“Light” or the Electromagnetic spectrum

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Diffraction and Light

• When passed through a prism or grating, light is separated into its component wavelengths
• This looks like a rainbow in visible light
• There are wavelengths we can’t see with our eyes
• White light contains all visible colors
### The Visible Spectrum

![Visible Spectrum Image](http://en.wikipedia.org/wiki/Visible_spectrum)

<table>
<thead>
<tr>
<th>Color</th>
<th>Wavelength Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>red</td>
<td>620-750 nm</td>
</tr>
<tr>
<td>orange</td>
<td>590-620 nm</td>
</tr>
<tr>
<td>yellow</td>
<td>570-590 nm</td>
</tr>
<tr>
<td>green</td>
<td>495-570 nm</td>
</tr>
<tr>
<td>blue</td>
<td>450-495 nm</td>
</tr>
<tr>
<td>indigo</td>
<td>420-450 nm</td>
</tr>
<tr>
<td>violet</td>
<td>380-420 nm</td>
</tr>
</tbody>
</table>
What do our eyes have to do with it?

The retina

- Rods detect light and dark
- A cones detects either Red, Blue, or green
- Cones concentrated at the center
- Rods at outside of eye

www.nasa.gov
Cone sensitivity

Numb3rs Blog: http://nuweb2.neu.edu/math/cp/blog/?showall=yes
Emission
What causes emission?

http://www.energystar.gov/
http://commons.wikimedia.org
http://sohowww.nascom.nasa.gov/
Absorption AND Emission
Absorption AND Emission
How is light created?

- Think of an atom as a bookshelf
- Think of the books as electrons
- Each atom has a distinct bookshelf not like any other atom!
Bookshelf for Hydrogen
Kirchoff’s Laws 1859

• Law 1- A hot, opaque body produces a continuous spectrum
• Law 2- A hot, transparent gas produces an emission line spectrum
• Law 3- A cool, transparent gas produces an absorption line spectrum
Kirchoff’s Laws 1859

- Law 1- A hot, opaque body produces a continuous spectrum.
- Law 2- A hot, transparent gas produces an emission line spectrum.
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LAW 1

Continuous Spectrum
Absorption Spectrum

Gas that appears COOLER than the background produces an absorption spectrum
LAW 3

Gas that appears HOTTER than the background produces an emission spectrum.
What's going on?

Gas Cloud
What’s going on?

Gas Cloud
What’s going on?

Light bulb → Gas Cloud → Spectrum of colors → Eye
What's going on?

Gas Cloud
What’s going on?

Gas Cloud
What’s going on?

It follows that….

Etc.
This guy named Fraunhofer

- Early 1800s
- Not the first (just the bestedest-er)
- Remember Kirchoff’s Laws--1859
- “Discovered” numerous lines in the solar spectrum using his invention, the “Spectrometer”

Fraunhofer lines- Solar Spectrum

Spectrum recorded as a plot of wavelength vs. intensity of the signal

What can this tell us?

• About light we can and cannot see
• What’s in an atmosphere
• What’s on the ground (absorbed then emitted light)
• About the solar atmosphere
• About comet tails
• About our galaxy
• About other planetary systems
• About other galaxies
**Imaging vs. Spectroscopy**

- Filters
- Sensitive optics

Composite image combines EIT images from three wavelengths (171Å, 195Å and 284Å)

Sun imaged in He I (5843 nm)

http://sohowww.nascom.nasa.gov/
Imaging vs. Spectroscopy

- Sun imaged in He I (5843 nm)
- Filters
- Sensitive optics

http://sohowww.nascom.nasa.gov/
Structure of SPECTRA

SOLAR SYSTEM DATA STORIES

- Modular
- Data-rich

Paper and pencil + Computer interactives

Graphing the Rainbow

Building a Spectrograph

Patterns in Nature

FOUNDATION
How do we address this in Middle and Early High School?

- Traditionally, because spectroscopy relies on understanding atomic transition states…. Well, it’s hard

- Project SPECTRA! doesn’t introduce atoms, photons, electrons, electron transitions, wavelength etc.
YIKES!

- Lyman
- Balmer
- Paschen
- Brackett
Much Better!
Patterns and Fingerprints

- Students find patterns in classmate’s fingerprints
- Students match “known” fingerprints to “unknown”
- Students determine pattern trends in series
- Relate patterns to nature
Graphing the Rainbow

• Bridge lesson
• Activity short (15 min)
• Introduction to light patterns
• Students match light patterns to their corresponding line spectrum
Using Spectral Data to Explore Saturn and Titan

Students view real spectra from the Cassini UVIS instrument to compare Saturn’s and Titan’s spectra with standard spectra of four different elements and identify which elements are present in Saturn’s rings and Titan’s atmosphere.

**Students consider:**
- Why hydrogen is so abundant
- Why nitrogen exists in Titan’s atmosphere but not Saturn’s rings
- Differences between Titan’s atmosphere and Earth’s with a focus on planetary habitability
Goldilocks and the Three Planets

Students use historic data on the atmospheres of Venus, Earth and Mars to compare and contrast levels of CO2.

Students consider:
- How greenhouse gases contribute to planetary temperature
- How atmosphere and distance from the Sun effect planetary temperature and habitability
The Engineering Connection: Building a Fancy Spectrograph

• Promotes engineering and engineering concepts
• Creates enthusiasm about space, planetary science, the Sun and stars, and atmospheres
• Students build (and use) their own inexpensive spectrograph
Designing an Open Spectrograph
and counterpart:
Designing a Spectroscopy Mission

• Students measure angles
• Establish the geometry of the spectrograph
• Students design a mission
• Let students be creative!
• Use missions in the news as an impetus