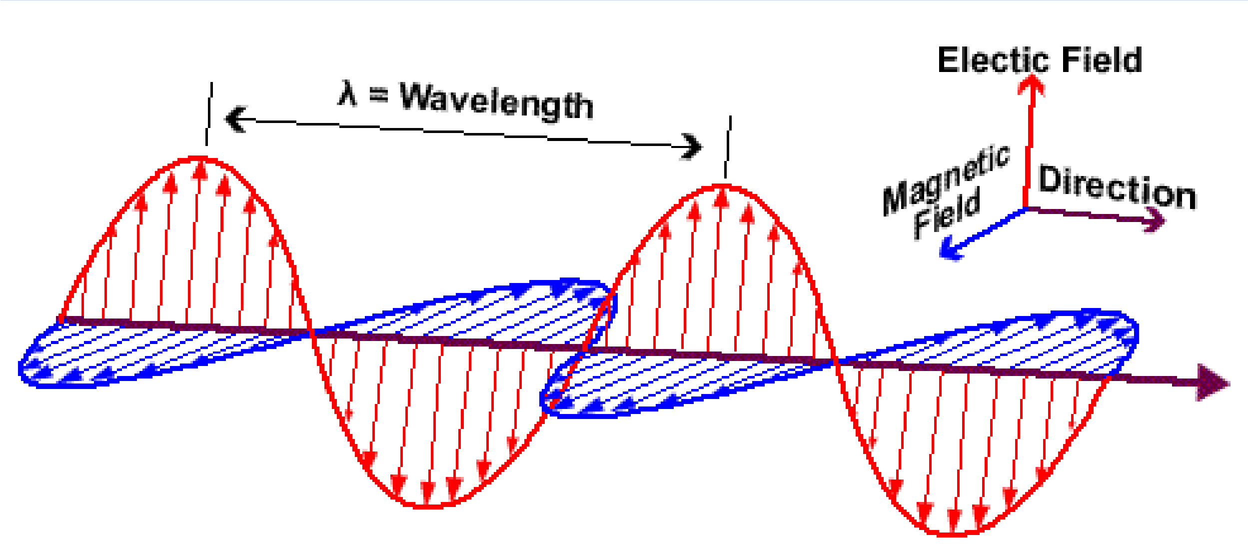
Traditional: 12-01
Themed: 02-01

What is light? Human vision, color mixing, blue skies, red sunset and how light dims.

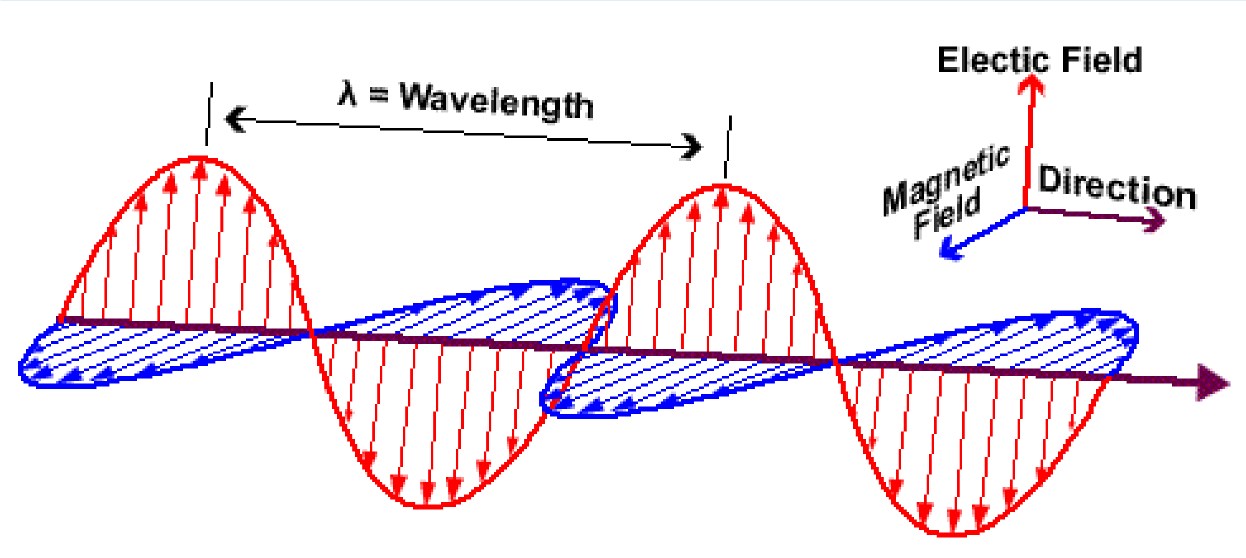
What light really is

- Energy moving in waves
- Electromagnetic radiation
- Changing mag. Field induces changing elec. Field which induces changing mag. Field…forever!
- Red hot iron emits light, do you emit light?



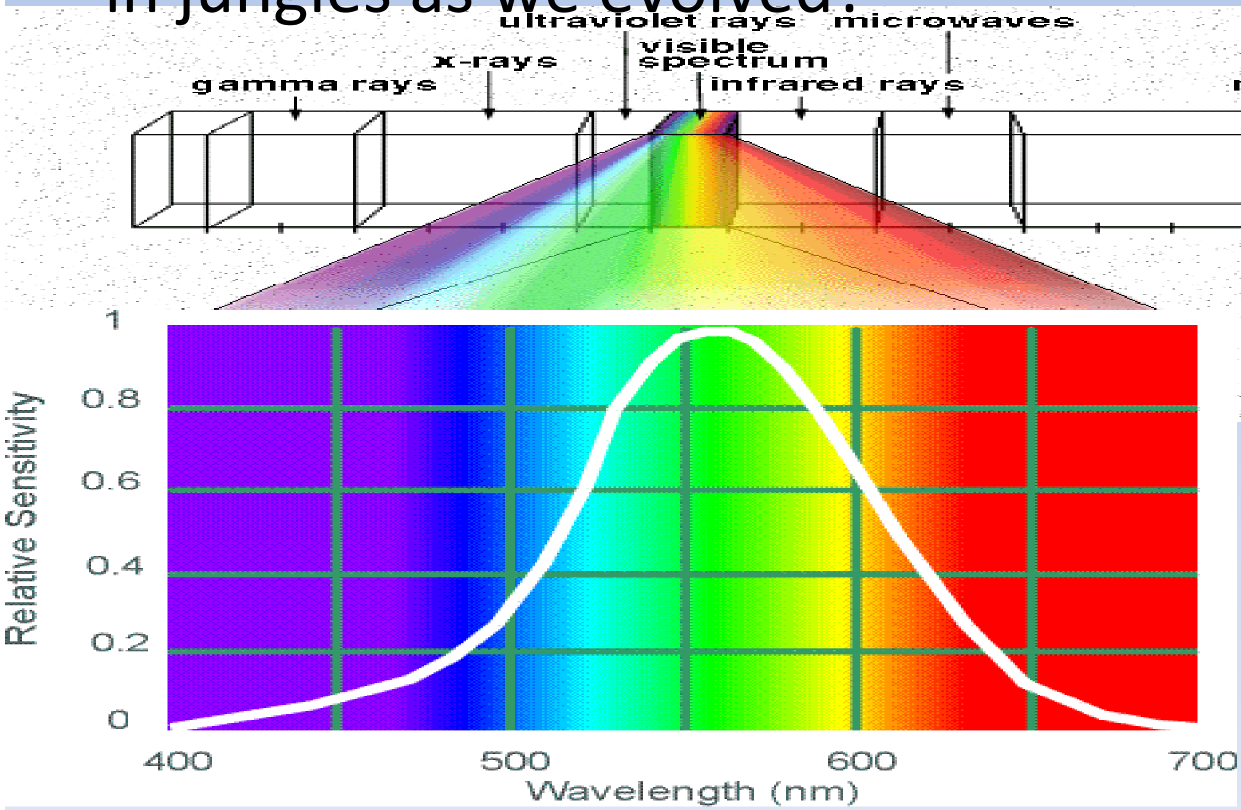
What light really is

- Light is a transverse wave (sound is longitudinal)
- Light exists because of induction, NO MEDIUM required!
- No medium means NOT a mechanical wave
- Light interacts with matter 3 ways:
  - Absorbs (heats up), reflects, transmits



Electromagnetic Spectrum

- Yes, you emit infrared radiation
- How night vision goggles can see you!
- Do you emit visible light?…sorry, nobody's that hot
- See how we're most sensitive to yellow-green. Helpful in jungles as we evolved?

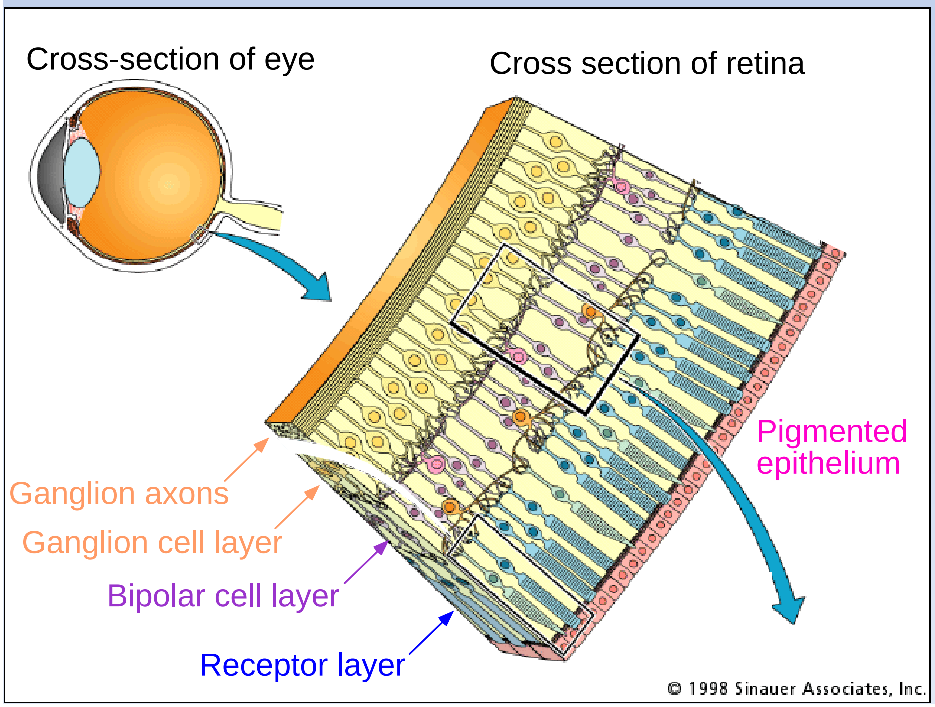


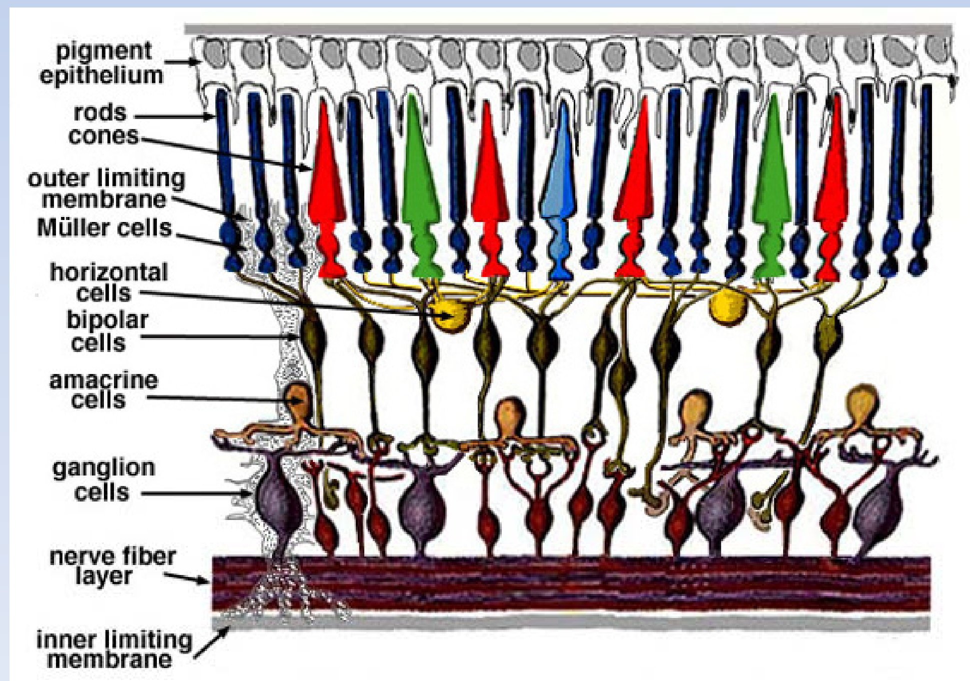
Human Luminance Sensitivity Function

http://www.yorku.ca/eye/photopik.htm

The Retina & Color Vision

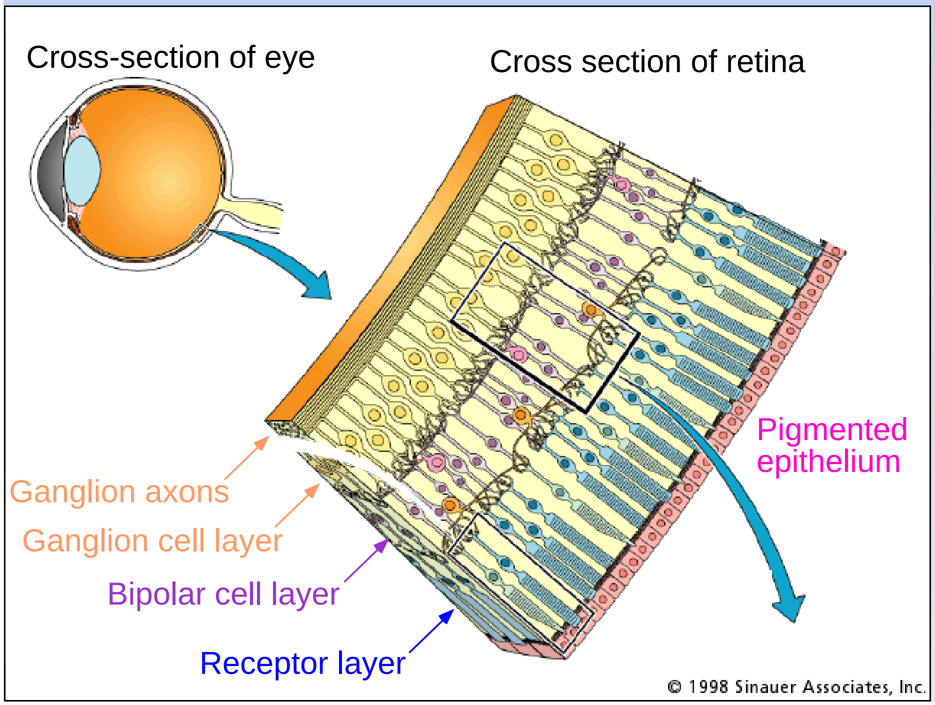
- Visible light – EMR that stimulates our retina (back of eye)
- Rods: Super sensitive to light – single photon is detected; no color capability (black and white vision, night vision)
- Cones: “Sharp vision” necessary for reading, color vision; nature gives us three types: R,G,B
- Red light: EMR frequencies that stimulation red cones
- Yellow light: EMR that stimulates both red and green cones equally

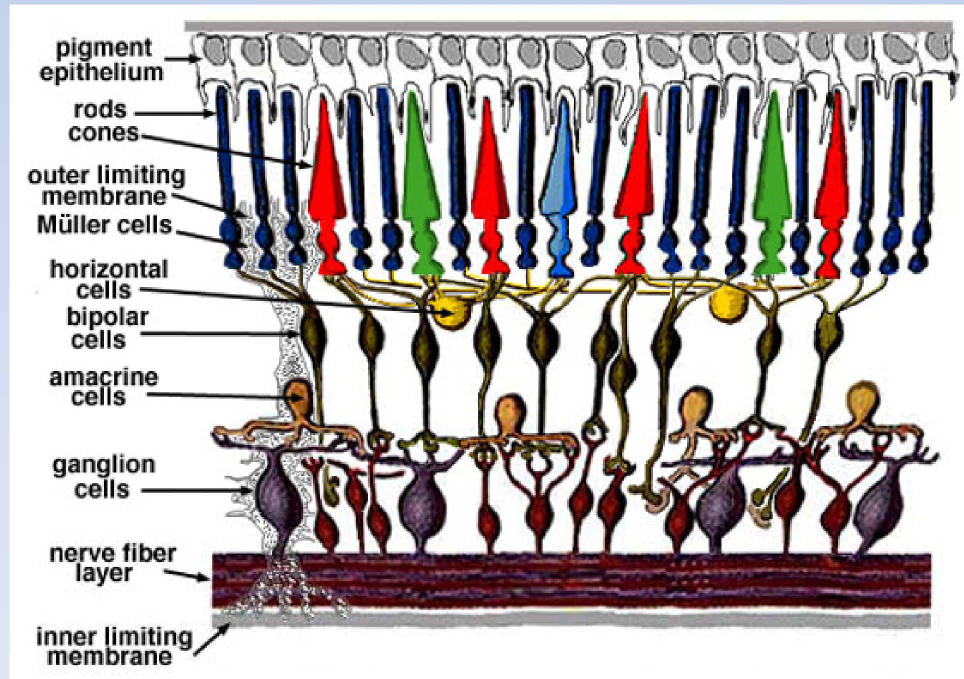




The Retina & Color Vision

•Fundamentally, we can see only combinations of three colors (RGB)
•If we see yellow as equal stimulation of R and G, is there such a thing as yellow light?
•"After images" form from cone fatigue of particular colors (demo?)
•Color deficiency: One of the three cone types not present (color blind)
•Color constancy: Colors form from the BRAIN'S processing of stimulation and the brain compensates for bad lighting (not dim)
•Individual points of light blend if they're too close (pointillism in art)





How we see colors

- We have three cones: RGB
- Large equal stimulation of all cones (RGB) is white
- No stimulation of any cones (RGB) is black
- What about equal stimulation
  - Two cones (3 possible combinations, demo?)
  - All three cones equal small stimulation?
    - (computer sim?)
  - How do we get the rich number of colors we see?
    - (computer sim?)

Additive color mixing

- Memorize which colors are in each RGB
- Recognize situations when two light sources are added together

Subtractive color mixing

- Everything we can see is based on three colors our eyes can sense, RGB
  - Primary subtractive colors are based on BRIGHT colors that reflect 2 of 3 RGB colors:
  - Cyan (BG), Yellow (RG), Magenta (RB)
- You see what is NOT absorbed (what IS reflected)
- Paints and pigments absorb certain colors and reflect others
- Mixing paints and pigments just makes things darker
- Examples……………

Three color model

- Humans have three cone types: Red, Green, Blue
- R, G, B: primary additive colors
- Looking at opaque object
  - See colors that reflect
  - Absorbed colors heat up object
- Looking at translucent object
  - Translucent means “clear” to some colors,
  - See the colors that don’t get absorbed (pass through)
- Three primary subtractive colors: C, Y, M
  - All are bright (reflect two of three RGB)
  - Cyan: Equal parts G, B
  - Yellow: Equal parts R, G
  - Magenta: Equal parts R, B
  - Black absorbs all light and reflect none
  - White reflects all light and absorbs none

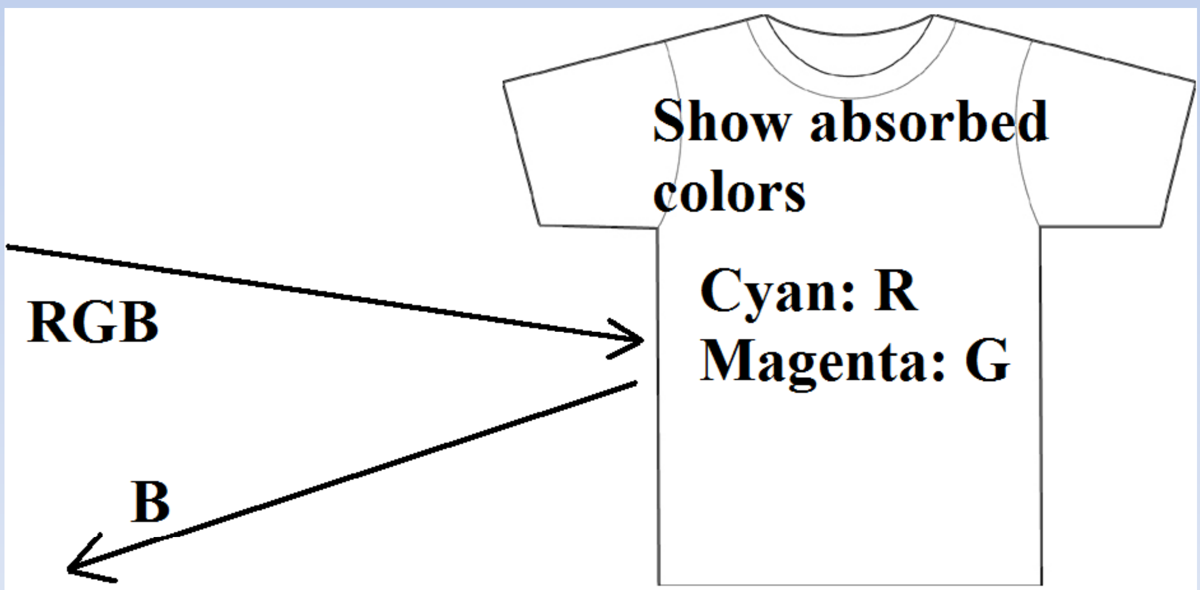
Example 1 – subtractive color mixing

- White light is shone upon a tshirt. The shirt has an even mix of cyan and magenta pigments. What color would an observer see?

Example 1 – subtractive color mixing

- White light is shone upon a tshirt. The shirt has an even mix of cyan and magenta pigments. What color would an observer see?

Solution:



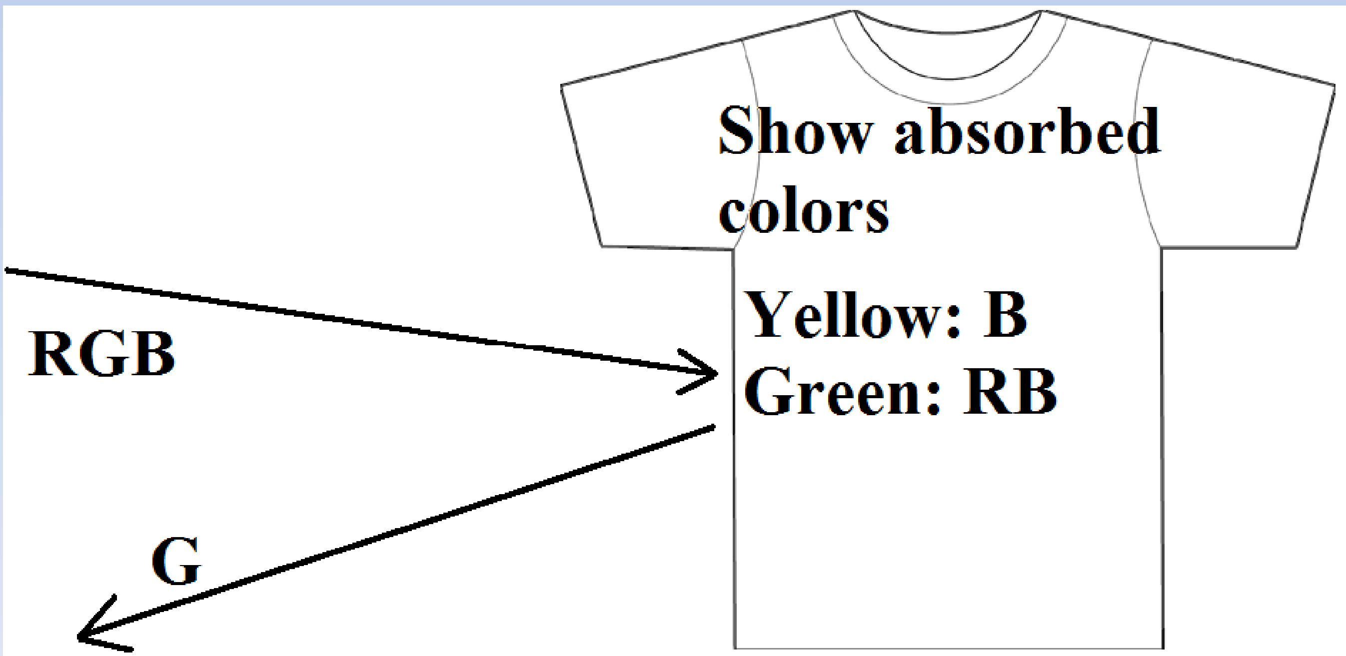
Example 2 – subtractive color mixing

- White light is shone upon a tshirt. The shirt has an even mix of yellow and green pigments. What color would an observer see?

Example 2 – subtractive color mixing

- White light is shone upon a tshirt. The shirt has an even mix of yellow and green pigments. What color would an observer see?

Solution:



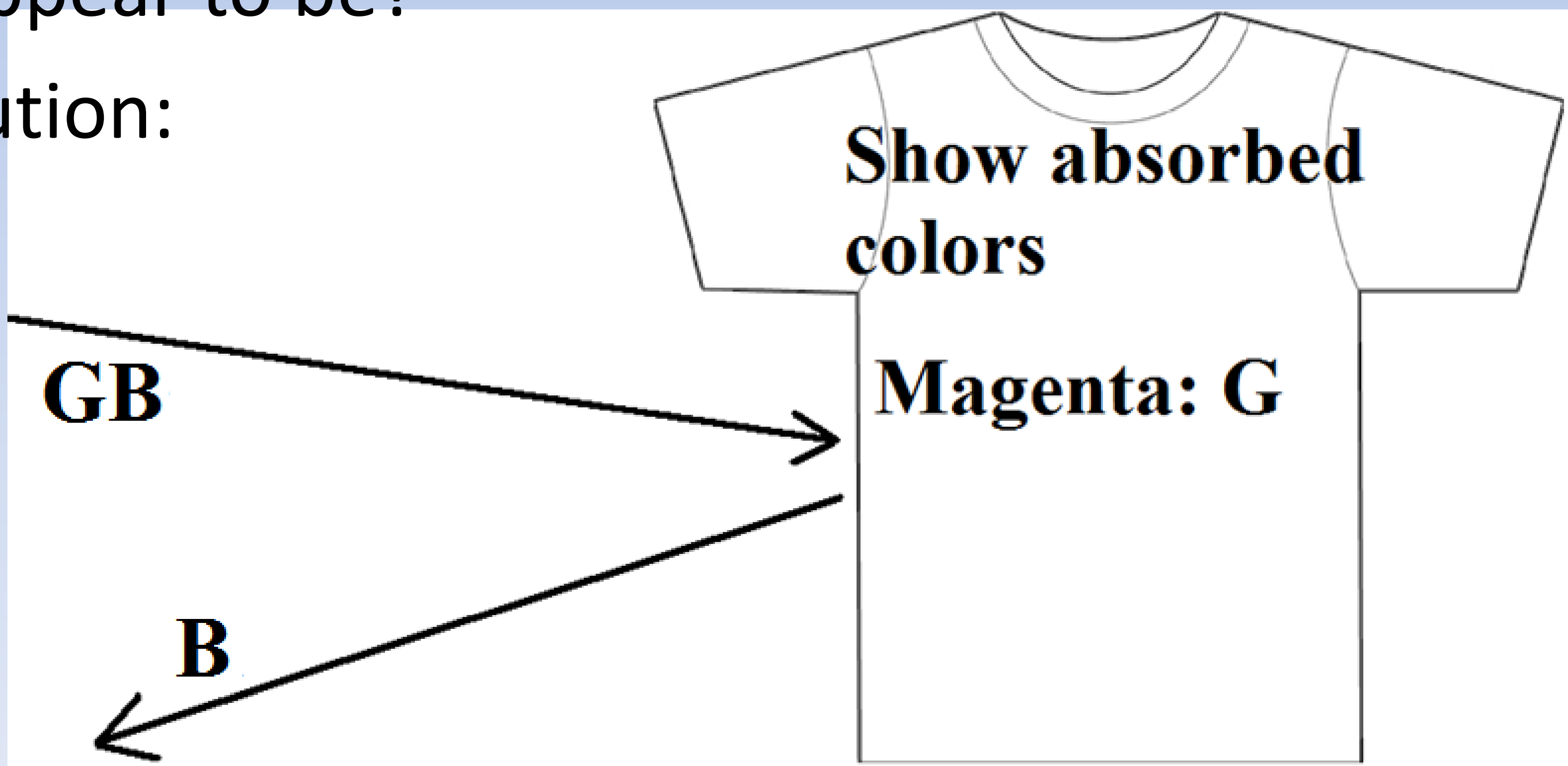
Example 3 – subtractive color mixing

- Stained glass also subtracts colors. For example, yellow stained glass takes white light and permits red and green to pass through and absorbs blue light. If white light passed through a cyan filter onto a magenta tshirt, what color would the tshirt appear to be?

Example 3 – subtractive color mixing

- If white light passed through a cyan filter onto a magenta tshirt, what color would the tshirt appear to be?

Solution:

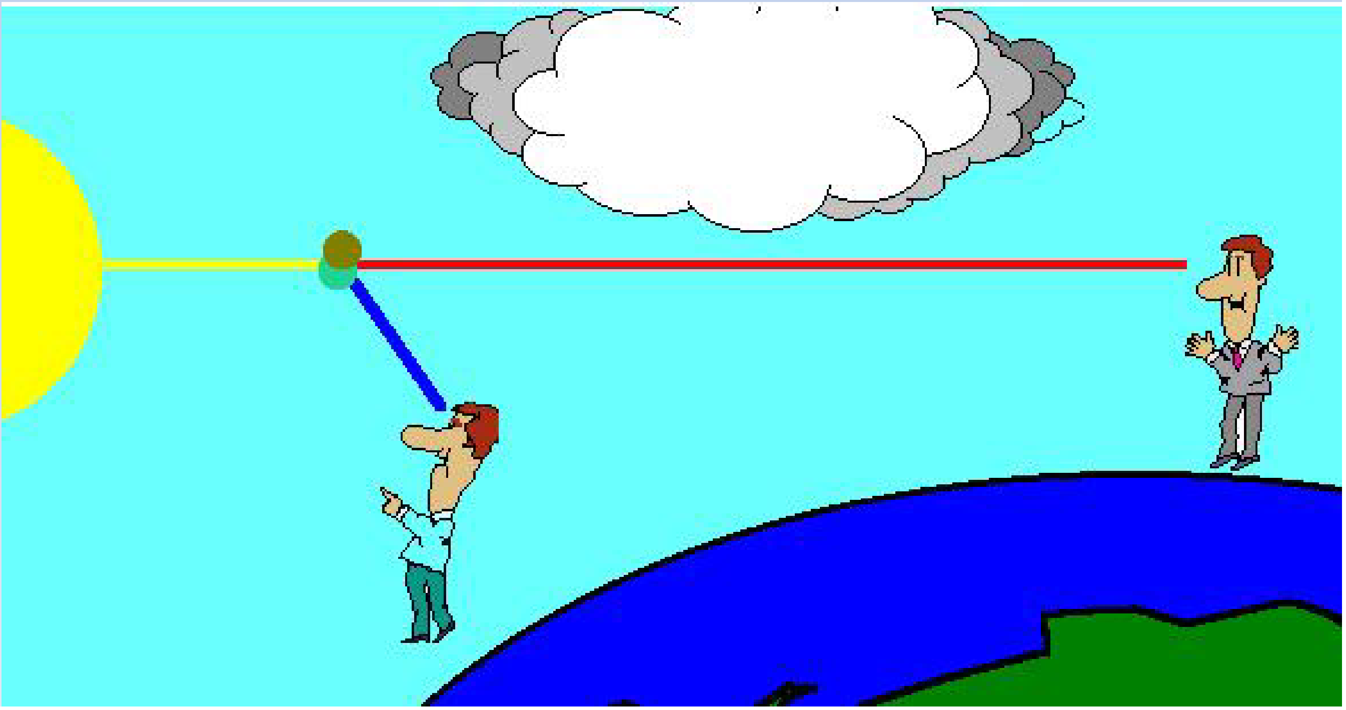


Why is the sky blue?

- Small waves, like light waves scatter when they interact with air molecules
- Violet (and blue) are the smallest light waves we can see, they scatter the most
- Red light waves are much larger (3x larger) and are 10x less likely to scatter than blue

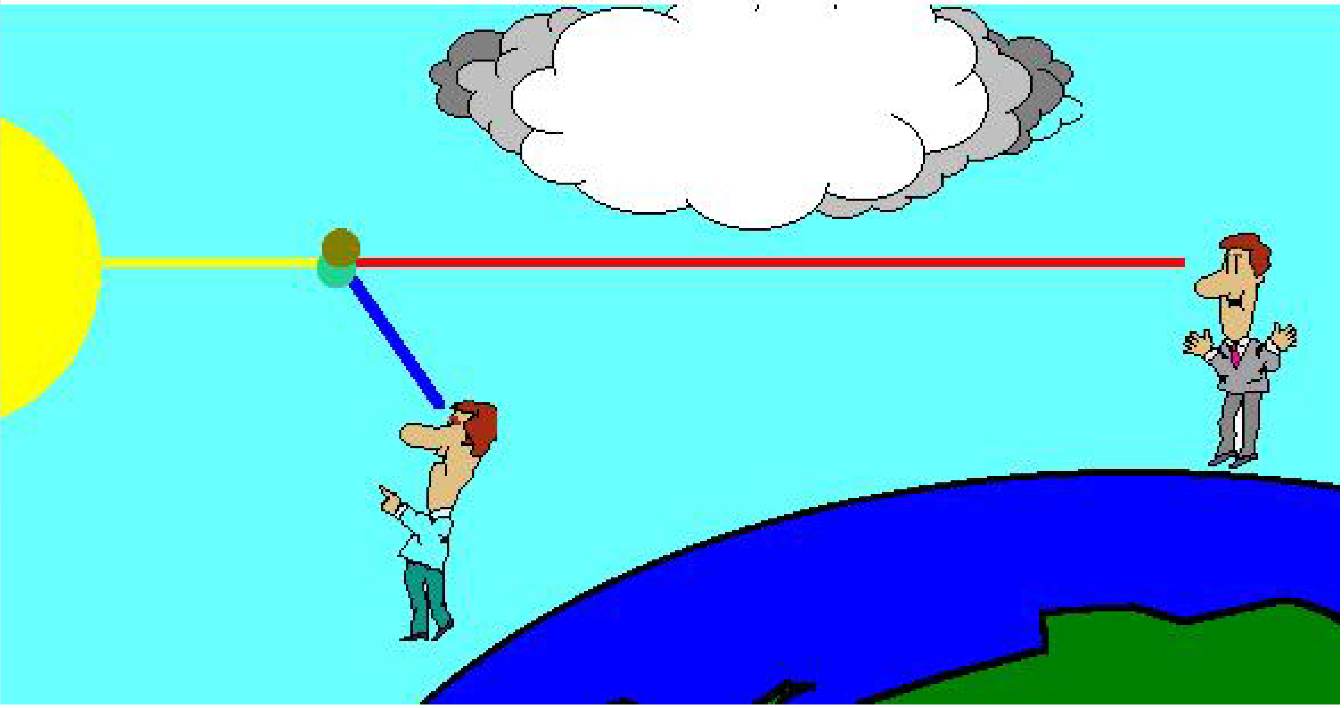
Why is the sky blue?

- Remember: Red light waves are much larger (3x larger) & are 10x less likely to scatter than blue
- Look at the sky-gazer guy on the left. The only light reaching is retina is scattered light (“deflected” by air molecules). What color reaches him?



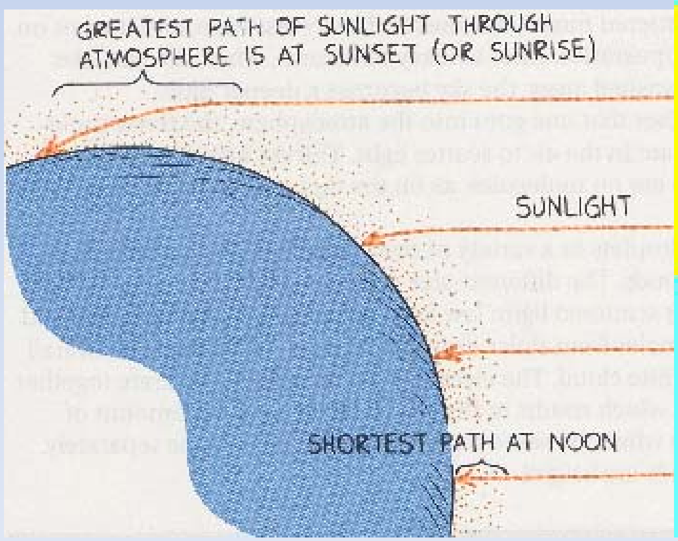
Why is the sky blue?

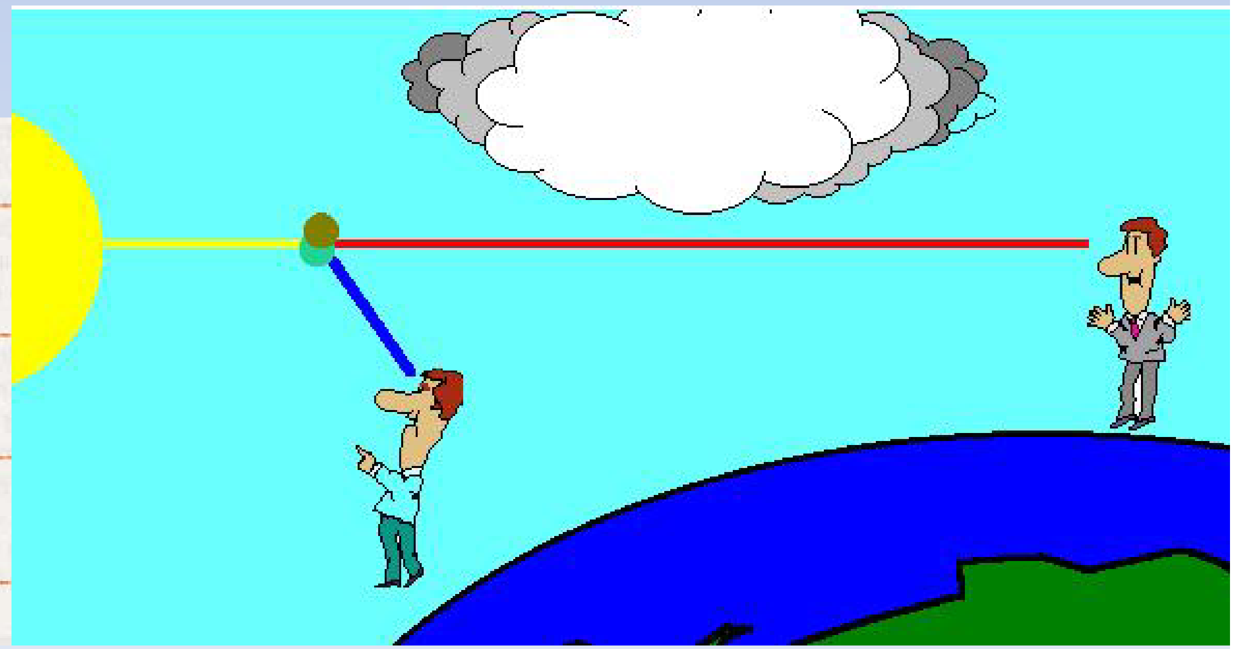
- Do you see why he sees a blue sky? There are 10x more blue photons reaching his retina than red.
- On the moon, there is no air to scatter light. No photons would reach his eye, since there's nothing to scatter them. What color is the moon's sky?



Why are sunsets red?

- Remember geometry? Since earth is like a circle, the "tangent-like" path at sunset means the sun's rays travel through much more air than at noon.
- The sun is sending us RGB, but with so much scattered from the long path, B's all gone, most of G is gone too.





How light dims with distance from light source

- Light intensity works exactly like sound intensity
- As light energy spread in all directions (concentric spheres), area sharing energy grows with r^2

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

Prefixes to MEMORIZE (for whole year)

- Why?
  - *How many Gigs does your I-pod have? Ever hear of nano technology? Songs take up about 4 MB of space? A common speed limit in Canada might be 80 km/hr, eh. I need a 2 TB drive to store all my files for school. My phone at home communicates at 5.8 GHz, my old phone used 900 MHz.*
  - *You need to know metric prefixes to buy the right thing and understand technology, rules of the road, medication doses. Etc.*
  - *These prefixes will follow you the rest of your lives and I'm holding you responsible to memorize them.*
- Sample problem: Green light's wavelength is about 450 nm. What is the frequency of this light in THz? (667 THz)

Prefix	Symbol	Amount as #	Amount as exponent
Tera	T	Trillion	10^{12}
Giga	G	Billion	10^{9}
Mega	M	Million	10^{6}
Kilo	K	Thousand	10^{3}
Centi	C	Hundredth	10^{-2}
Milli	m	Thousandth	10^{-3}
Micro	µ	Millionth	10^{-6}
Nano	n	Billionth	10^{-9}