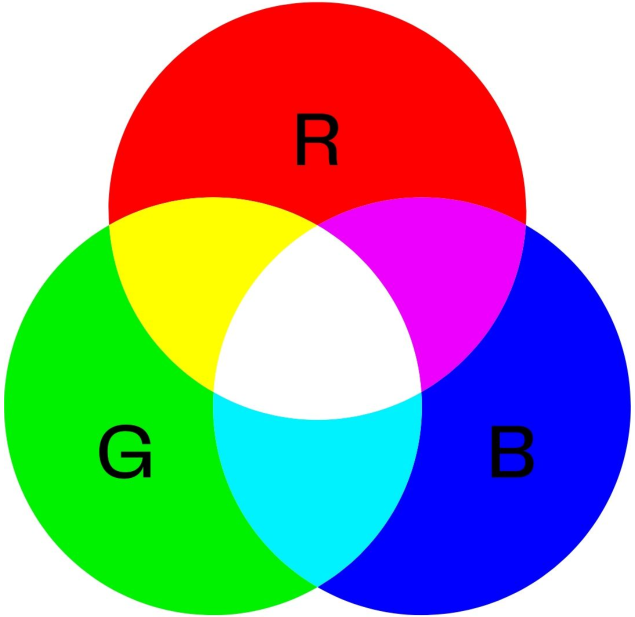
Multispectral Rendering

Jonas Loeser, Dylan Carroll, Nic Preisig

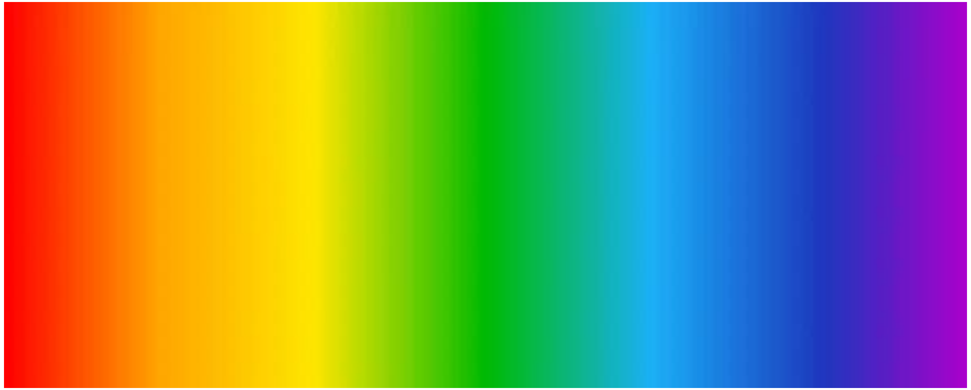
What is Light?

- RGB
  - Looks great
  - Easy to display



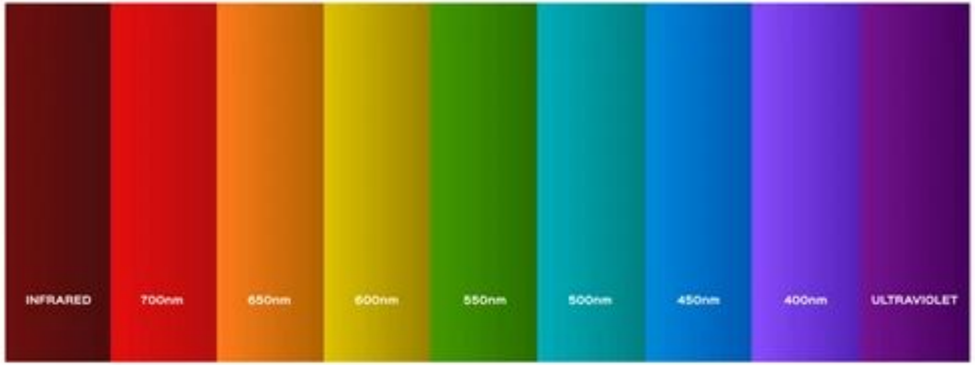
What is Light?

- RGB
- Continuous Light Spectrum
    - Perfectly realistic



What is Light?

- RGB
- Continuous Light Spectrum
- Bins
  - Storable + Computable



How do we track Light as a spectrum?

- All rays carry spectra
  - ~~Point, direction, ⇒ RGB~~
  - Point, direction ⇒ spectrum

How do we track Light as a spectrum?

- All rays carry spectra
- All material reflect a spectrum
  - Each bin has its own “reflectance”
  - Ranging 0 to 1

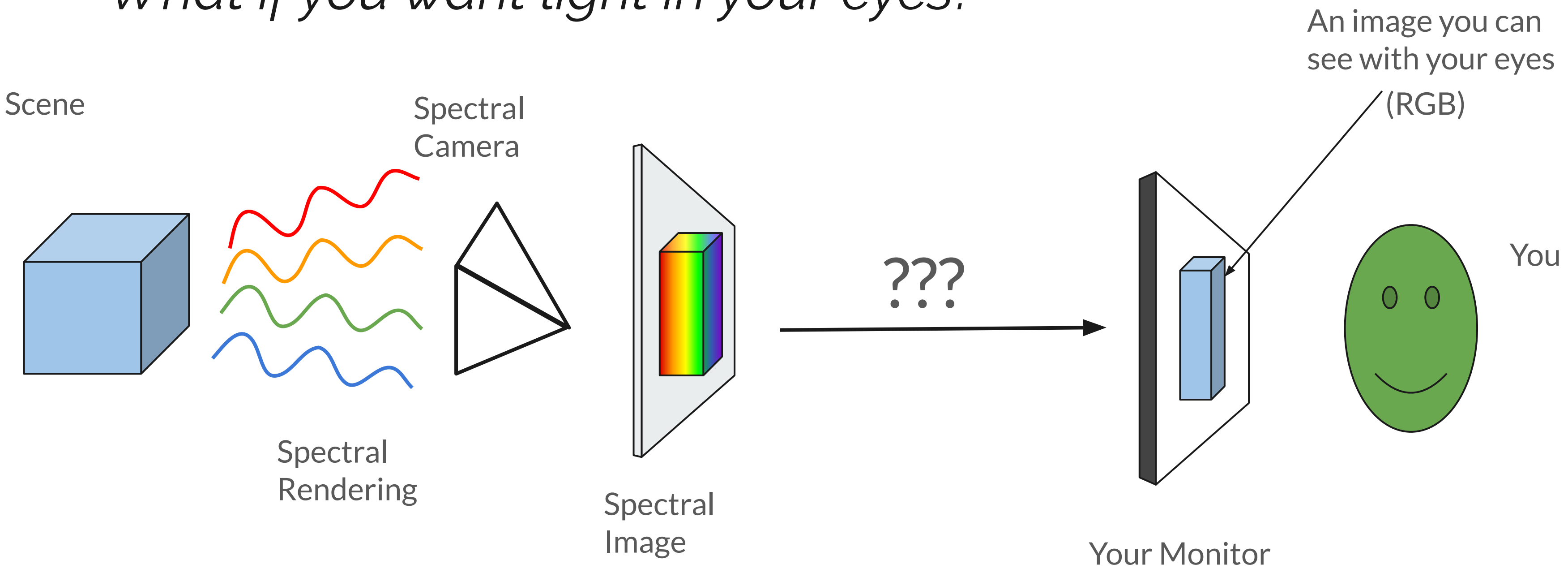
How do we track Light as a spectrum?

- All rays carry spectra
- All material reflect a spectrum
- Light sources produce a spectrum
  - White light is all light at some brightness
  - Colorful light is non-uniform composition

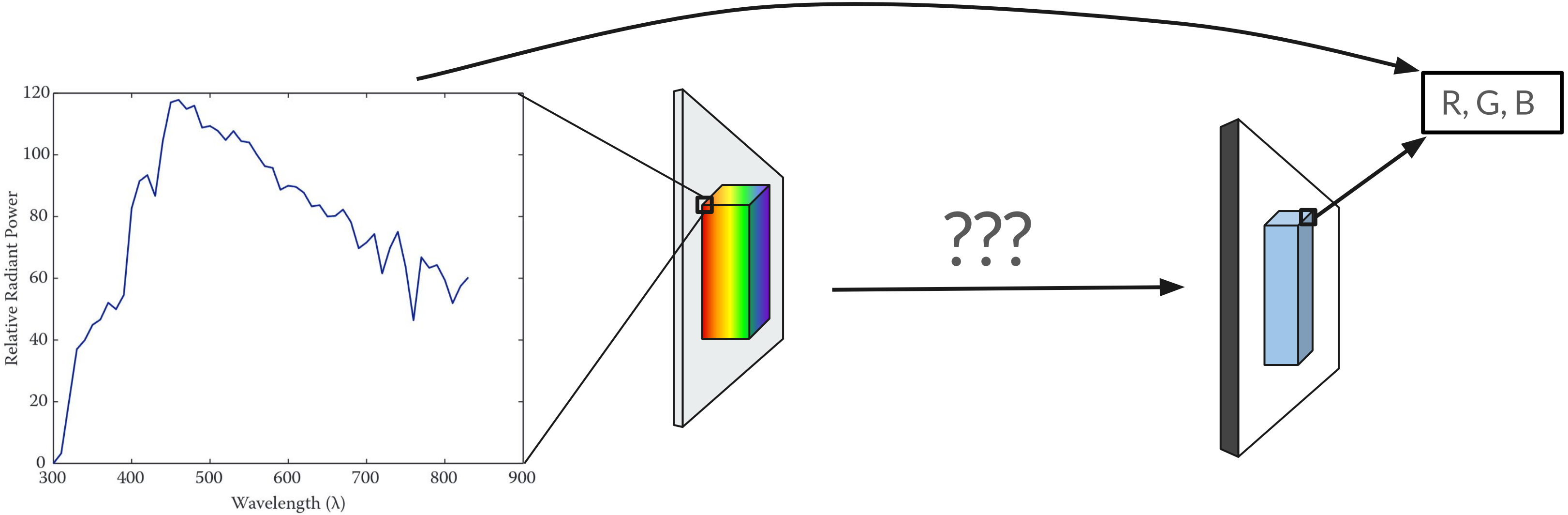
How do we track Light as a spectrum?

- All rays carry spectra
- All material reflect a spectrum
- Light sources produce a spectrum
- Each pixel is left with a spectrum
    - How do we display a spectrum?

What if you want light in your eyes?

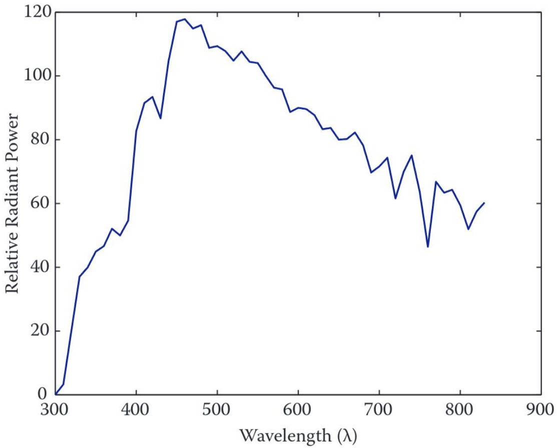


What if you want light in your eyes?

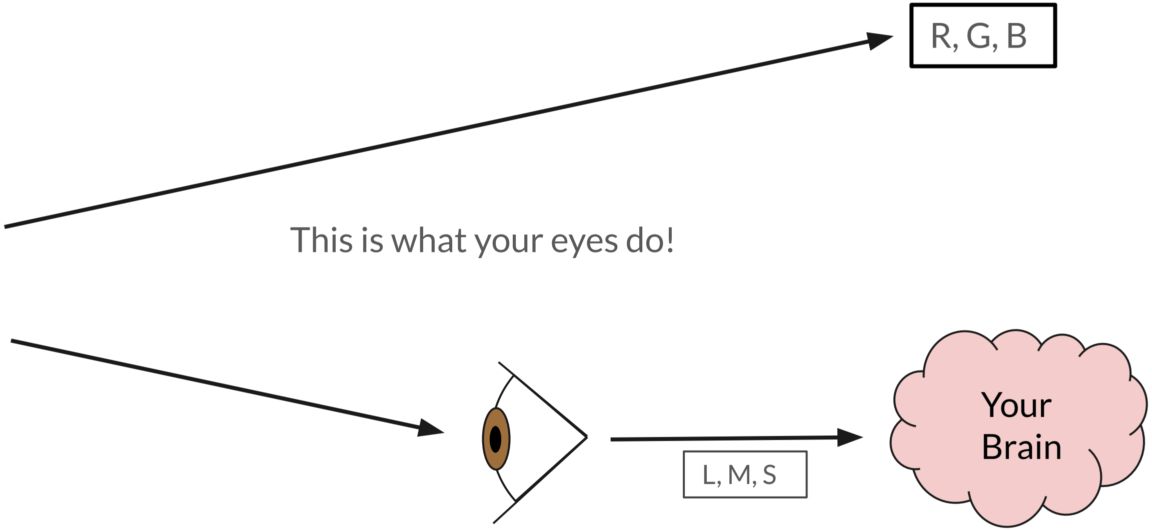


Fundamentals of Computer Graphics 4th Edition

What if you want light in your eyes?



Fundamentals of Computer Graphics 4th Edition



What if you have light in your eyes?

Your eyes have two kinds of cells:

- Rods (dim light)
- Cones (bright light / color)

There are three kinds of cones

- L
  - Long wavelengths
- M
  - Medium Wavelengths
- S
  - You'll never guess
  - Short wavelengths

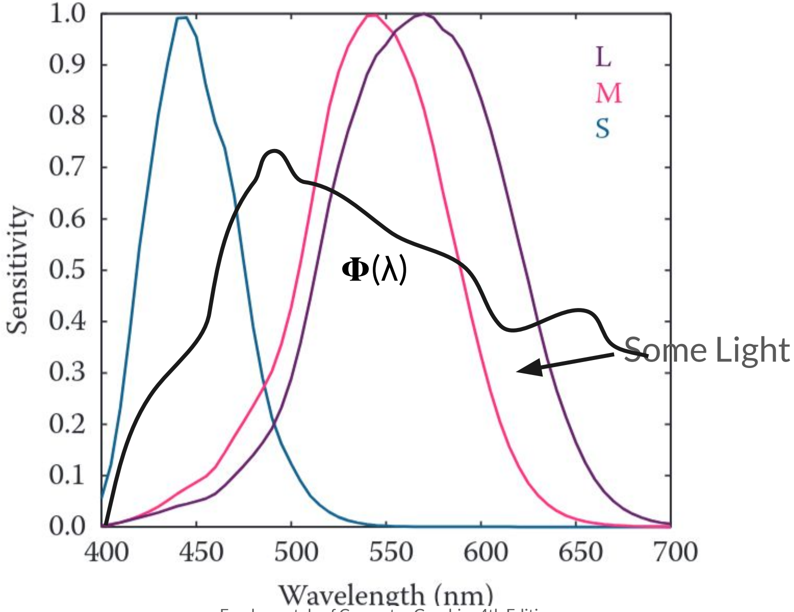
$$L = \int_\lambda \Phi(\lambda)\, L(\lambda)\, d\lambda,$$

$$M = \int_\lambda \Phi(\lambda)\, M(\lambda)\, d\lambda,$$

$$S = \int_\lambda \Phi(\lambda)\, S(\lambda)\, d\lambda.$$

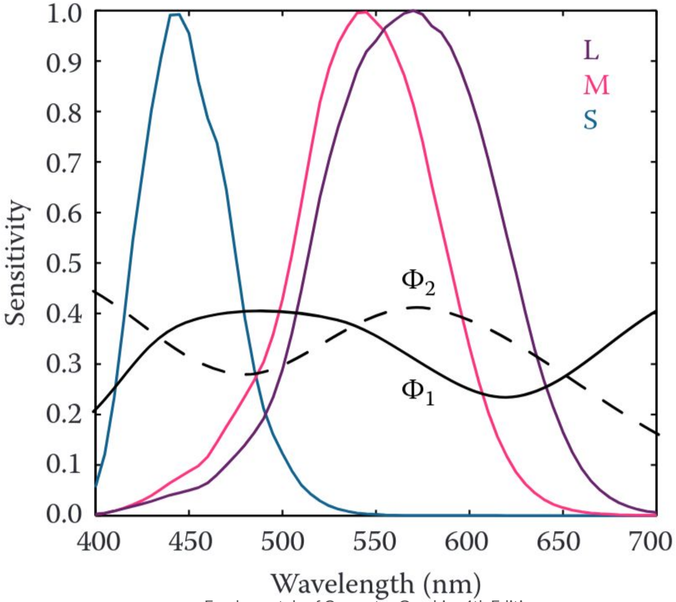
Cone Activation Values

Cone Frequency Responses



Fundamentals of Computer Graphics 4th Edition

What if you have light in your eyes?



Fundamentals of Computer Graphics 4th Edition

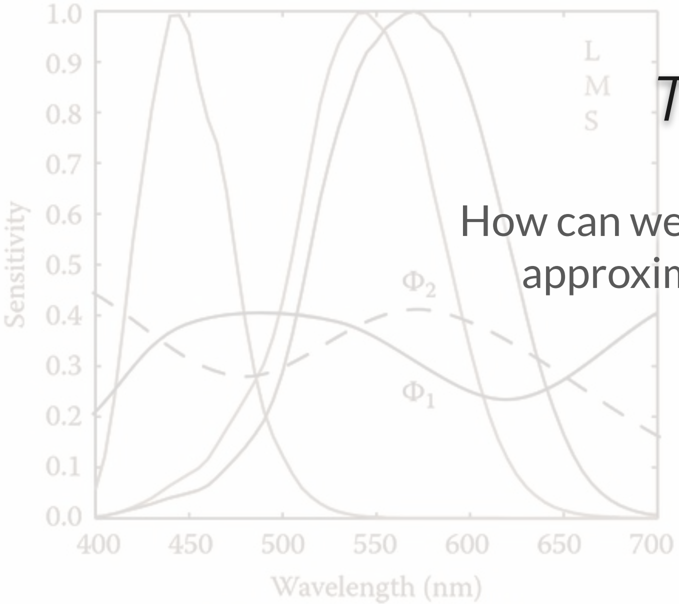
There are multiple spectra that result in the same cone activations

$$L = \int_\lambda \Phi_1(\lambda)\, L(\lambda)\, d\lambda, \quad = \int_\lambda \Phi_2(\lambda)\, L(\lambda)\, d\lambda,$$

$$M = \int_\lambda \Phi_1(\lambda)\, M(\lambda)\, d\lambda, \quad = \int_\lambda \Phi_2(\lambda)\, M(\lambda)\, d\lambda,$$

$$S = \int_\lambda \Phi_1(\lambda)\, S(\lambda)\, d\lambda. \quad = \int_\lambda \Phi_2(\lambda)\, S(\lambda)\, d\lambda.$$

How can we make light for your eyes?



Fundamentals of Computer Graphics 4th Edition

There are multiple spectra that result in the same cone activations

$$L = \int_\lambda \Phi_1(\lambda)\, L(\lambda)\, d\lambda, \quad = \int_\lambda \Phi_2(\lambda)\, L(\lambda)\, d\lambda,$$

$$M = \int_\lambda \Phi_1(\lambda)\, M(\lambda)\, d\lambda, \quad = \int_\lambda \Phi_2(\lambda)\, M(\lambda)\, d\lambda,$$

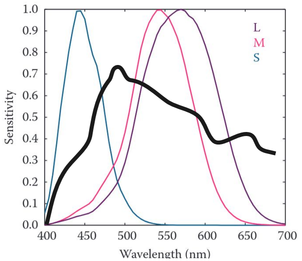
$$S = \int_\lambda \Phi_1(\lambda)\, S(\lambda)\, d\lambda. \quad = \int_\lambda \Phi_2(\lambda)\, S(\lambda)\, d\lambda.$$

Turn and Talk

How can we use this to find RGB values that approximate the full-spectrum color?

How can we make light for your eyes?

A given spectrum



Fundamentals of Computer Graphics 4th Edition

$$L = \int_\lambda \Phi(\lambda)\, L(\lambda)\, d\lambda,$$

$$M = \int_\lambda \Phi(\lambda)\, M(\lambda)\, d\lambda,$$

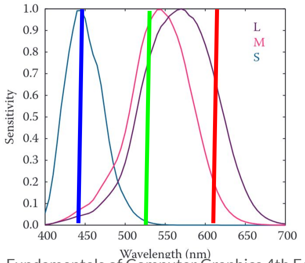
$$S = \int_\lambda \Phi(\lambda)\, S(\lambda)\, d\lambda.$$

results in

Cone Activations
L
M
S

the same

We want some RGB Values



Fundamentals of Computer Graphics 4th Edition

RGB(??, ??, ??)

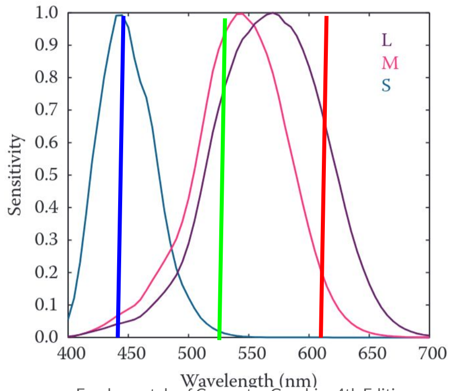
That results in

How can we make light for your eyes?

Let R = 700.0 nm

Let G = 546.1 nm

Let B = 435.8 nm



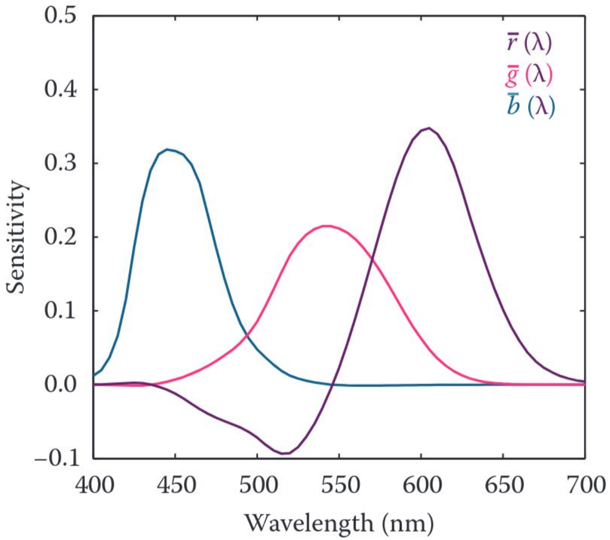
Fundamentals of Computer Graphics 4th Edition

Do some fancy math...

$$\int_\lambda \Phi_1(\lambda)\, \bar{r}(\lambda)$$

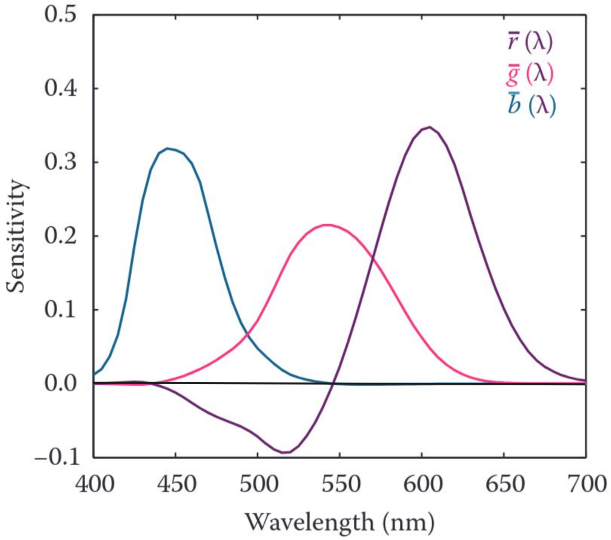
$$\int_\lambda \Phi_1(\lambda)\, \bar{g}(\lambda)$$

$$\int_\lambda \Phi_1(\lambda)\, \bar{b}(\lambda)$$



Fundamentals of Computer Graphics 4th Edition

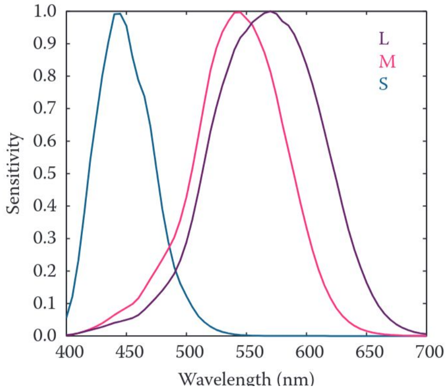
How can we make light for your eyes?



Fundamentals of Computer Graphics 4th Edition

Negative values?

- Yup, RGB isn't a perfect color space
- Only approximates all wavelengths



Fundamentals of Computer Graphics 4th Edition

There's a lot of overlap in the L and M cones...

Section 3 Outcomes

This allows simple implementations of prisms and fluorescence!

Colored light!

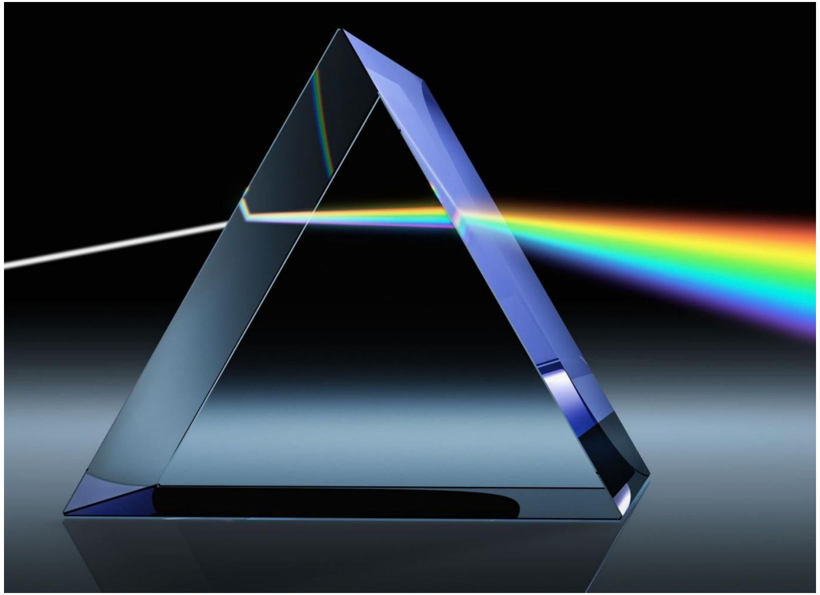
How is this simpler

Why isn’t this done though

How is it done in practice then

What does this let us do?

By making our ray tracer more accurate to real life, more phenomena can be depicted without any major overhauls:



Britannica - Prism Optics

What does this let us do?

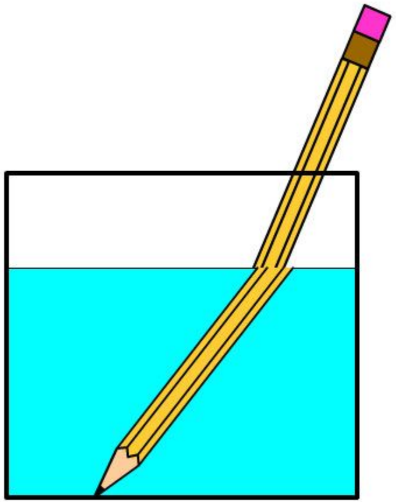
By making our ray tracer more accurate to real life, more phenomena can be depicted without any major overhauls:

- Filtered Light

What does this let us do?

By making our ray tracer more accurate to real life, more phenomena can be depicted without any major overhauls:

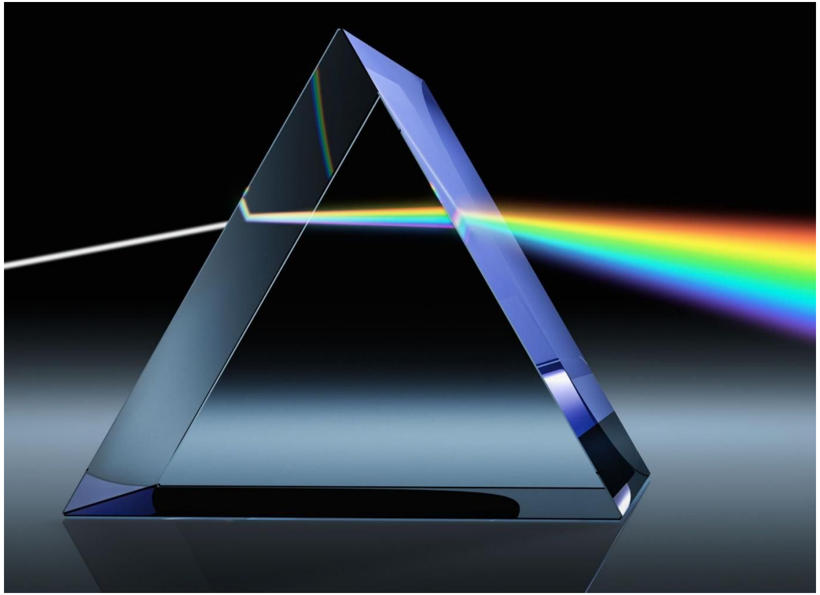
- Filtered Light
- Refraction



What does this let us do?

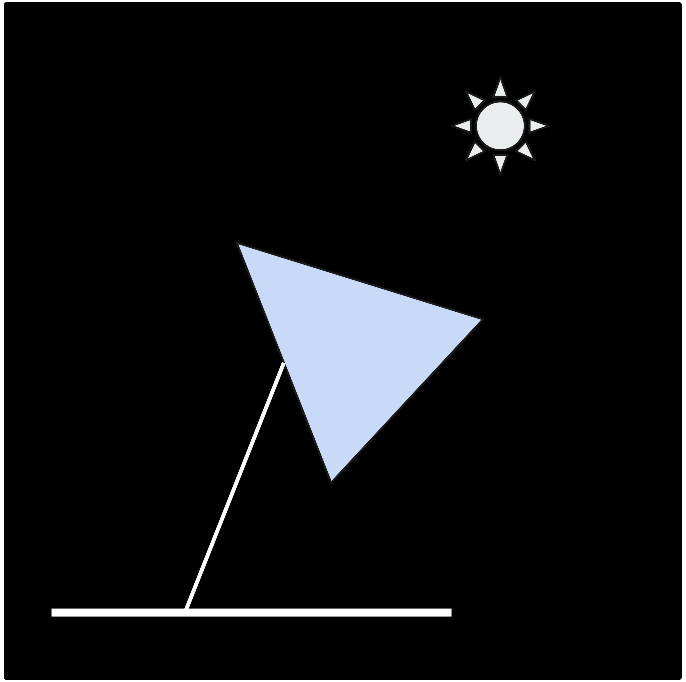
By making our ray tracer more accurate to real life, more phenomena can be depicted without any major overhauls:

- Filtered Light
- ~~Refraction~~ Prisms

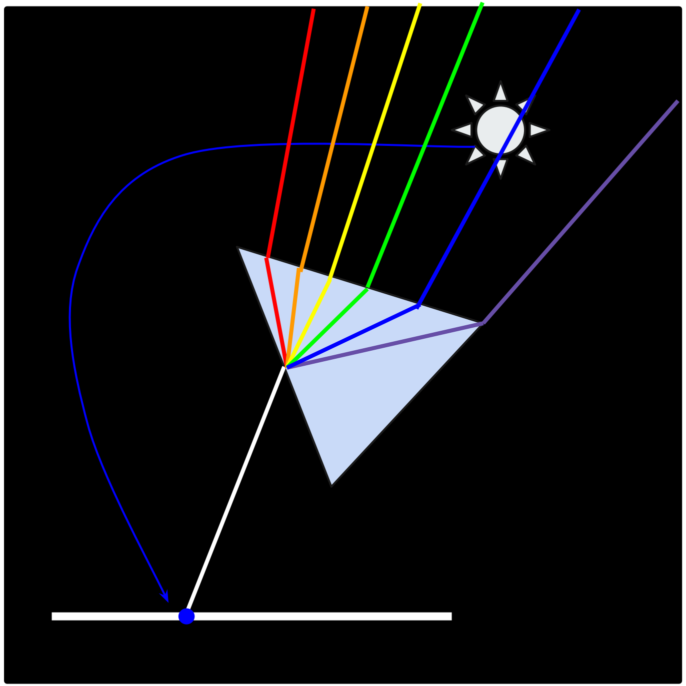


Britannica - Prism Optics

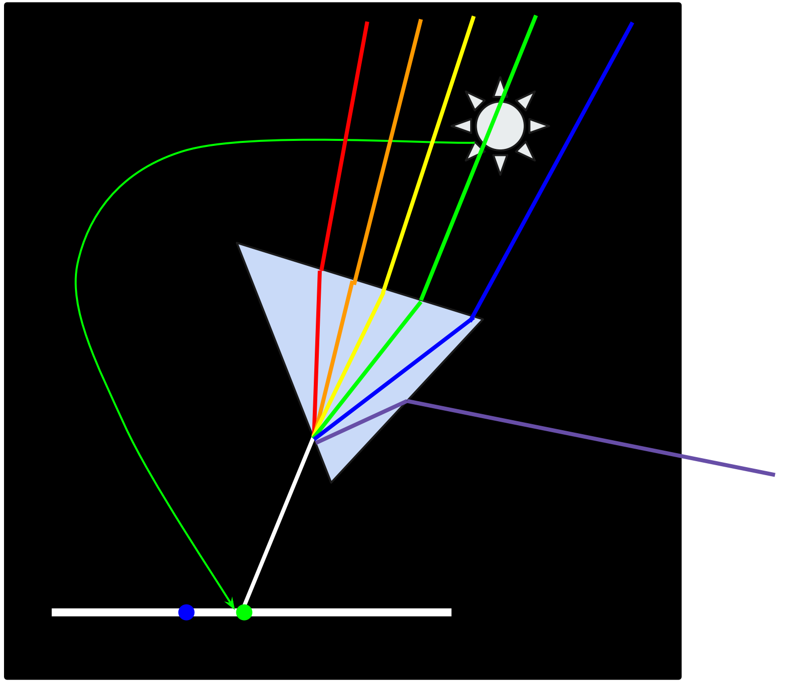
Prisms



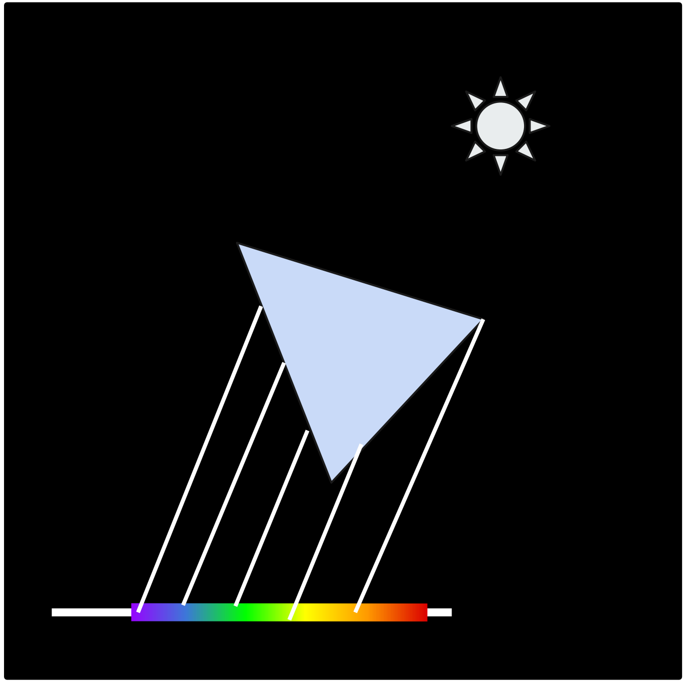
Prisms



Prisms



Prisms



Fluorescence

- Objects usually reflect light at the same frequency they absorb.
- In fluorescence, objects emit light at higher wavelengths than absorbed.
- The Stokes shift causes fluorescent objects to re-emit light at a longer wavelength.
- Multispectral rendering can simulate this process directly in the ray tracer.

Art in nature: Moonlight Fossicking

*Why **you** will regret this*

- Computationally expensive
- Limited perceptible differences
- Fewer existing libraries

Conclusion

- More realistic
- More flexible
- More useful than RGB

Questions?