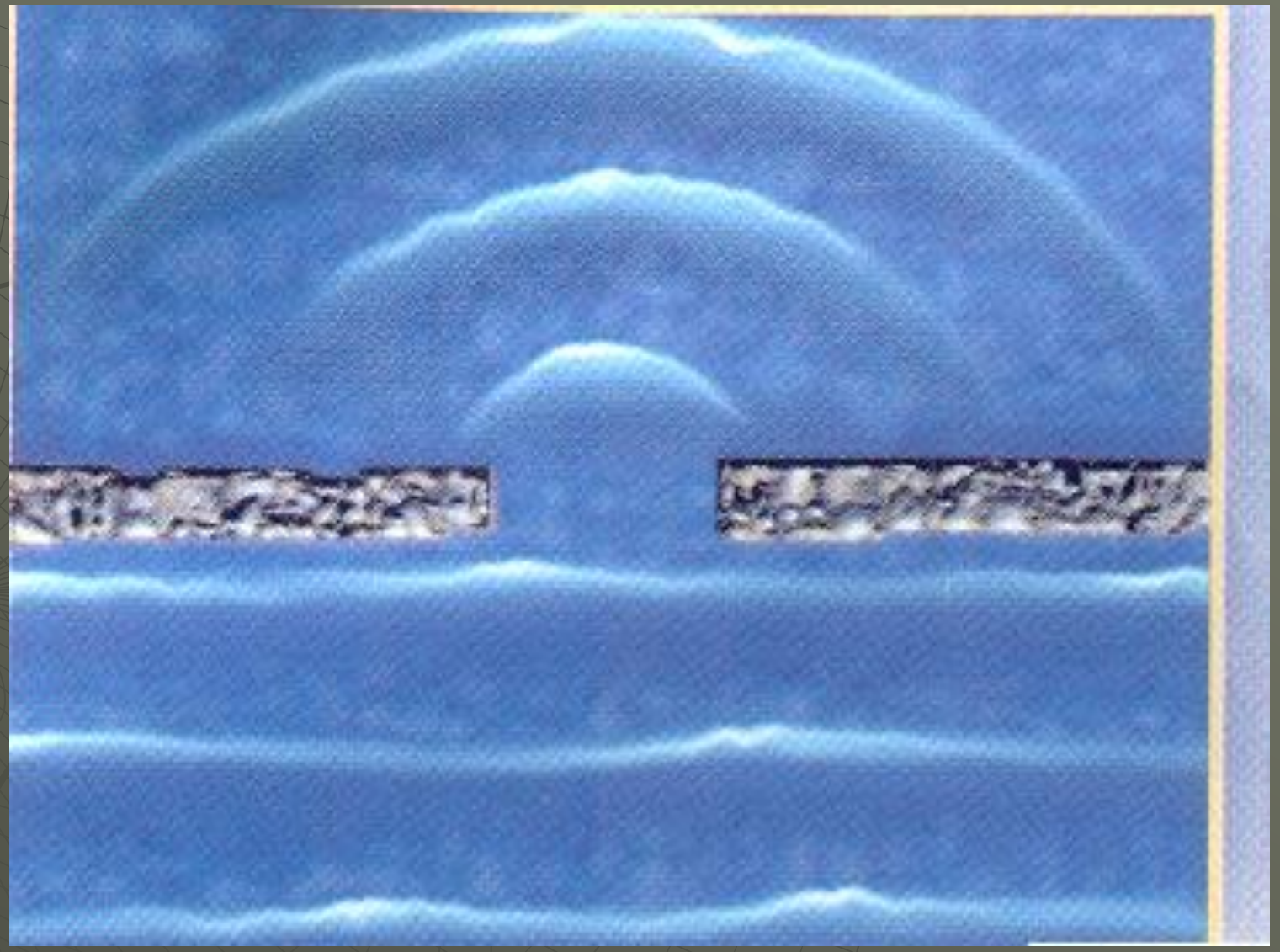


Light as a particle???



Water Waves

- Diffraction: the apparent bending of waves around small obstacles and the spreading out of waves past small openings.



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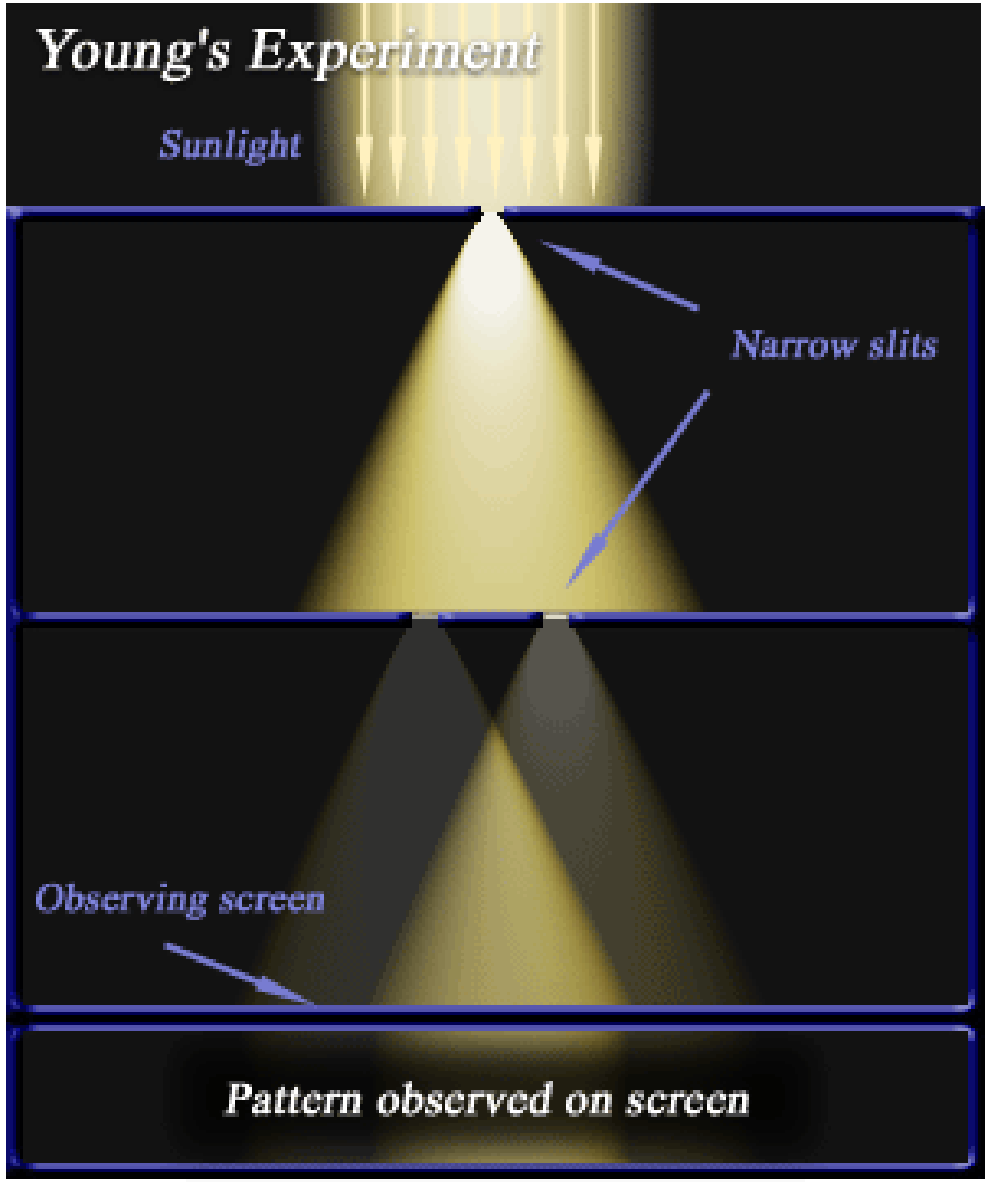
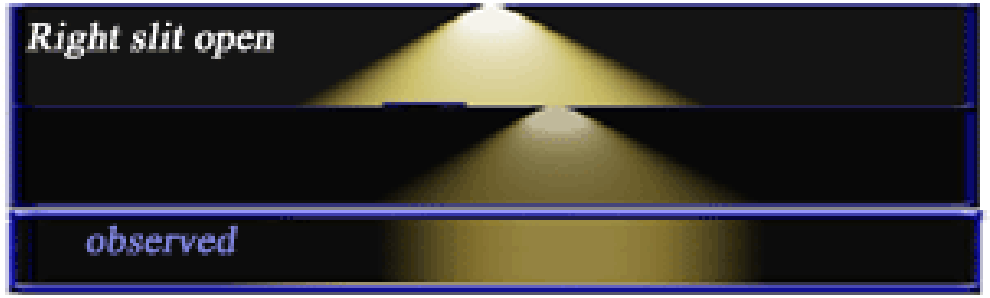
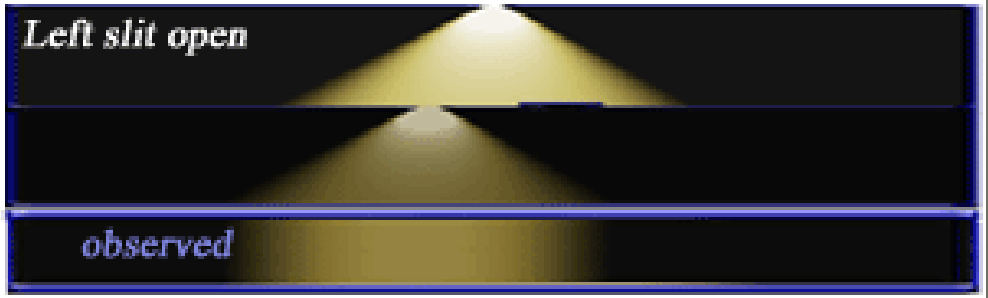
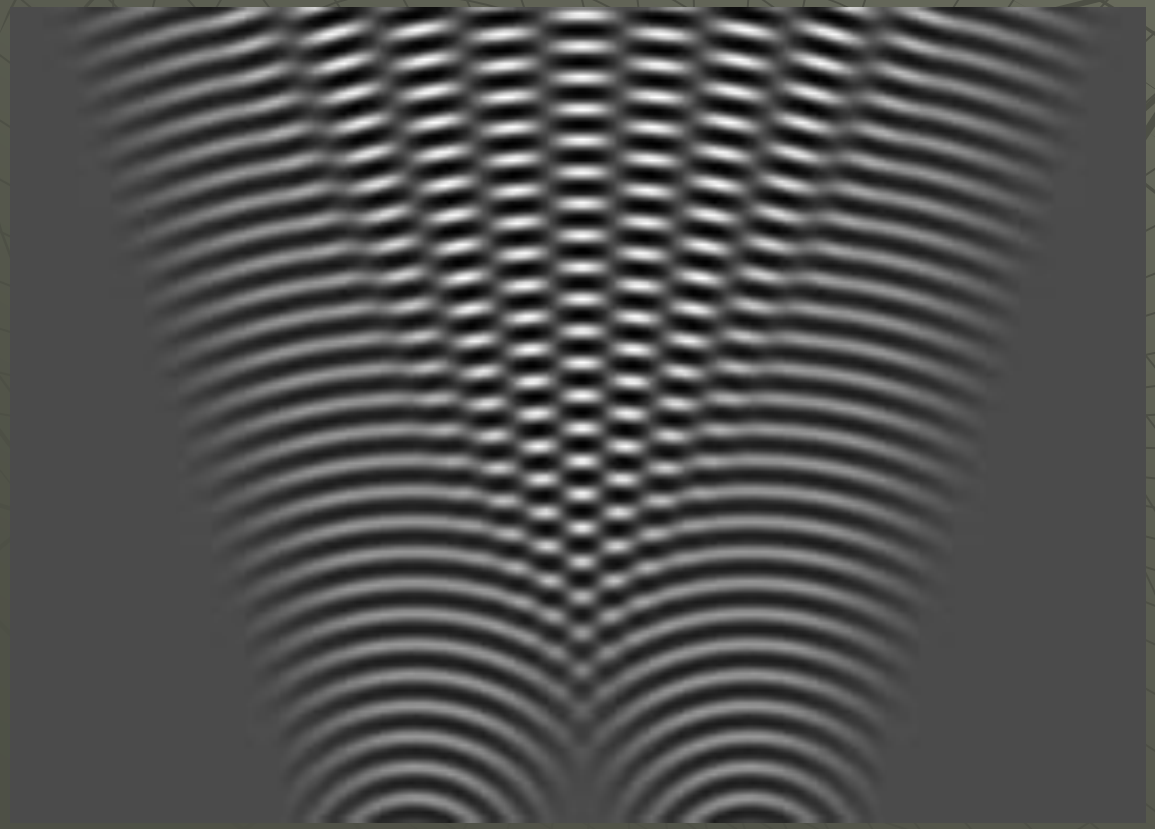


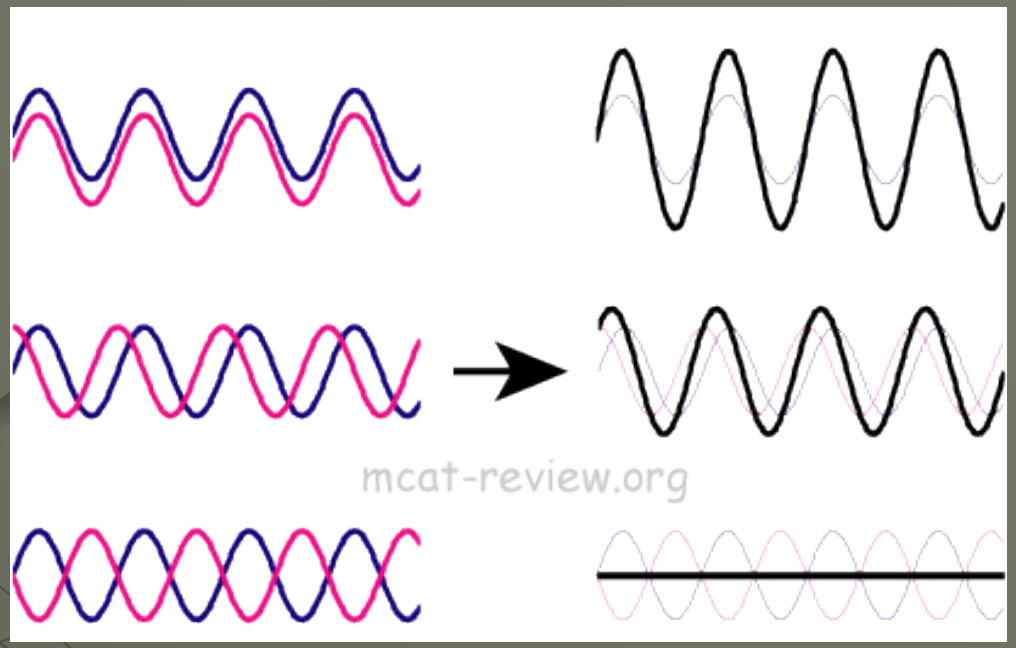


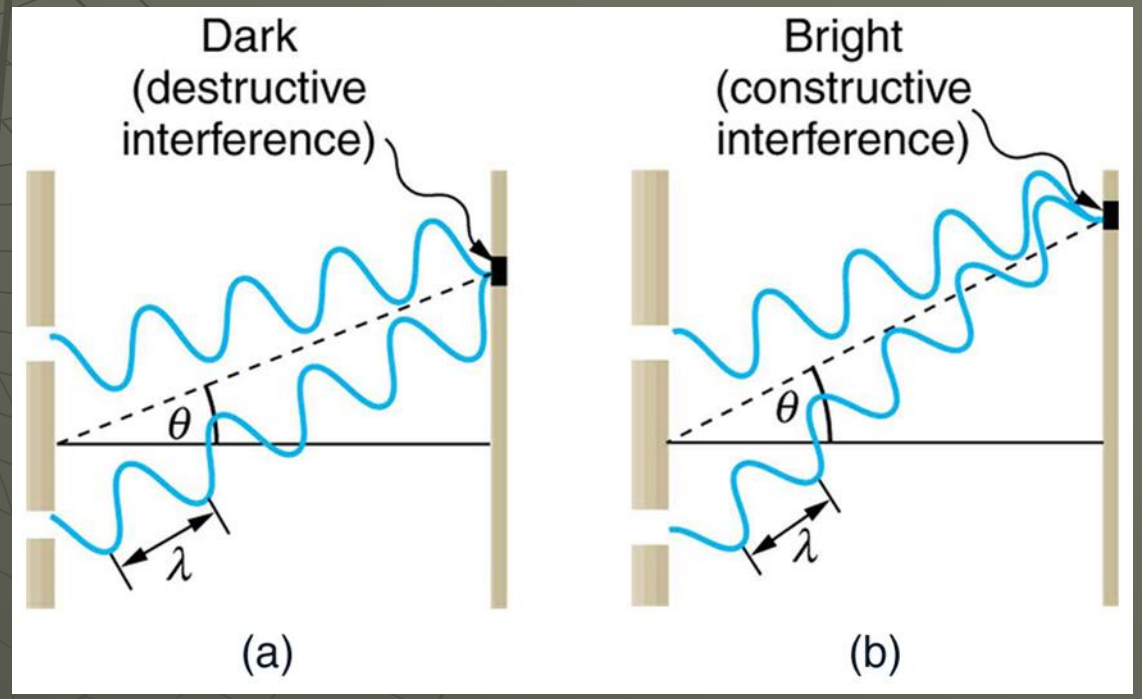


Is light a wave or a particle

- It's both!







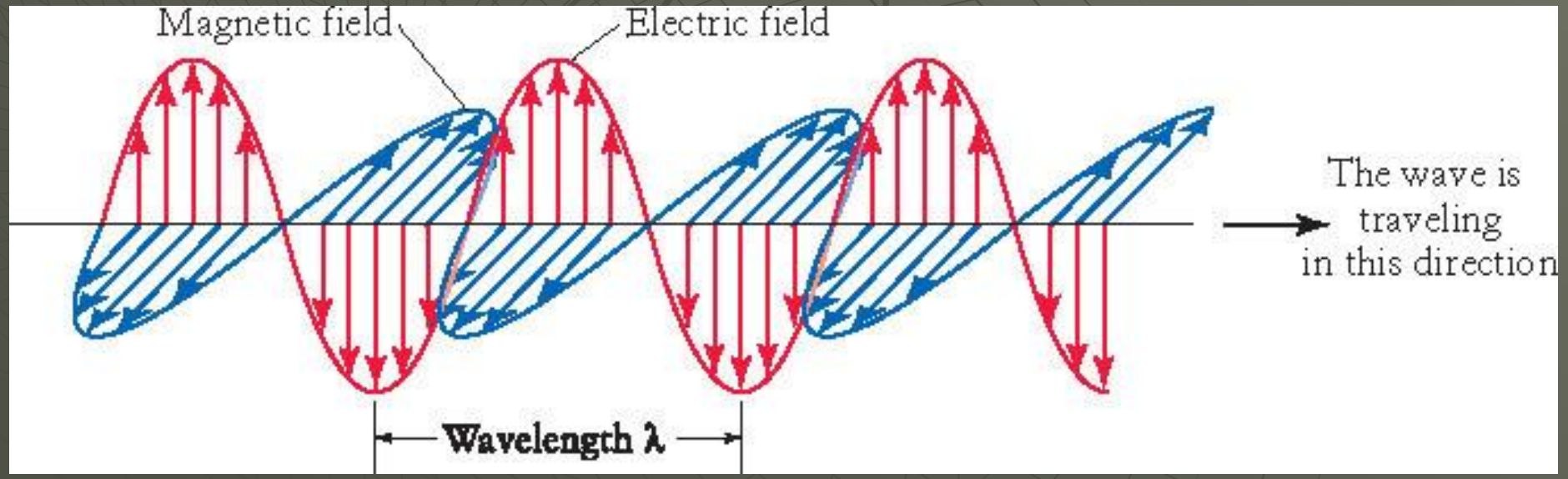
DEMO!

Wave Nature of Light

- Light is now known to be *electromagnetic radiation*

- Oscillating E and M fields. The distance between peaks is called the *wavelength (λ)*

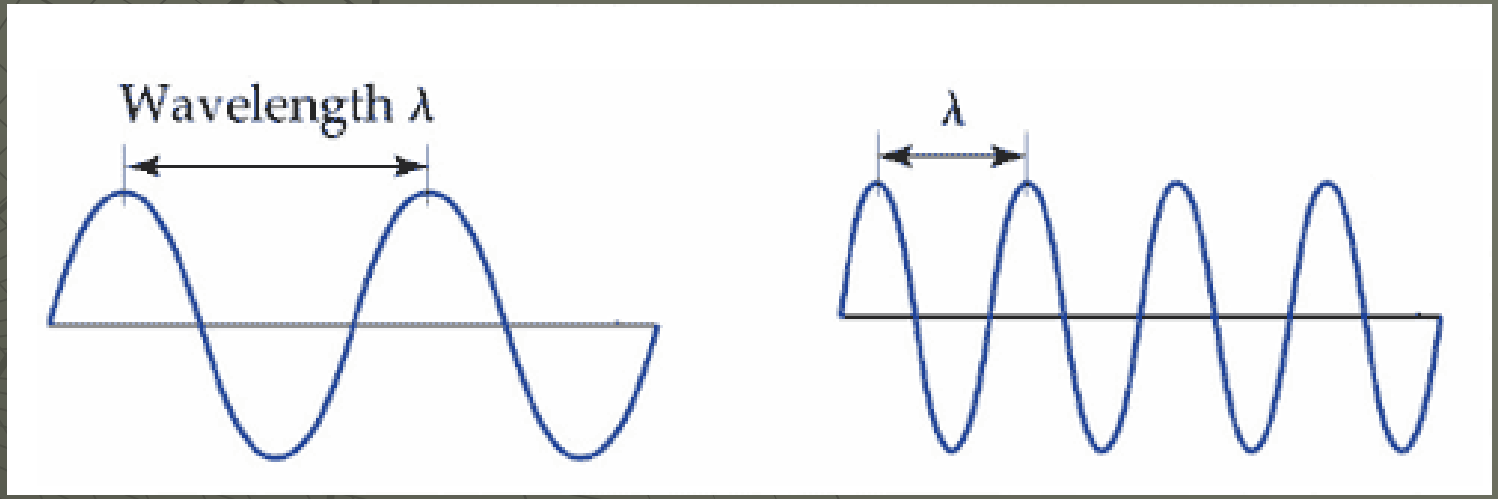
- *Remember the magnetic fields of planets*
  - *Caused by moving charged particles*



Properties of Light

- Speed: ALL FORMS OF LIGHT travel at same speed:
  - $C = 3.0 \times 10^8$ m/s

- Wavelength (λ): distance between 2 crests of wave
  - Unit: length; ex. Meters



- Frequency (f): vibrational rate of EM wave (cycles per second);
  - Unit: Hertz (1/time); ex. 1/sec

Photon Energy

- Relationship between f and λ:
  - Because "c" is a constant, as frequency goes *up*, wavelength goes *down*, and vice versa

$$c = f\lambda \quad (1/\text{sec} * \text{m})$$

- Each photon has a *specific* amount of energy, determined by its frequency or wavelength:

$$E = hf = hc/\lambda$$

- E = photon energy
- h = Planck's constant
- f = frequency

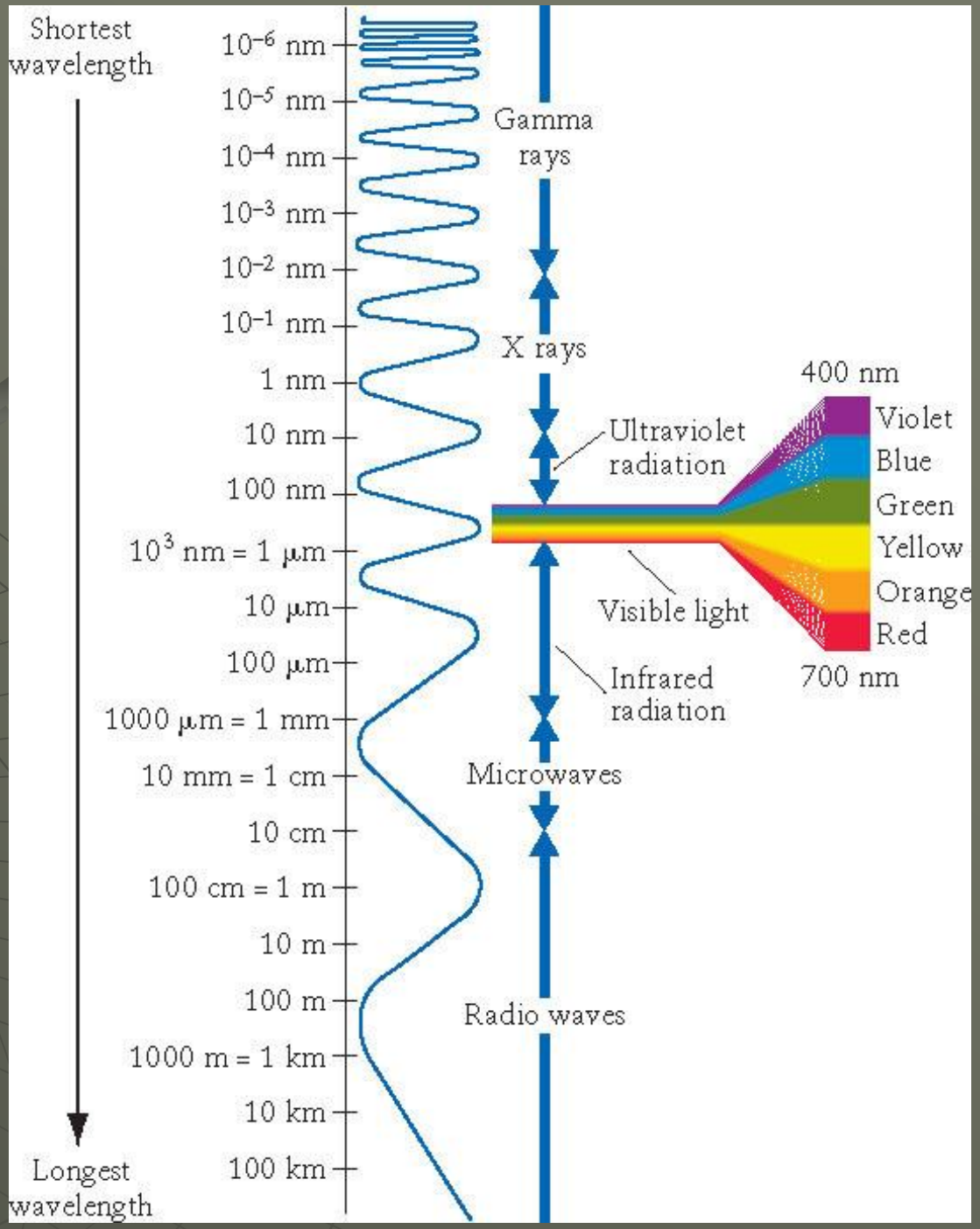
Wavelengths and Color

- Light can have any wavelength
- We call different ranges different types of light

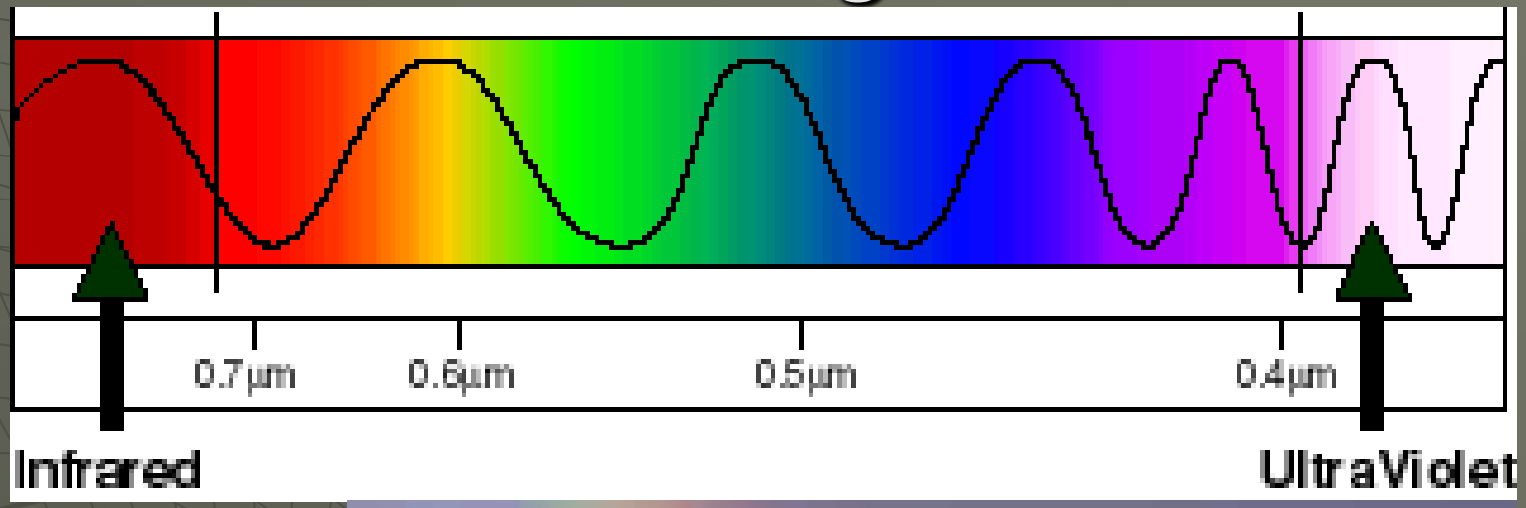
- Visible light λ~400-700 *nanometers (nm)*

1 nm = 10^{-9} m

Shorter λ → "bluer"
Longer λ → "redder"



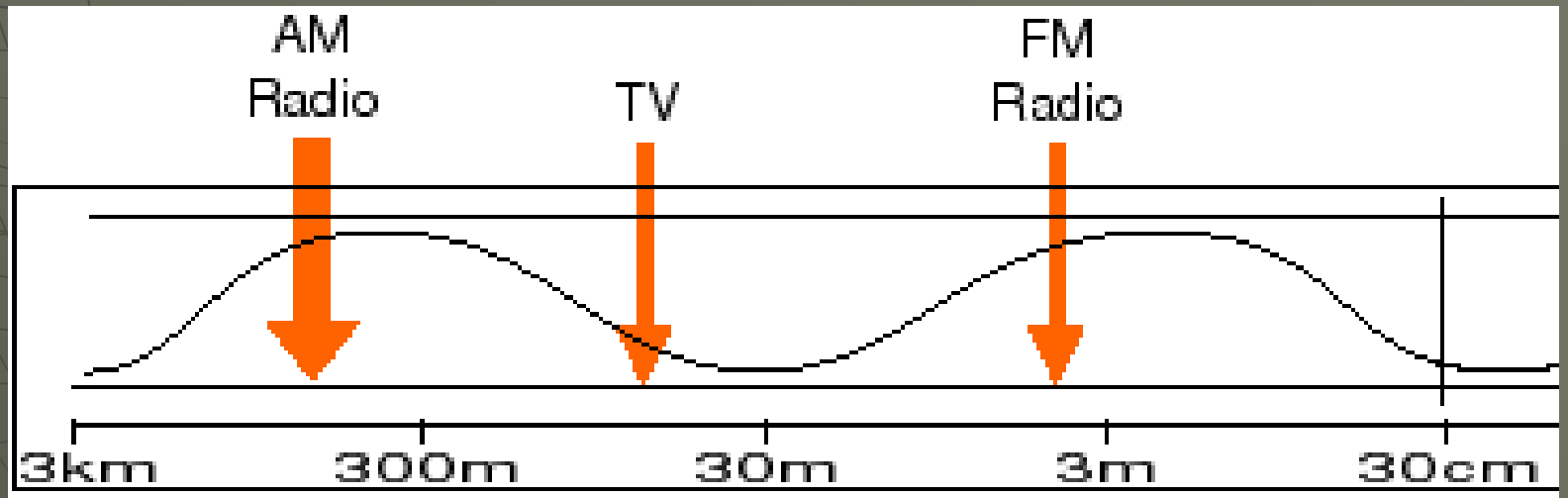
Visible Light



Our eyes are built to detect this kind of light

Likely due to the fact that the sun gives off more visible light than anything else

Radio Waves



Radio Wave Region of the Electromagnetic Spectrum

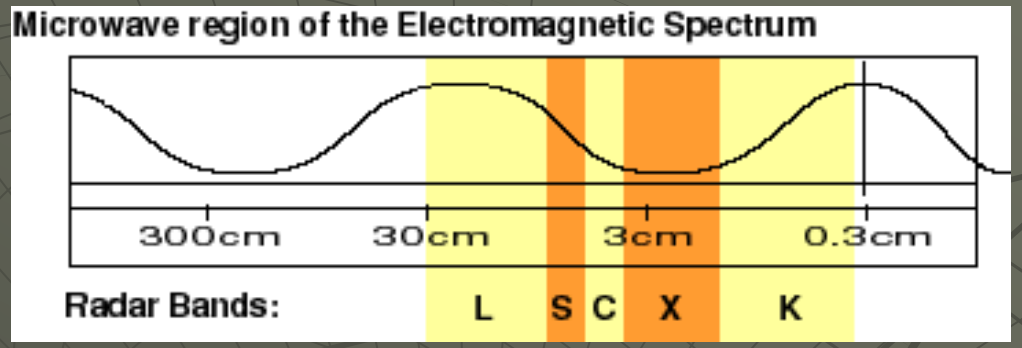
- Radio waves NOT sound waves, they are **light waves**

- But we commonly use them to encode and transmit ***audio information***

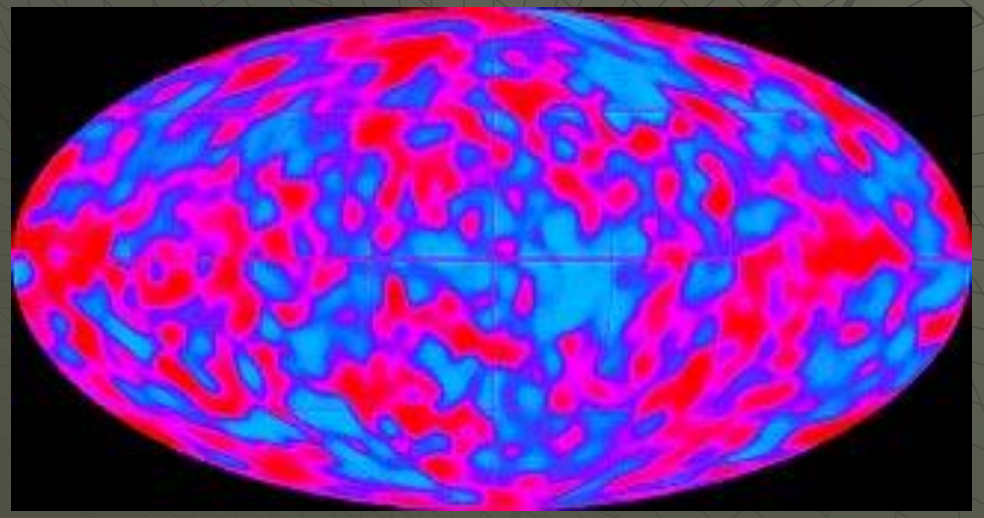
Extremely harmless radiation, unless transmitting the songs of one "David Hasselhoff"

"Dude, Nooo! Make it stop!"

Microwaves



Microwave oven



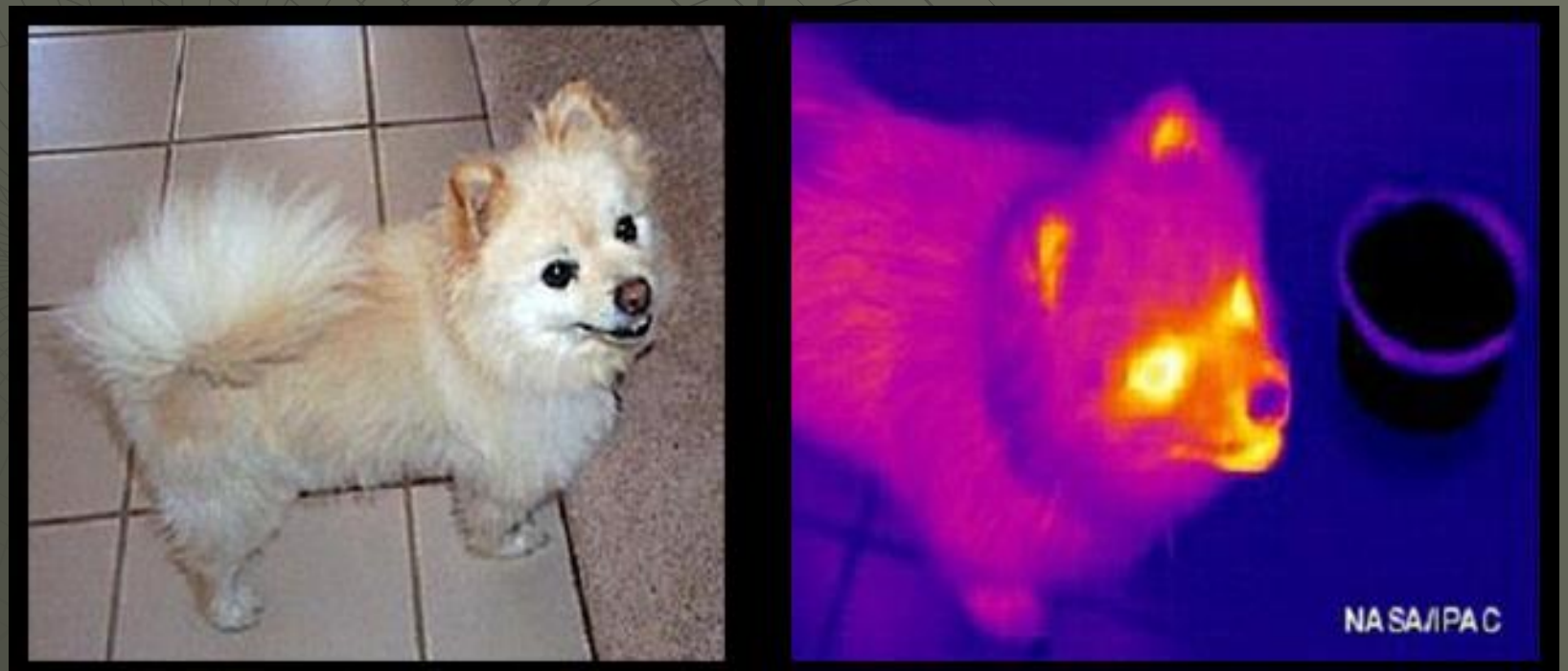
Cosmic microwave background

Microwaves have undermined the great accomplishments of cavemen, who spent thousands of frustrating years trying to get that stupid fire to light, so they could finally cook their steaks.

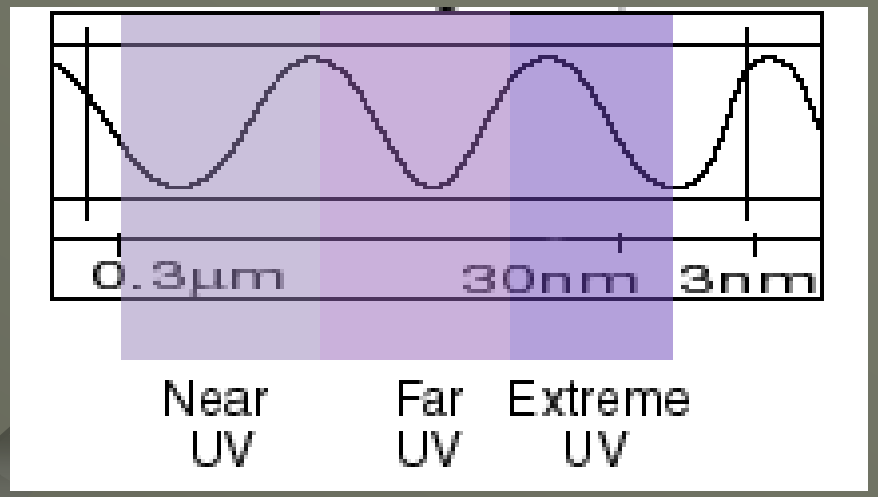
Infrared Radiation

We experience this radiation in the form of “heat”

Fires, people, hot stovetops, and little yapping dogs (otherwise known as uncoordinated barking cats) are all very “bright” in infrared radiation

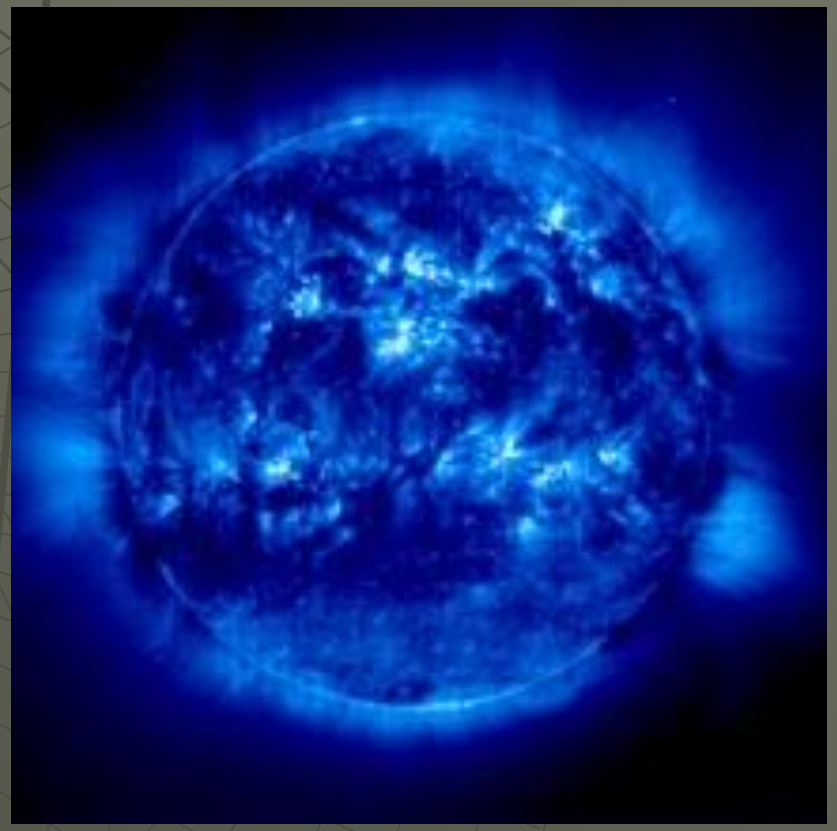


Ultraviolet Light



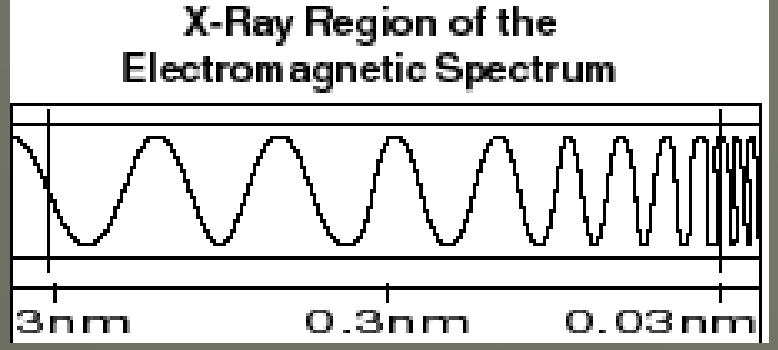
Some birds & bees can see UV as well as visible light.

In UV, flowers look more delicious?

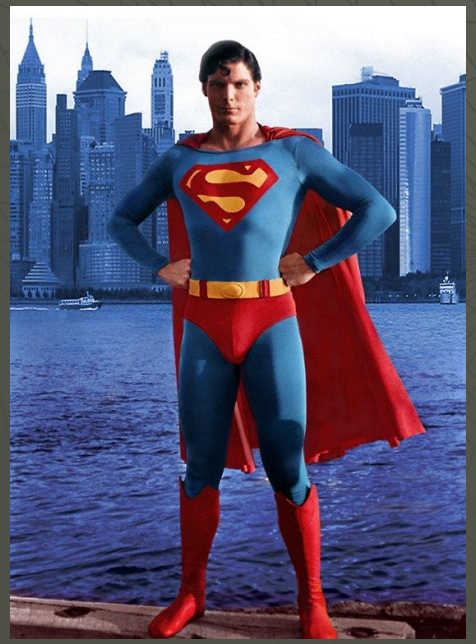


10% of sunlight is in the UV

X-rays

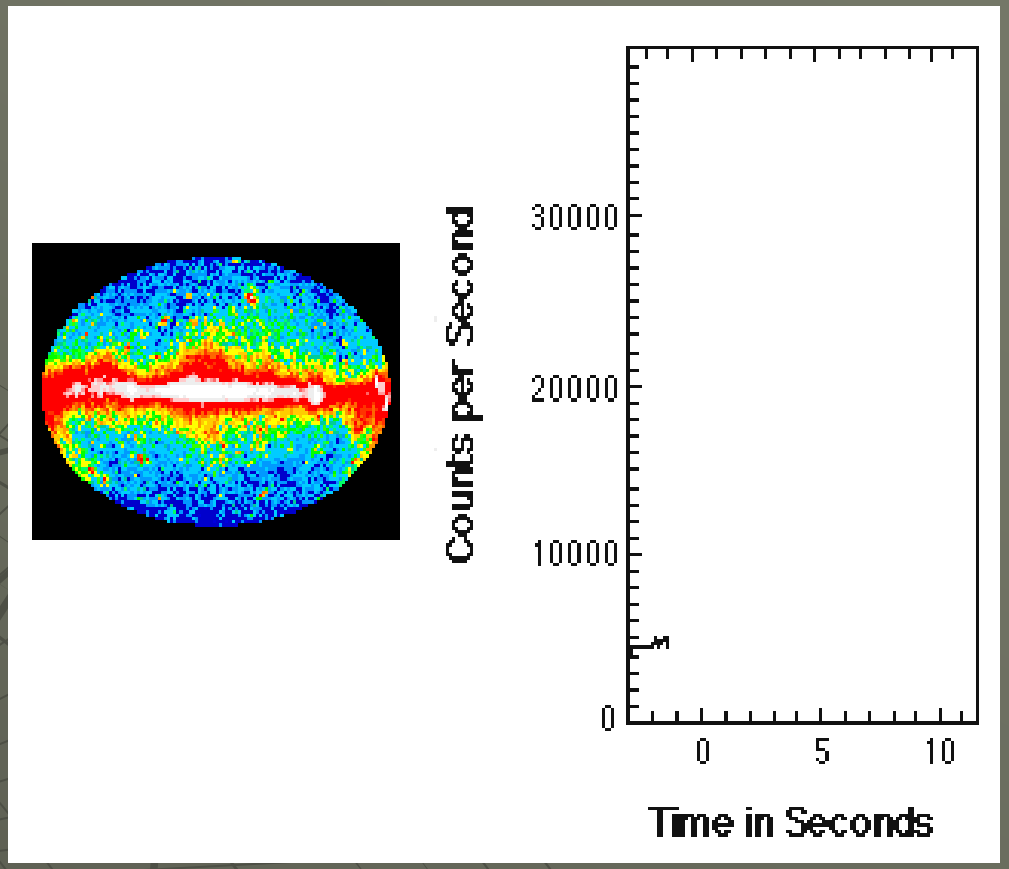


- Can pass through many materials quite easily
- X-ray vision vastly overrated
  - X-rays can be very, very harmful
  - Superman:
    - People will think you have the worst superpower ever



Gamma Rays

- Wavelength: 10^{-12} – 10^{-13} m
- A serious dose of gamma rays will mess you up, big time.



Gamma Ray Bursts (GRB):

Can release more energy in 10 seconds than released by the sun in 10 billion yrs.

TPS

1. Which of the following has the shortest wavelength?

A. ultraviolet light
B. green light
C. An X-ray
D. A radio wave

2. Which of the following has the lowest energy?

A. ultraviolet light
B. green light
C. An X-ray
D. A radio wave

3. You detect two different colors of light, yellow and green. You determine the wavelength of the green light to be *shorter* than that of yellow. The green light must

A. Be traveling slower than the yellow light
B. Have a higher frequency than the yellow light
C. Have a higher energy than the yellow light
D. B and C are true

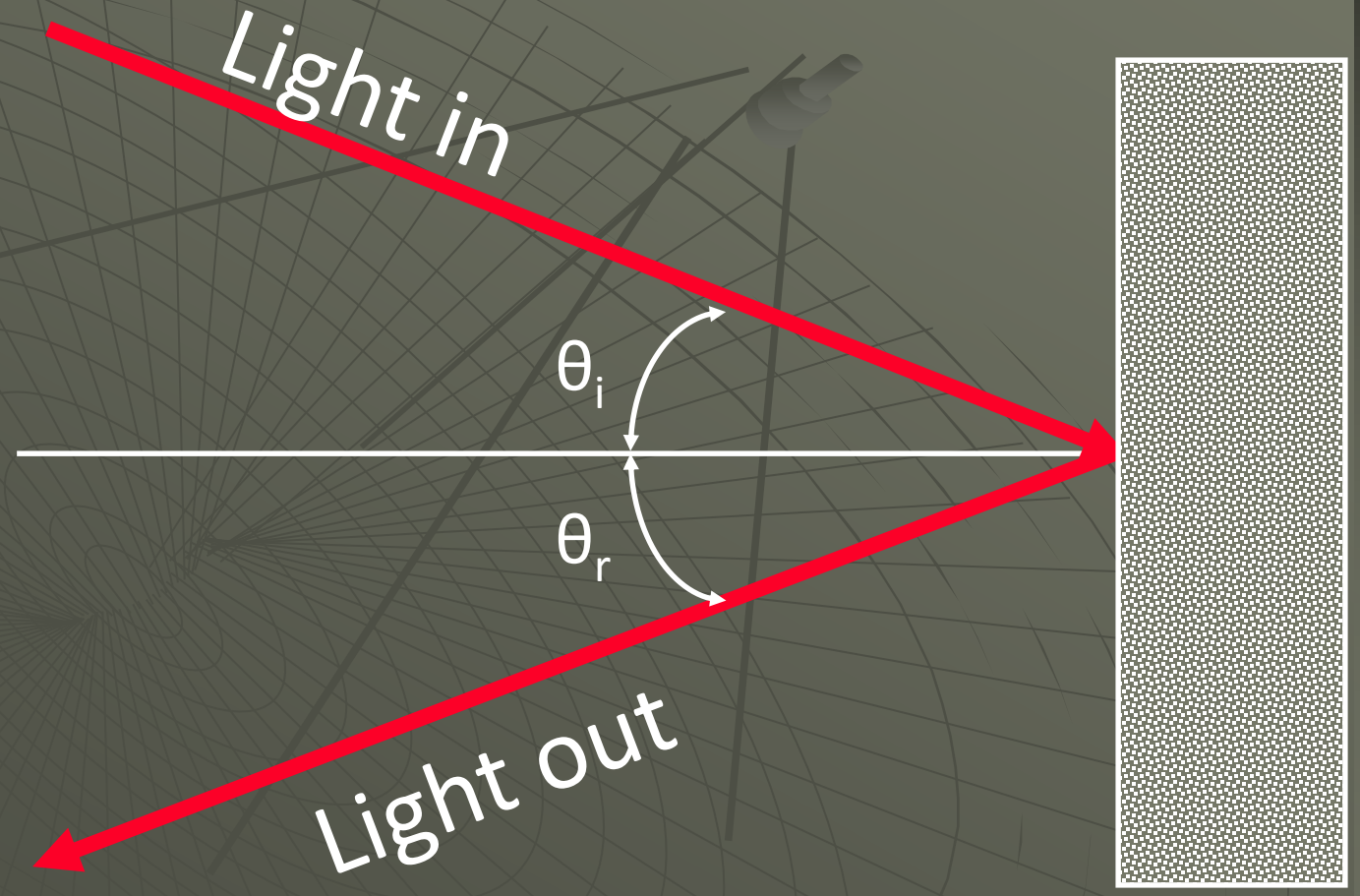
4. Which of the following would be true about comparing gamma rays and radio waves?

A. The radio waves would have a lower energy and would travel slower than gamma rays.
B. The gamma rays would have a shorter wavelength and lower energy than radio waves.
C. The radio waves would have a longer wavelength and travel the same speed as gamma rays.
D. The radio waves would have a shorter wavelength and higher energy than gamma rays.

LT

- EM spectrum

Reflection



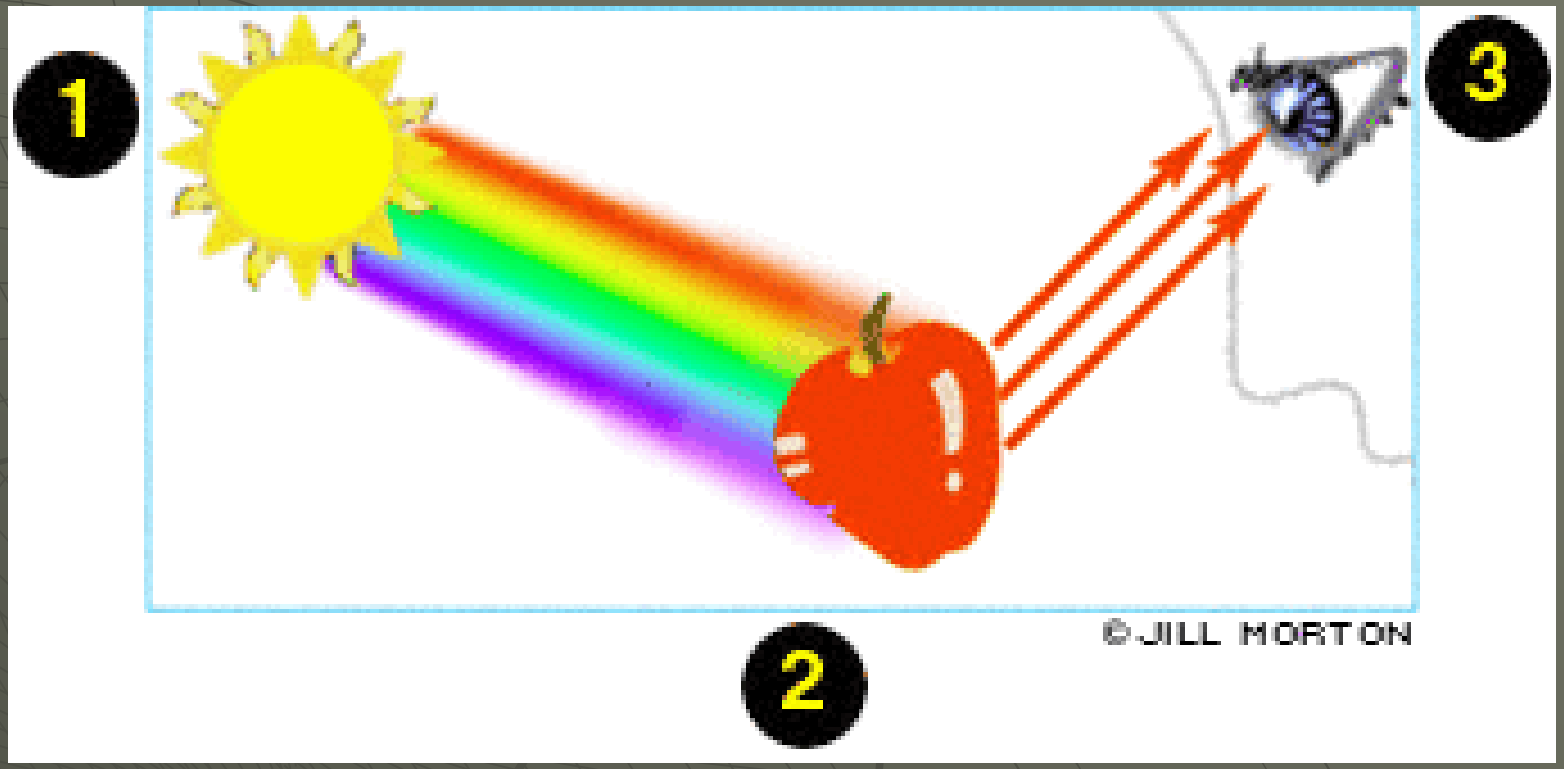
Refraction

- Light passes from one medium to another: speed changes
- Results in “bending” of light
  - Different colors bend at different angles
  - This spreads the light into component colors (eg., white light becomes a rainbow)

Tires Through Mud Analogy

- Big tires: long wavelength (bent less)
  - Easier to go through denser material
- Small tires: short wavelengths (bent more)
  - Harder to go through denser material

How Do We See Color?



1. Sun emits light at all wavelengths (white)
2. Apple absorbs all wavelengths but reflects red
3. Eye senses red light coming from the apple