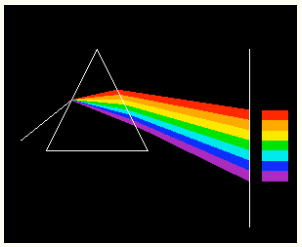


Light

Color

Color Addition & Subtraction

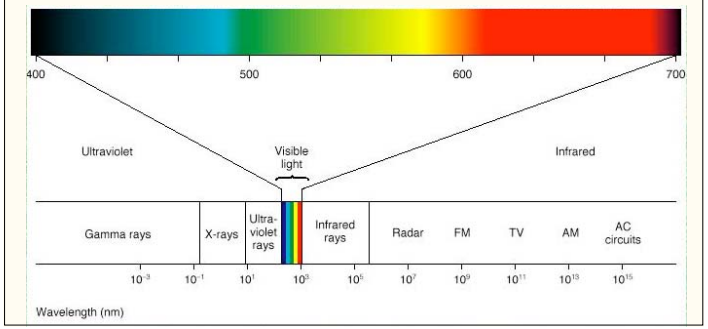
Spectra

What do we see?

- Our eyes can't detect intrinsic light from objects (mostly infrared), unless they get "red hot"
- The light we see is from the sun or from artificial light (bulbs, etc.)
- When we see objects, we see *reflected* light
  - immediate bouncing of incident light (zero delay)
- Very occasionally we see light that has been absorbed, then re-emitted at a different wavelength
  - called fluorescence, phosphorescence, luminescence

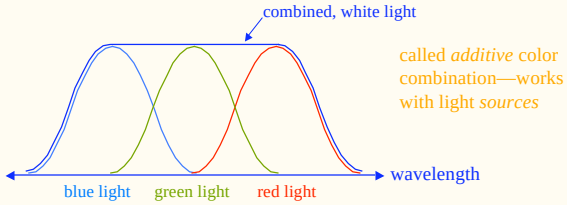
Colors

- Light is characterized by frequency, or more commonly, by wavelength
- Visible light spans from 400 nm to 700 nm
  - or 0.4 μm to 0.7 μm; 0.0004 mm to 0.0007 mm, etc.

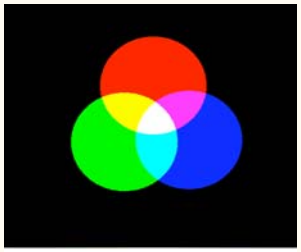


White light

- White light is the combination of all wavelengths, with equal representation
  - "red hot" poker has much more red than blue light
  - experiment: red, green, and blue light bulbs make white
  - RGB monitor combines these colors to display white



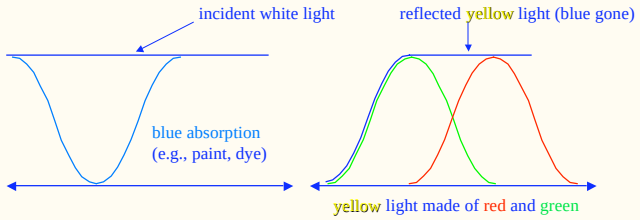
Additive Colors



- Red, Green, and Blue light sources can be used to synthesize almost any perceivable color
- Red + Green = Yellow
- Red + Blue = Magenta
- Green + Blue = Cyan
- These three dual-source colors become the primary colors for subtraction
  - why? because absence of green is magenta
  - absence of red is cyan, etc.

Subtractive colors

- But most things we see are *not* light *sources*
- Reflection *takes away* some of the incident light
  - thus the term *subtractive*
- If incident light is white, yellow is *absence* of blue



Questions

- Why, when you mix all your paints together, do you just get dark brown or black? Why not white?
- Why is the sky blue, and the low sun/moon orange? Are these related?

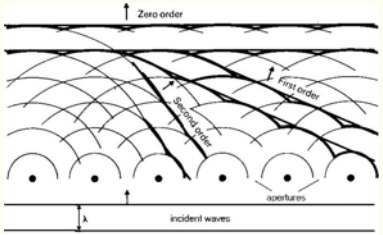
Introduction to Spectra

- We can make a spectrum out of light, dissecting its constituent colors
  - A prism is one way to do this
  - A diffraction grating also does the job

- The spectrum represents the wavelength-by-wavelength content of light
  - can represent this in a color graphic like that above
  - or can plot intensity vs. wavelength

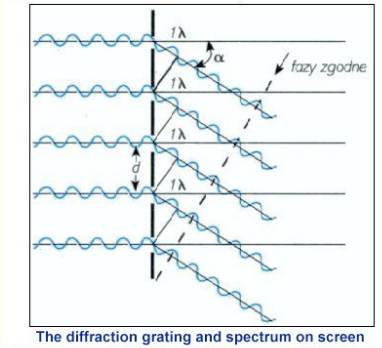
How do diffraction gratings work?

- A diffraction grating is a regular array of optical scattering points
  - spherical wave emerges from each scattering point
  - constructively or destructively interfere at different angles depending on wavelength



Another look at diffraction gratings

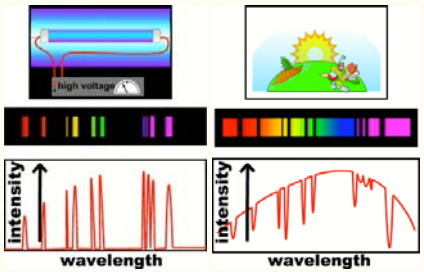
- For a given wavelength, a special angle will result in constructive interference: $d \times \sin\alpha = \lambda$
  - this angle is different for different wavelengths



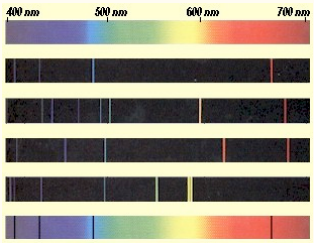
The diffraction grating and spectrum on screen
d grating constant, λ wave length, α angle of deflection,

Spectral Content of Light

- A spectrum is a plot representing light content on a wavelength-by-wavelength basis
  - the myriad colors we can perceive are simply different spectral amalgams of light
  - much like different instruments have different sound: it depends on its (harmonic) spectral content



Example Spectra



white light spectrum

hydrogen lamp spectrum

helium lamp spectrum

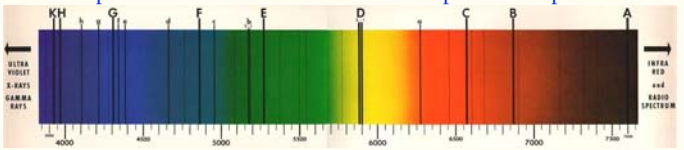
lithium lamp spectrum

mercury lamp spectrum

hydrogen absorption spectrum

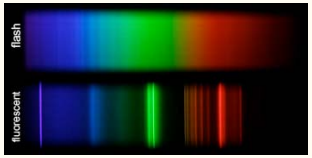
Spectra provide "fingerprints" of atomic species, which can be used to identify atoms across the universe!

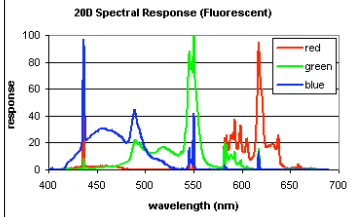
Solar Spectrum with Fraunhofer solar atmosphere absorption lines



C: Hydrogen; D: Sodium; E: Iron; F: Hydrogen; G: Iron; H&K: Calcium

Fluorescent lights

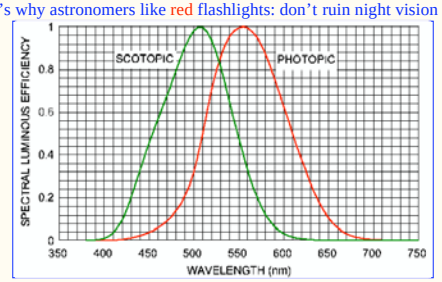




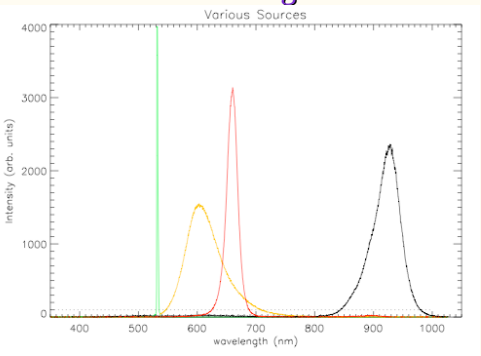
- Fluorescent lights stimulate emission among atoms like argon, mercury, neon
  - they do this by ionizing the gas with high voltage
  - as electrons recombine with ions, they emit light at discrete wavelengths, or *lines*
- Mercury puts out a strong line at 254 nm (UV)
  - this and other lines hit the phosphor coating on the inside of the tube and stimulate emission in the visible part of the spectrum

Our limited sensitivity to light

- In bright-light situations (photopic, using cones), our sensitivity peaks around 550 nm, going from 400 to 700
- In the dark, we switch to scotopic vision (rods), centered at 510 nm, going from 370 to 630
  - it's why astronomers like red flashlights: don't ruin night vision



Light Sources



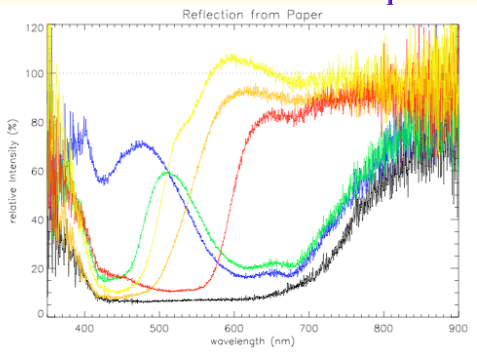
Here are a variety of light sources. Included are:

- H-ITT IR LED*
- red LED*
- green laser pointer
- flourescence of orange H-ITT trans-mitter illuminated by green laser

Note that light has to be blue-ward (shorter wavelength) of the fluorescence for it to work.

* LED: Light Emitting Diode

Colored Paper



Reflected light (in this case, sunlight) off of paper appearing:

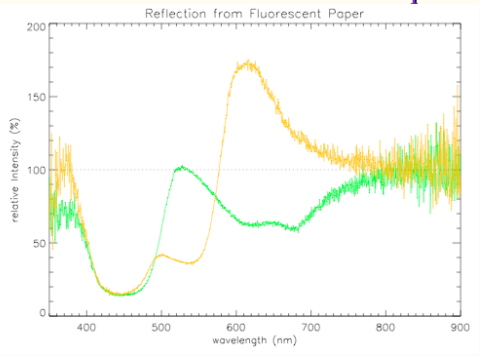
blue
green
yellow
orange
red
black

aside from slight fluorescence in yellow paper chosen here, paper colors operate by reflection only: never peeks above 100%

white paper would be a flat line at 100%

UCSD Physics 10

Fluorescent Paper



Bright fluorescent paper follows different rules: absorbs blue or UV light and re-emits at some characteristic wavelength.

These examples are of lime green paper and bright orange fluorescent paper.

Note especially in the orange case, the light exceeds the amount that would be passively reflected off of white paper (100% level)

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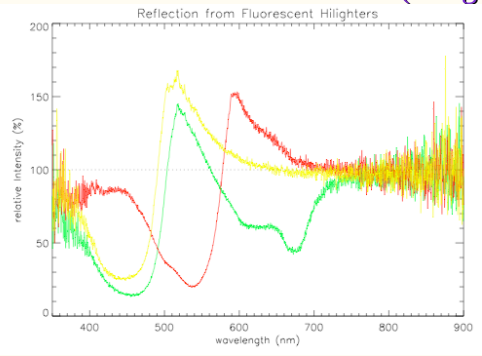
Fluorescent Markers (hi-lighters)



Likewise, fluorescent markers (hi-lighters) absorb and re-emit light.

In this case, we see yellow, green, and pink fluorescent markers

The pink actually has a bit of blue/violet in it, surprisingly

All three have emission above the 100% that one gets from straight reflection

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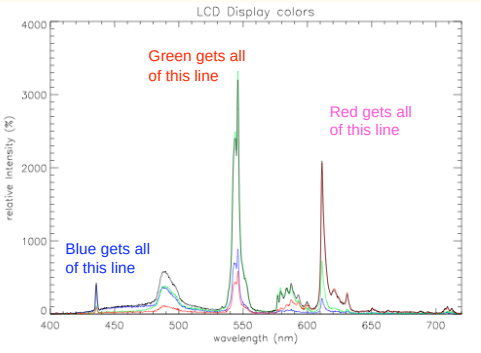
LCD Monitor



LCD monitors use fluorescent lights to illuminate the pixels (from behind).

The black curve shows what my LCD laptop monitor looks like in a section of the screen that's white.

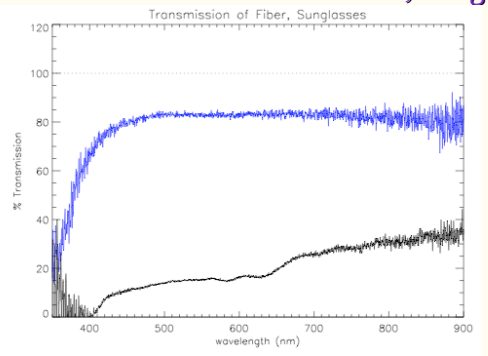
Blue, green, and red curves show sections of the screen with these colors

Note that the colors are achieved simply by suppression

Thus LCDs just filter the background light

UCSD Physics 10

Transmission of Glass, Sunglasses



By obtaining a spectrum of sunlight reflected off of a piece of white paper (using the spectrograph without the fiber feed), then doing the same thing through the fiber and also through sunglasses, the trans-mission properties of each can be elucidated.

The fiber is about 82% transmission for most wavelengths, but has significant UV absorption.

The sunglasses block UV almost totally!

This is why you can't get sunburn through glass

Assignments and other stuff

- **Assignments:**
  - Read Hewitt chapter 27 pp. 515–526
  - Read Hewitt chapter 28 pp. 544–547
  - Read Hewitt chapter 30 (just skim fluorescence onward)
  - HW 7 due 5/30: 26.E.3, 26.E.4, 26.E.10, 26.E.14, 26.E.38, 26.P.4, 31.E.4, 31.E.9, plus additional problems on website
- **Pick up a grating (one per person) in front of class**
- **You can build a groovy spectrometer using the diffraction grating used in class**
  - http://physics.ucsd.edu/~tmurphy/phys10/spectrometer.html