Spectral Ray Tracer

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CS 284A: Group 30

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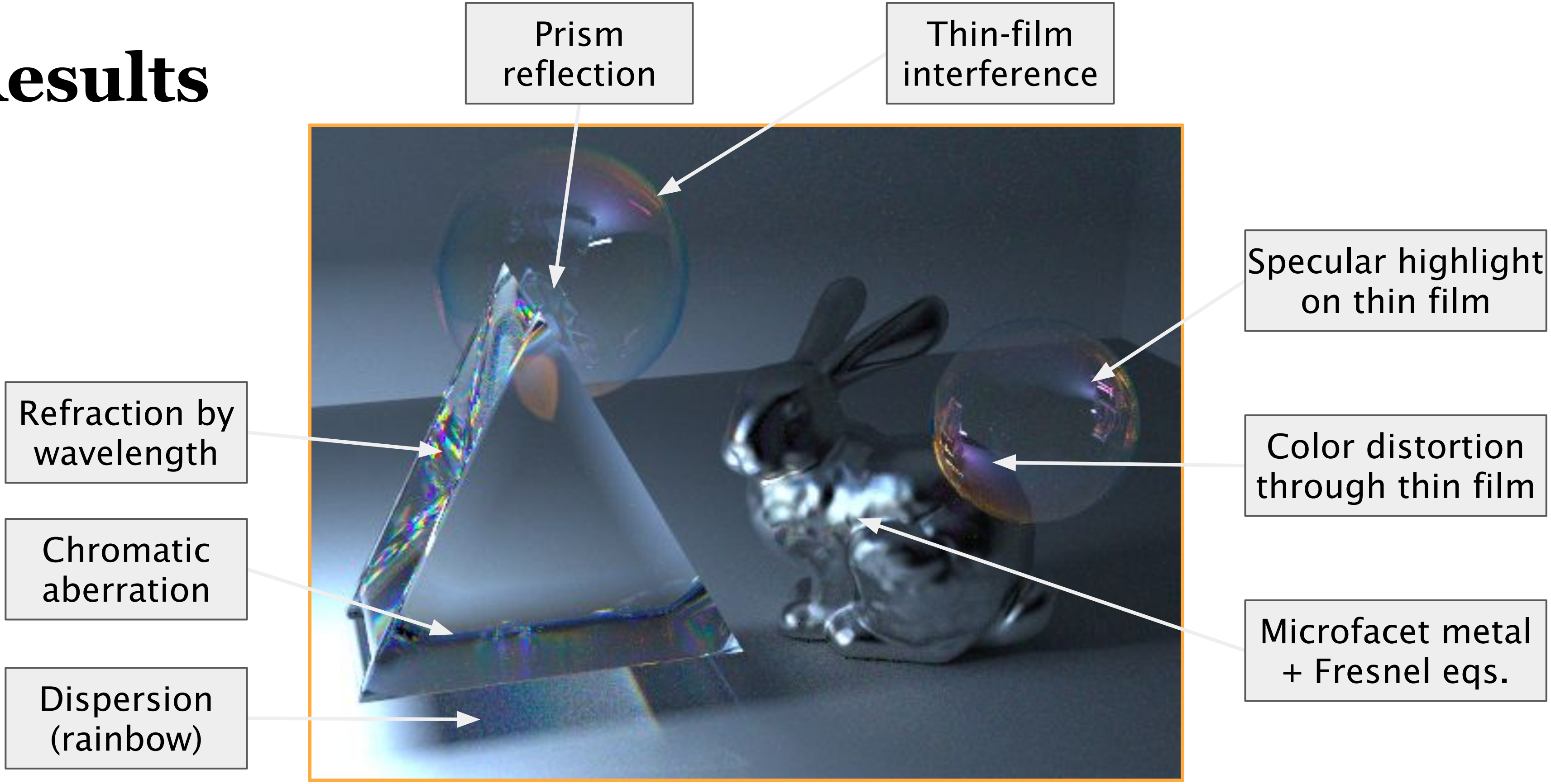
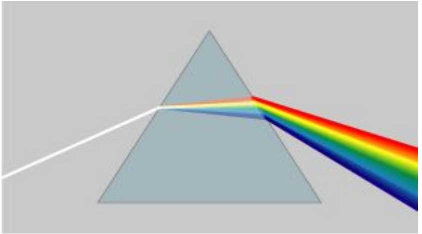
Results

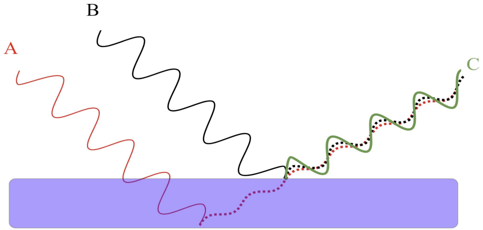

Prism reflection
Thin-film interference
Specular highlight on thin film
Color distortion through thin film
Microfacet metal + Fresnel eqs.
Refraction by wavelength
Chromatic aberration
Dispersion (rainbow)

Motivation

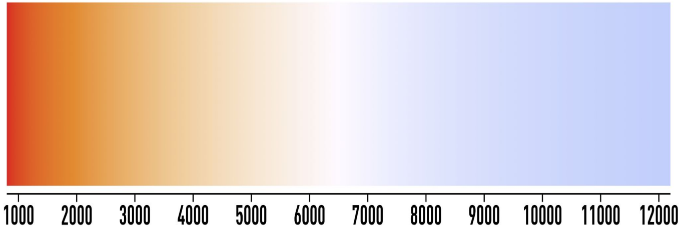
- Light is infinite-dimensional, rather than three-dimensional
- Optical effects that arise from wavelength-dependence:
  - Dispersion, thin film iridescence, microfacet materials, black body emitters



https://en.wikipedia.org/wiki/Dispersion_relation



https://en.wikipedia.org/wiki/Thin-film_interference

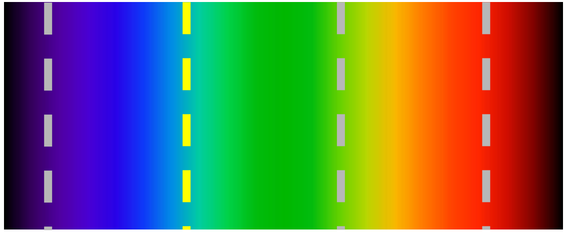


https://en.wikipedia.org/wiki/Black-body_radiation

Moving from RGB to Spectral Ray Tracing

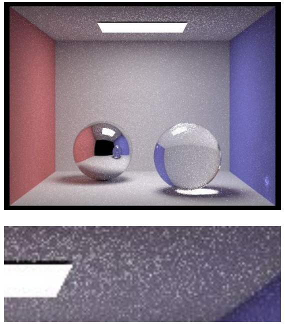
- Starting point: HW 3 Ray tracer
- Each ray has an associated **wavelength**
- Methods return `float` instead of `Vector3`
- Implemented an inner loop for spectral sampling
  - Hero wavelength sampling
  - **Unbiased** and **reduces noise**

random sample

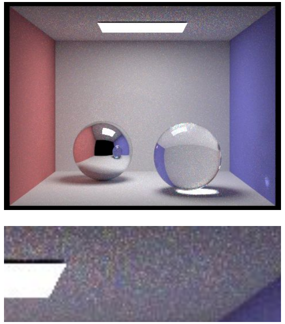


equispaced points from random sample

RGB



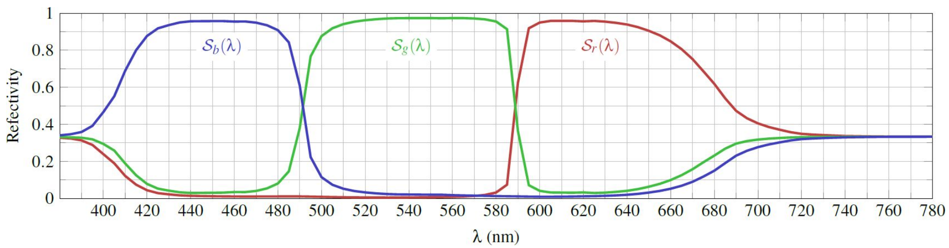
Spectral



Up- and Down-sampling of RGB Values

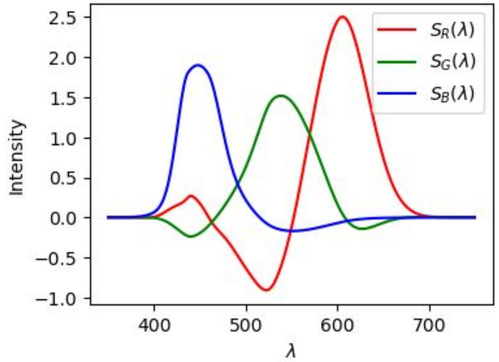
- We want our ray tracer to be consistent with RGB materials and light sources
  - How do we **upsample** RGB parameters to spectral parameters?
  - How do we **downsample** our final spectrum to RGB display values?

<u>Upsampling</u>



I. Mallett and C. Yuskel, *EGSR* (2019).

<u>Downsampling</u>

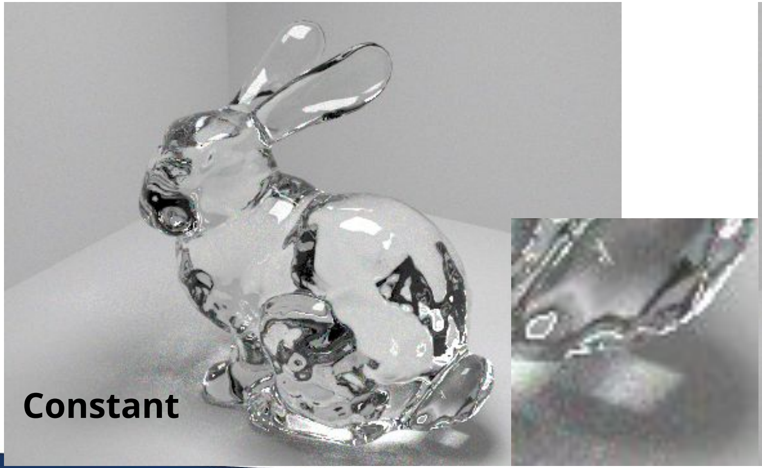


CIE 1931

Dispersive Glass

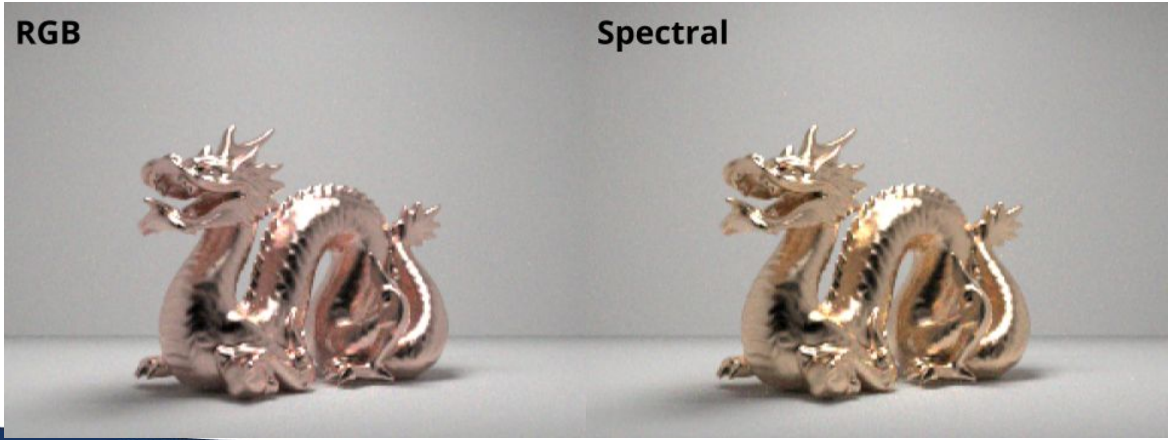
- Change refraction index to be wavelength-dependent using Cauchy's approximation
- Visible dispersion effects in the spectral version

$$\eta(\lambda) = A + \frac{B}{\lambda^2}$$



Spectral Microfacets

- Store discretization of refraction index and extinction coefficient functions and lerp at sampled wavelengths
- The RGB version may appear more “saturated” because it only samples the three primary wavelengths



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Thin-Films on Dielectrics and Conductors

- Implement thin-film reflectance (Airy reflectance) to create iridescent effects
- Constructive interference depends on wavelength

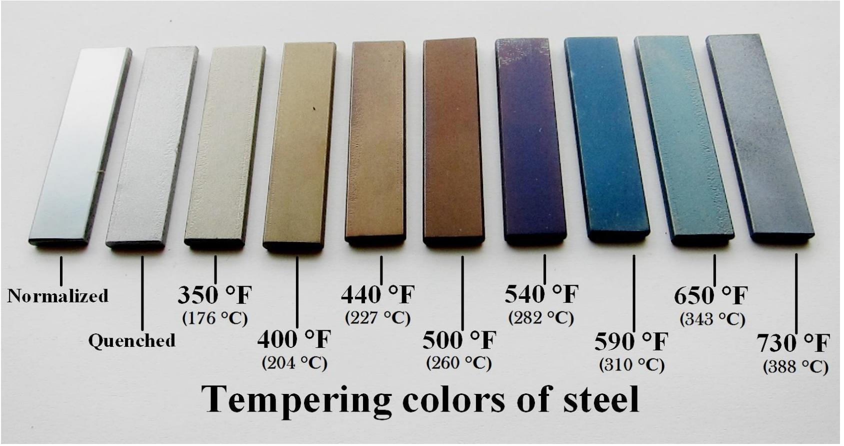
350 nm soap on PVC

400 nm soap on shiny plastic

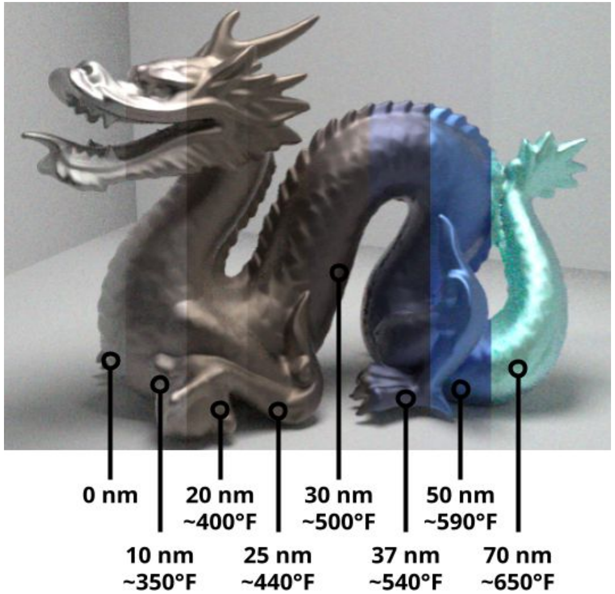
500 nm soap on Copper

Thin-Films → Steel tempering colors

- Model increasing thickness of iron oxide film due to tempering

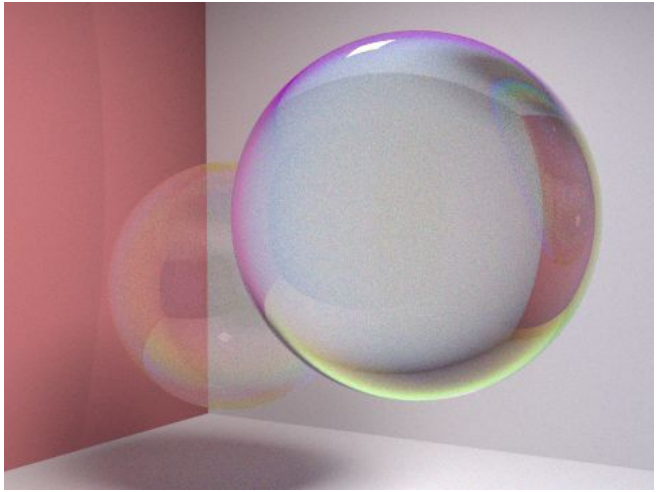


https://en.wikipedia.org/wiki/Tempering_(metallurgy)

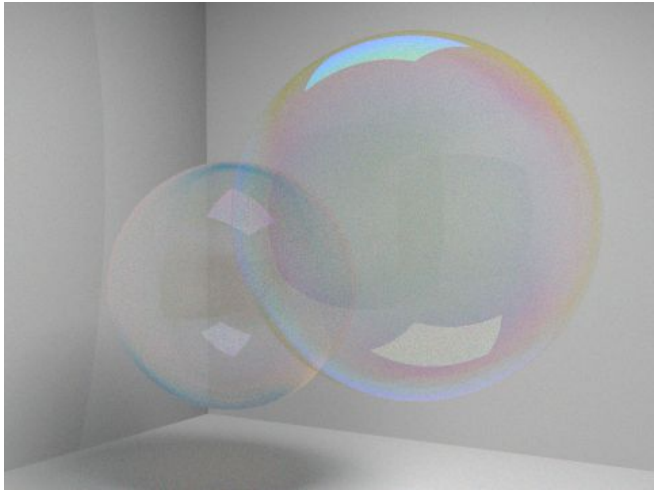


Transparent Films

- Replace Fresnel reflectance with Airy reflectance for transparent objects



Film on glass (foreground)

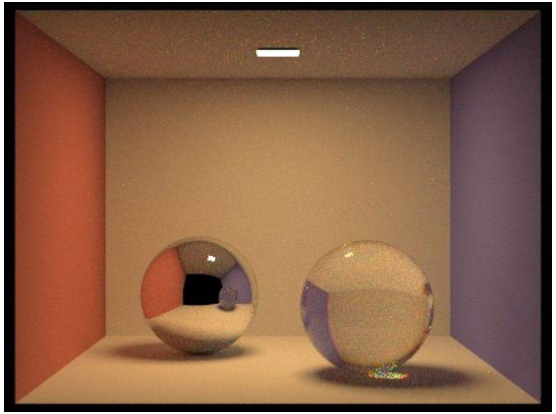


Soap bubbles

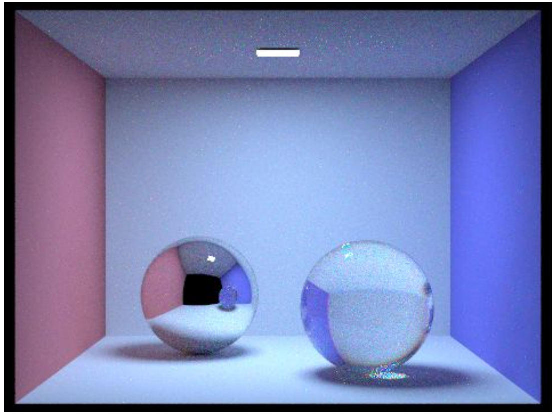
Black Body Radiation

- Return intensity of black body for zero bounce radiance

$$s(\lambda) = \frac{2hc^2}{\lambda^5}\left[\exp\left(\frac{hc}{\lambda k_B T}\right) - 1\right]^{-1}$$



3000 Kelvin



12000 Kelvin

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Conclusions

Lessons learned:

- Lots of new optics/physics!
- Need refined mesh for angular objects to achieve correct convergence
- Dispersion is **very difficult** to capture and converge!

There is significant power/utility gained in spectral ray tracing at the cost of increased compute time and slower convergence.

Questions?