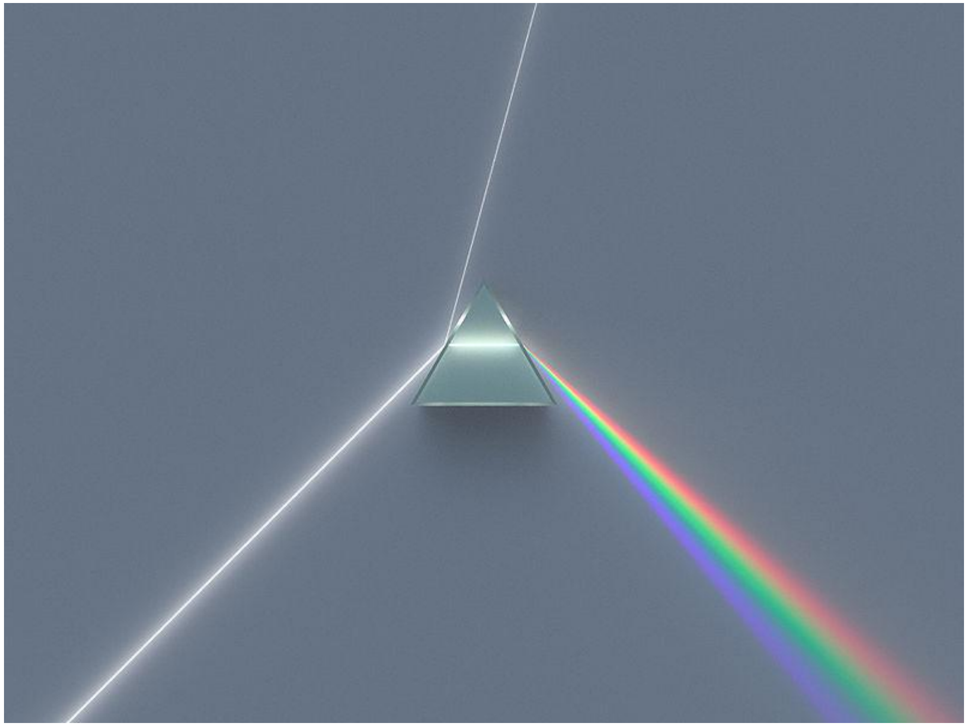
Overview

- What we’re trying to do
- Why we’re interested
- The research approach we’re taking
- Understanding the science behind light physics
- The development approach we’re using
- Challenges and risks

What we're trying to do

- We are studying the refraction of light through any material and trying to model how light breaks down into its spectral components



Why we’re interested

The only way we can see anything is if light interacts with it in some way. *How we see it*, depends entirely on how light interacts with it. Therefore, precisely understanding the behavior of light helps us render more realistically accurate images.

Scientific Curiosity

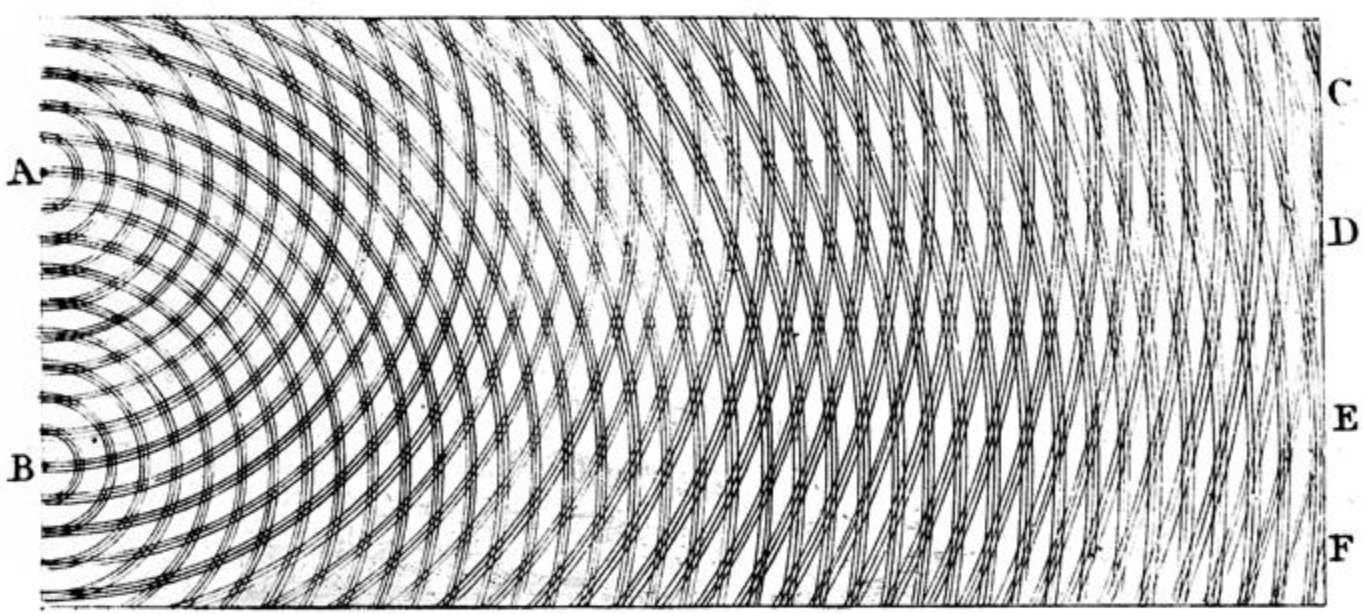
- If we can create a generalized algorithm accurately based on scientific and physics models, we can create predictions of results which can be tested by observation.
- What would a “rainbow” look like if the light source is a neon light?
- What would a rainbow look like in a star system which has a red giant or white dwarf star?
- How does refractive index influence the appearance of a rainbow? What would a rainbow look like if diamonds were falling out of the sky?

Research Approach

1. Define what we're trying to do
2. Understand the science and physics of it
3. Find any existing mathematical models
4. Look at the current ray tracer capabilities
5. Figure out what new capabilities we need to add
6. Create a plan of implementation

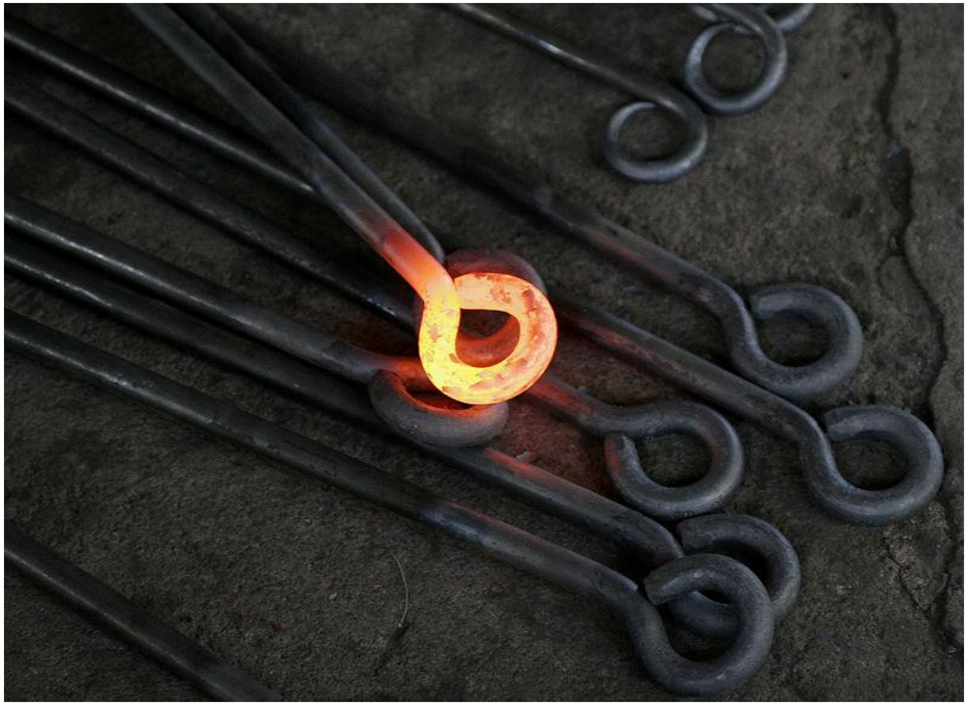
What is light?

- Light behaves as both a particle (photon) and a wave (light wave).



Electrons & Orbitals

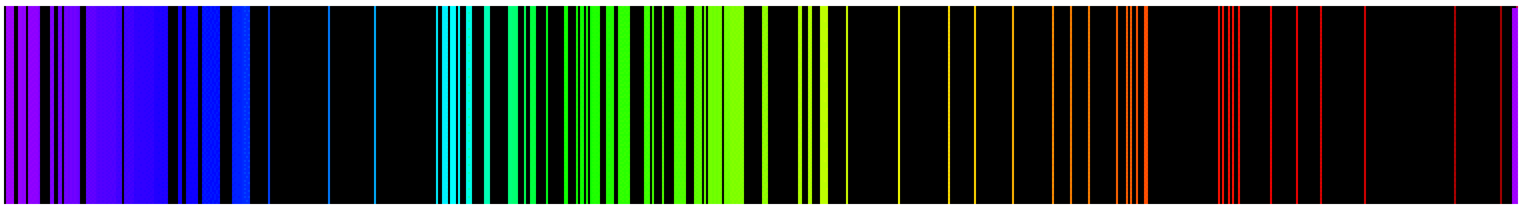
- Light is a form of electromagnetic radiation emitted by electrons in an atom. A photon particle is emitted when an electron drops to a lower orbital.

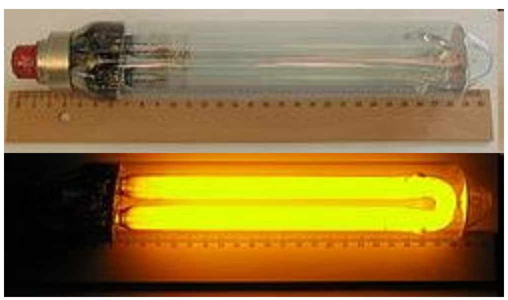


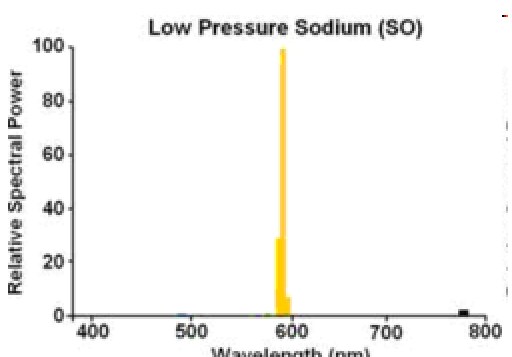
Spectroscopy

Emission Spectrum for Hydrogen

Emission Spectrum for Iron

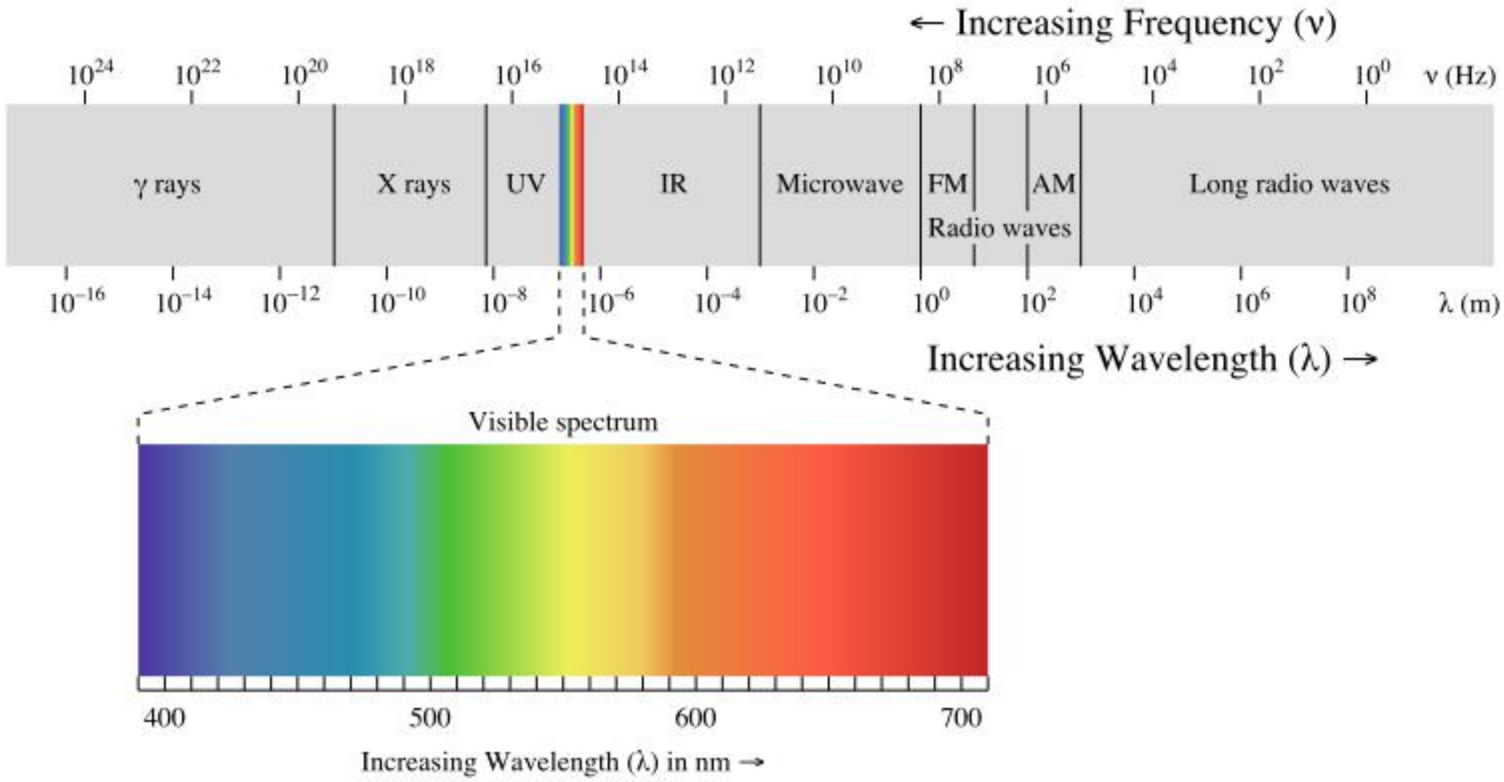




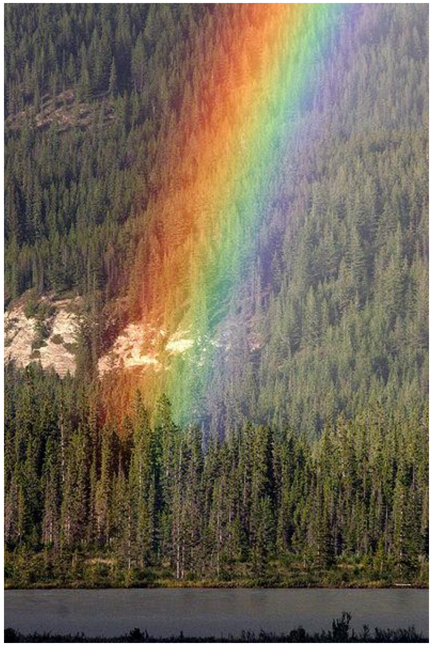


Light, Continued

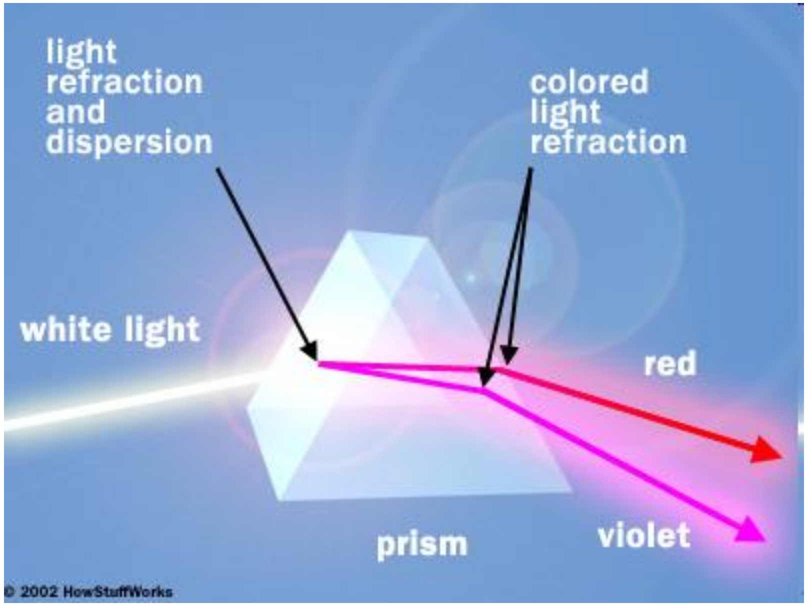
Light color can be represented either with frequency (f) or wavelength (λ)

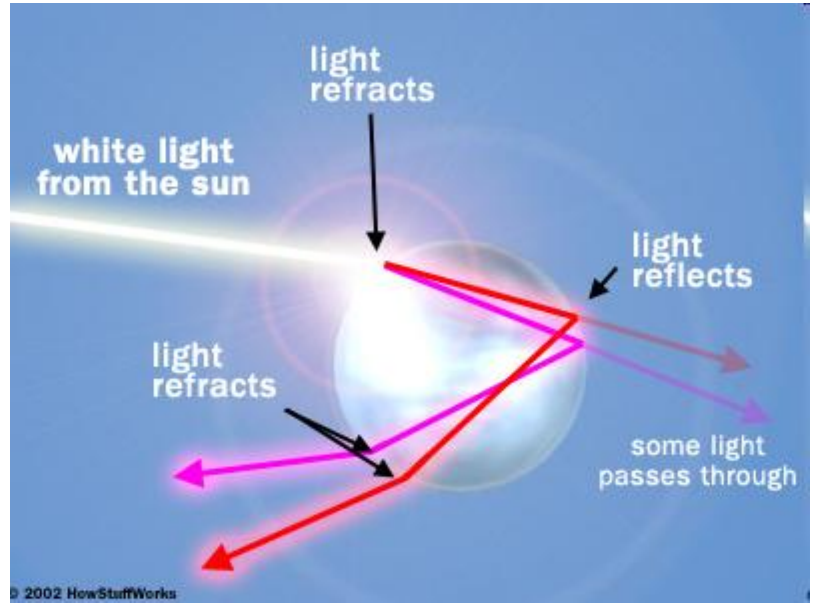


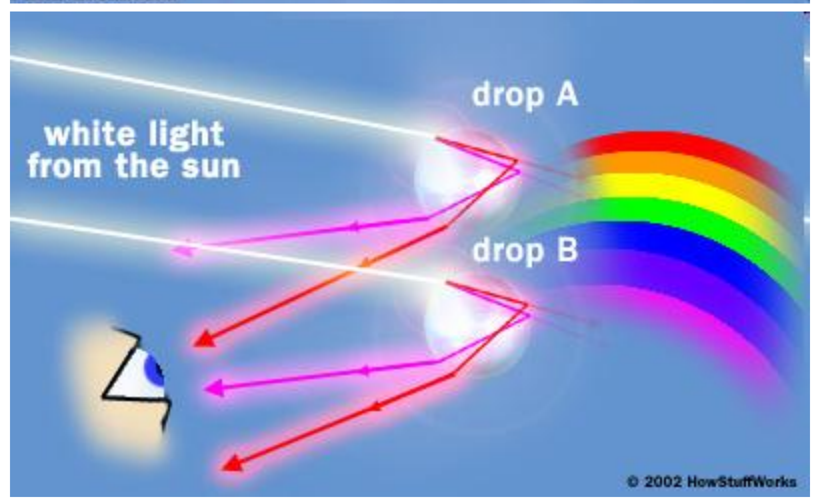
So, what is a rainbow?



How does it work?







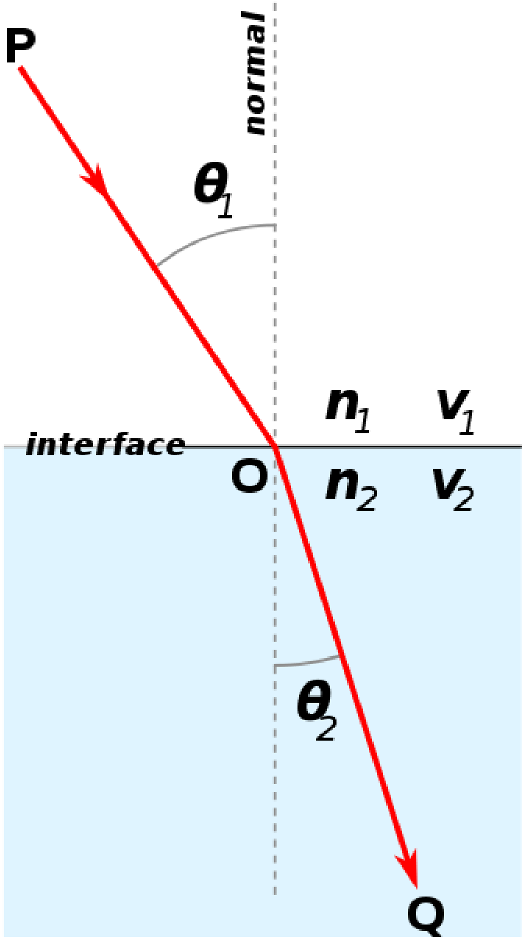
Source: http://science.howstuffworks.com/rainbow2.htm

Things we need to know

- Eye Position
- Light position
- Light wave lengths (colors)
- Object position & geometric shape
- Refractive index of object
- The point where light ray hits object (intersection record)

Snell's Law of Refraction

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$



N_1: refractive index of outgoing material (air)

N_2: refractive index of incoming material (water)

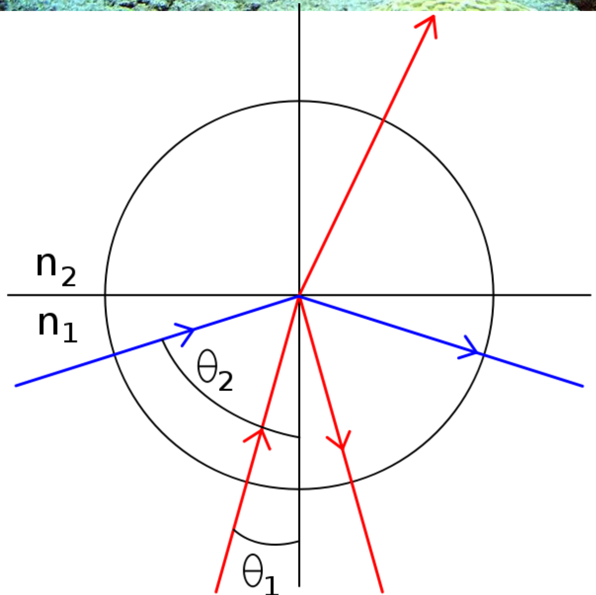
Demo:

1. http://interactagram.com/physics/optics/refraction/
2. http://www.atoptics.co.uk/rainbows/primrays.htm

Total Internal Reflection

- **Definition:** an optical phenomenon that occurs when a ray of light strikes a medium boundary at an angle larger than a particular critical angle with respect to the normal to the surface
- This can only occur when light is travelling from a more dense material to a less dense material.

- Critical Angle: $\theta_c = \arcsin\left(\frac{n_2}{n_1}\right),$
- If $\left(\frac{n_2}{n_1}\right) > 1$
- then no internal reflection occurs. This is because arcsin is undefined.



Changes to the ray tracer

1. We need to change the way light is represented in order to support color spectrums
2. For each light, we specify a range of wave lengths which are present, and in pairs.

White light:
<wavelengths>350 750</wavelengths>

Pure Red Light:

<wavelengths>700 700</wavelengths>

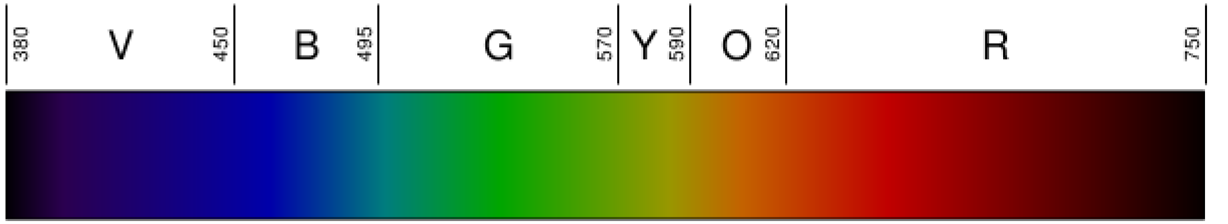
Hydrogen:

<wavelengths>350 360 420 425 530 570 700 720<wavelengths>

- When a light ray impacts a geometry with a transparency and refractive index, we loop through the range of wavelengths and create new light rays for each wavelength present. So, a white light ray would generate (700-350) = 350 new light rays.
- Each light ray would have a slightly different refraction angle based on wavelength.
- We would then compute the path of the new light rays within the medium (raindrop or prism) to find the exit point
- At the exit point, we must compute refraction again.
- Finally, the light ray continues on its merry way through the scene.

Implementation Continued

- When a light ray impacts a geometry, we need to figure out the color of the light ray based on its wavelengths.
- We will use a high resolution image of the color spectrum and, given a wavelength, sample a pixel for its RGB value, and add it to the total resulting color.



This needs a two phase renderer

- Remember, we are tracing a ray from the light source into the scene.
- When the light ray impacts a geometry, we get the color of the light and the point of impact.
- We then create a data structure which contains all the points of impact and the associated light colors for each point. (Call it “Light Table”)
- When we ray trace the scene from the camera view, we check to see if the intersection record point is also contained in the Light Table, and add its color value.

Risks and Challenges

- This could take a really long time to compute when we generate hundreds of thousands of light rays.
- We may have to come up with a really efficient search algorithm to parse the Light Table. For now, maybe linear search will work.
- This seems to be a really tough assignment to pull off correctly.

Addressing risks & challenges

- For simplicity, we'll start by working with one light ray of white light impacting a glass prism at a known point.
- First, we'll make sure that the refraction code works
- Then we'll make sure the two phase rendering process works
- Finally, we'll break the white light down into its spectral components.
- This will be our "Proof of Concept" which we hope to demo.
- If we have time, we'll create rainbows using thousands of really small spheres to represent rain.

Summary

- This seems to be a more scientifically accurate model for rendering a scene
- Since we represent light by its wavelength instead of RGB color, its now possible to redefine material color by specifying which wavelengths are absorbed.
- What would be the resulting color of an object under hydrogen light which absorbs red?
- What colors appear black under red light?
- How does wavelength intensity (in a color band) influence light color in the scene?

Awesome Sources

- http://interactagram.com/physics/optics/refraction/
- http://www.atoptics.co.uk/bows.htm
- http://en.wikipedia.org/wiki/Prism_%28optics%29
- http://en.wikipedia.org/wiki/Rainbows