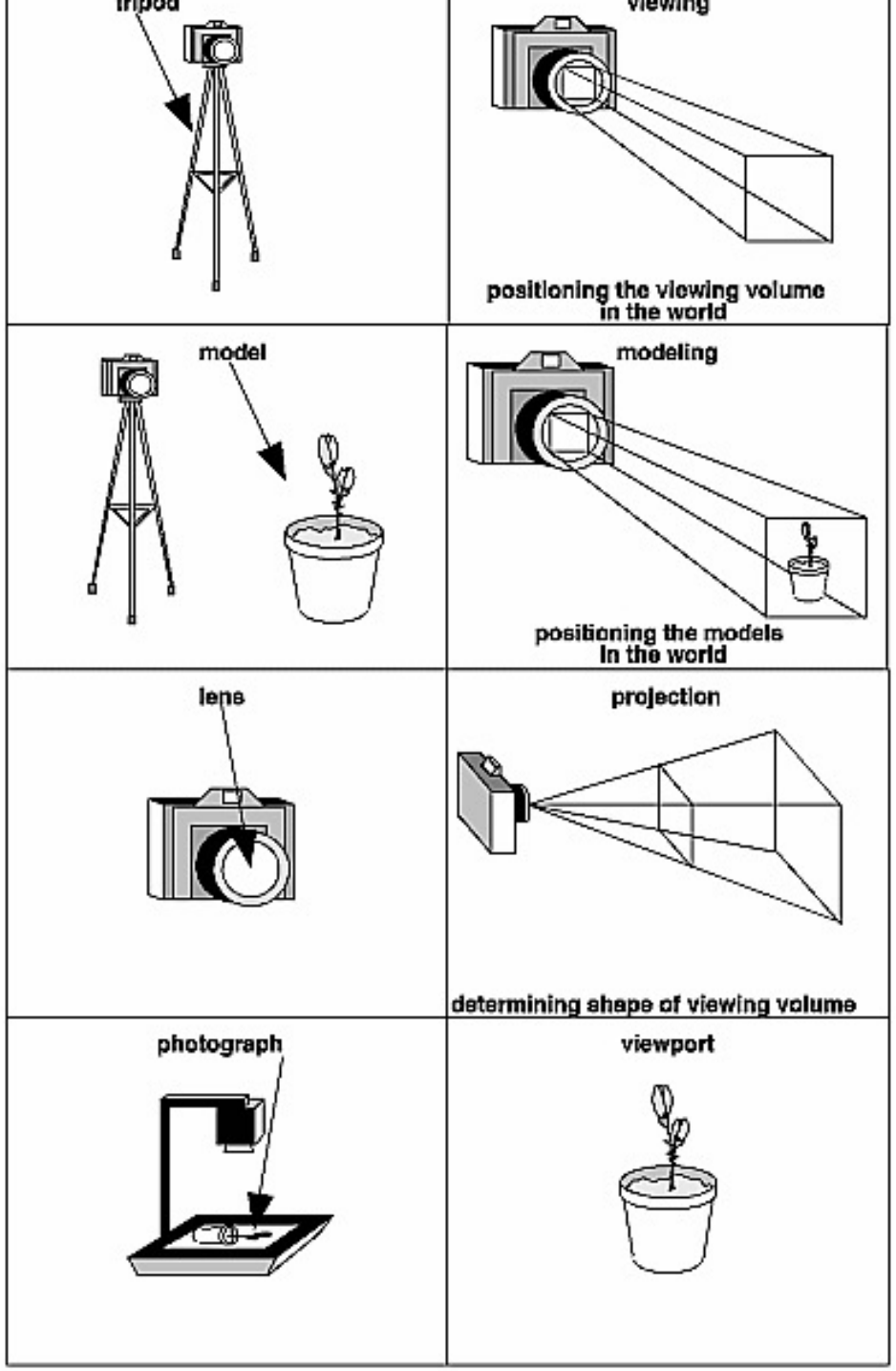
20 - Review

Dr. Rafael Kuffner dos Anjos



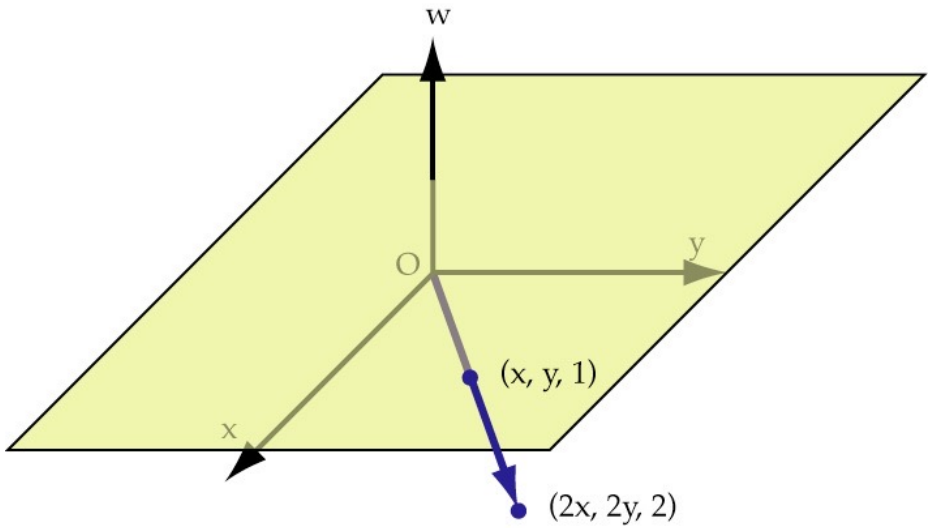
1. Projective Rendering

- Standard Coordinate Systems
- Projective Rendering
- Painter's Algorithm
- Depth (Z-) Buffer
- Projective Pipeline
  - Geometry / Raster / Fragment Stages

2. Homogeneous Coords

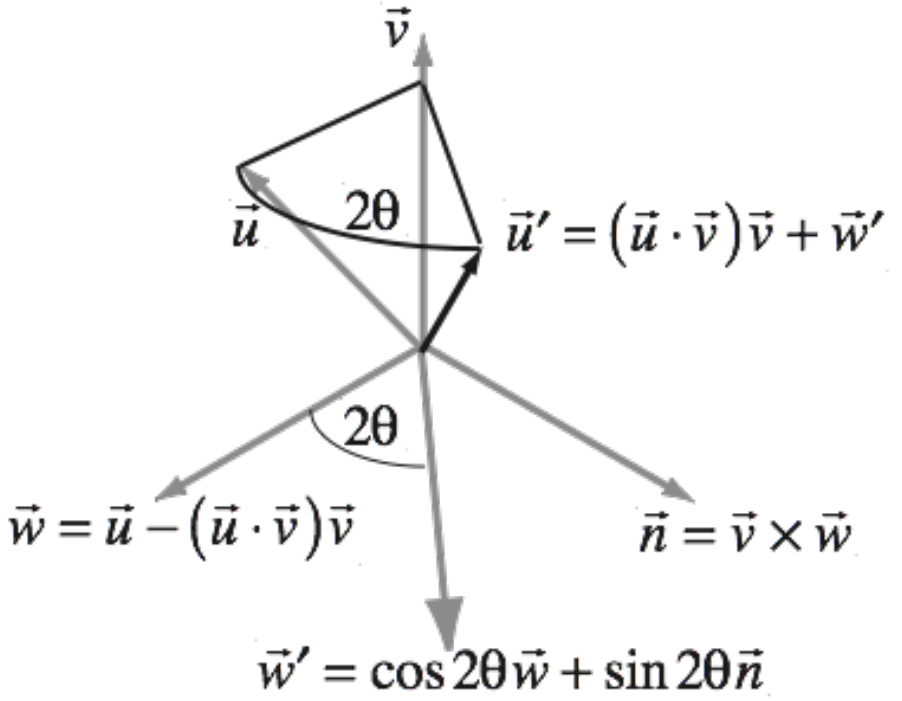
- Projective Nature of Homogeneous Coords
- Conversion to/from Cartesian Coords
- Rotation Matrices
- Translation Matrices
- Rotation around Arbitrary Point
- Orthogonal & Perspective Projection
- Speed Advantages

$$\begin{bmatrix} r & r & r & t \\ r & r & r & t \\ r & r & r & t \\ \hline p & p & p & 1 \end{bmatrix}$$



3. Quaternions

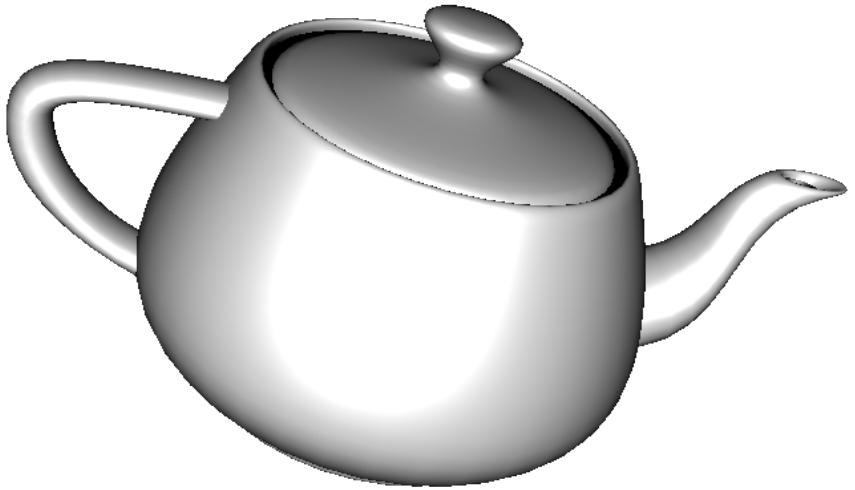
- Fundamental maths for rotations
- Used very heavily in animation
- Gimbal locks, great circles
- Complex numbers & transformations
- Action of a Quaternion
- Conversion to/from matrix
- Arcball controller



4. Rasterization & Blinn-Phong Lighting

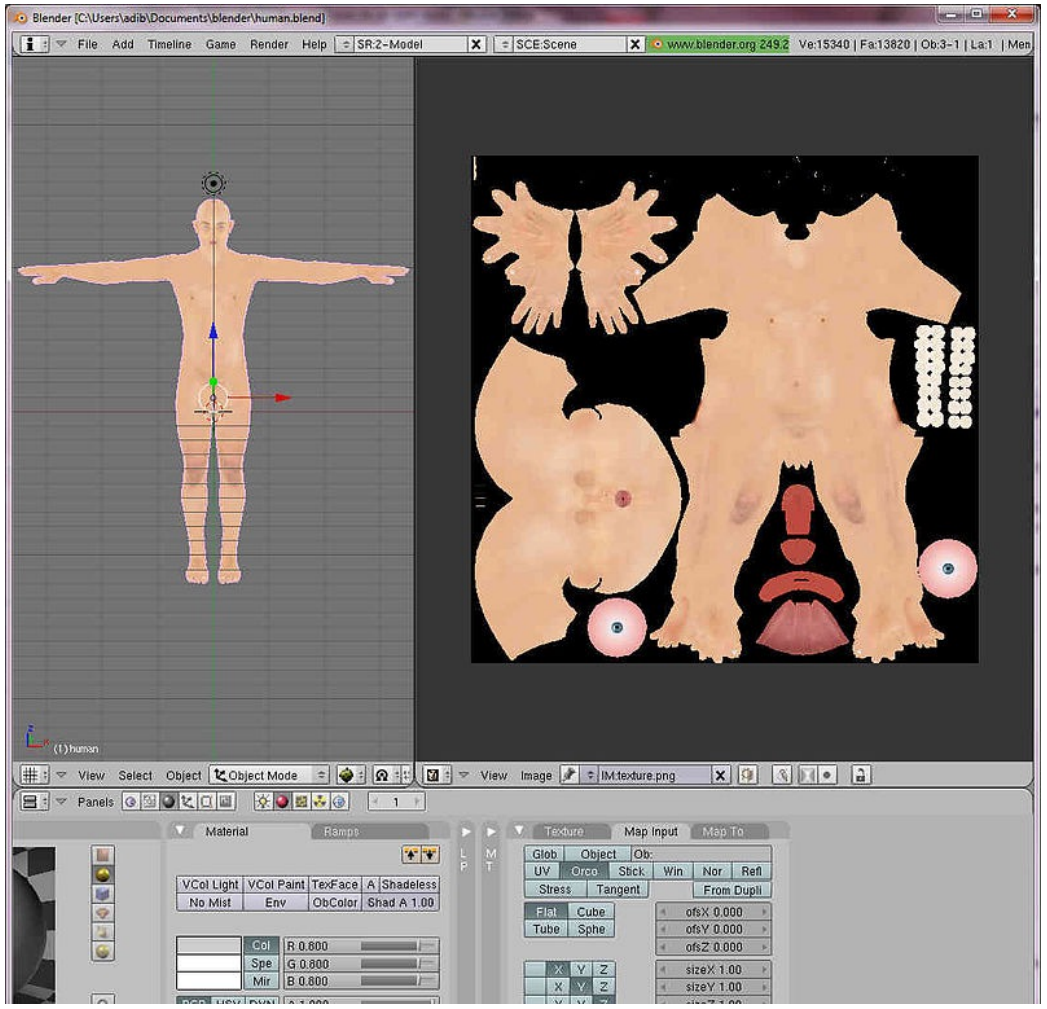
- Normal & Parametric Forms of a Line
- Linear Interpolation
- Raster Scan Algorithm
- Half-Plane Test
- Barycentric Coordinates

- Local vs. Global Illumination
- Specular (Glossy, *not* Mirror)
- Diffuse (Lambertian)
- Ambient (approximates Local Illumination)
- Emissive



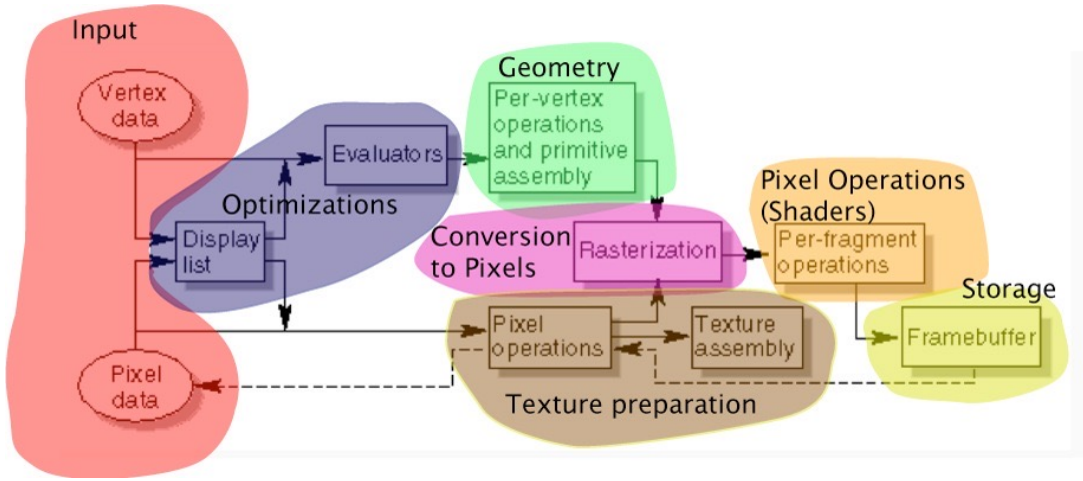
5. Texture Mapping

- Mapping From Manifold to Surface
  - Forwards (u,v -> x,y,z)
  - Backwards (x,y,z -> u,v)
  - Bilinear Interpolation
  - Replacement vs. Modulation
  - Mipmaps
- Uses & Construction



6. Pipeline Implementation

- Pipeline Stages
- State & Queues
- Pipeline Flush
- Framebuffer
- TransformVertex()
- RasterisePrimitive()
- ProcessFragment()

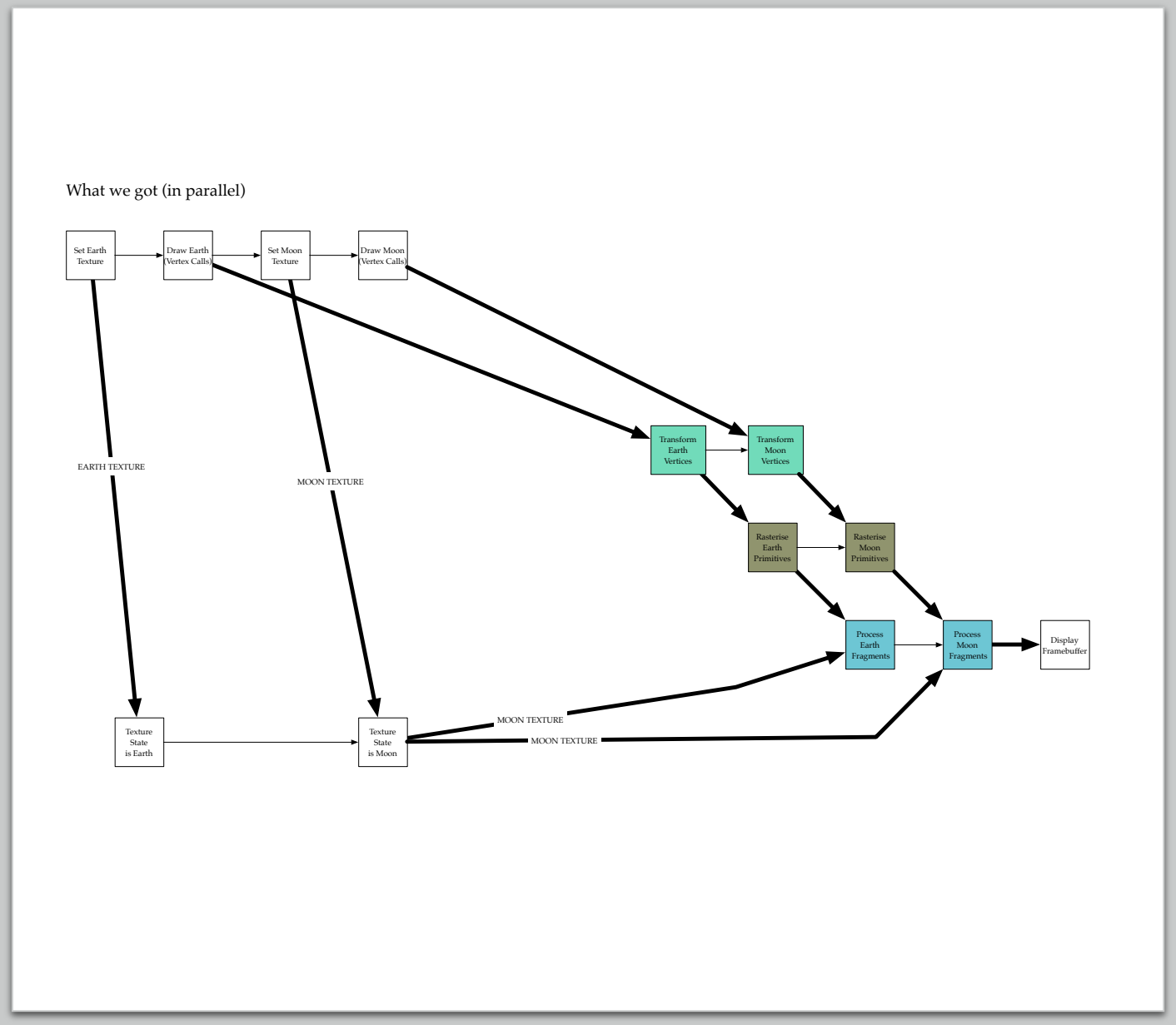


7: GPU Architecture

- Details of the typical architecture
- SIMD Parallelism
- Standard Modern Pipeline
  - And the standard stages
  - With their uses
- Malleability of stages
- Compute shaders

8. Flushing & Buffers

- When to Flush
- How to Flush
- Vertex buffer location: RAM/VRAM/shared
- Packaging attributes
- Transfer via *staging* buffer
- Access via layout & location



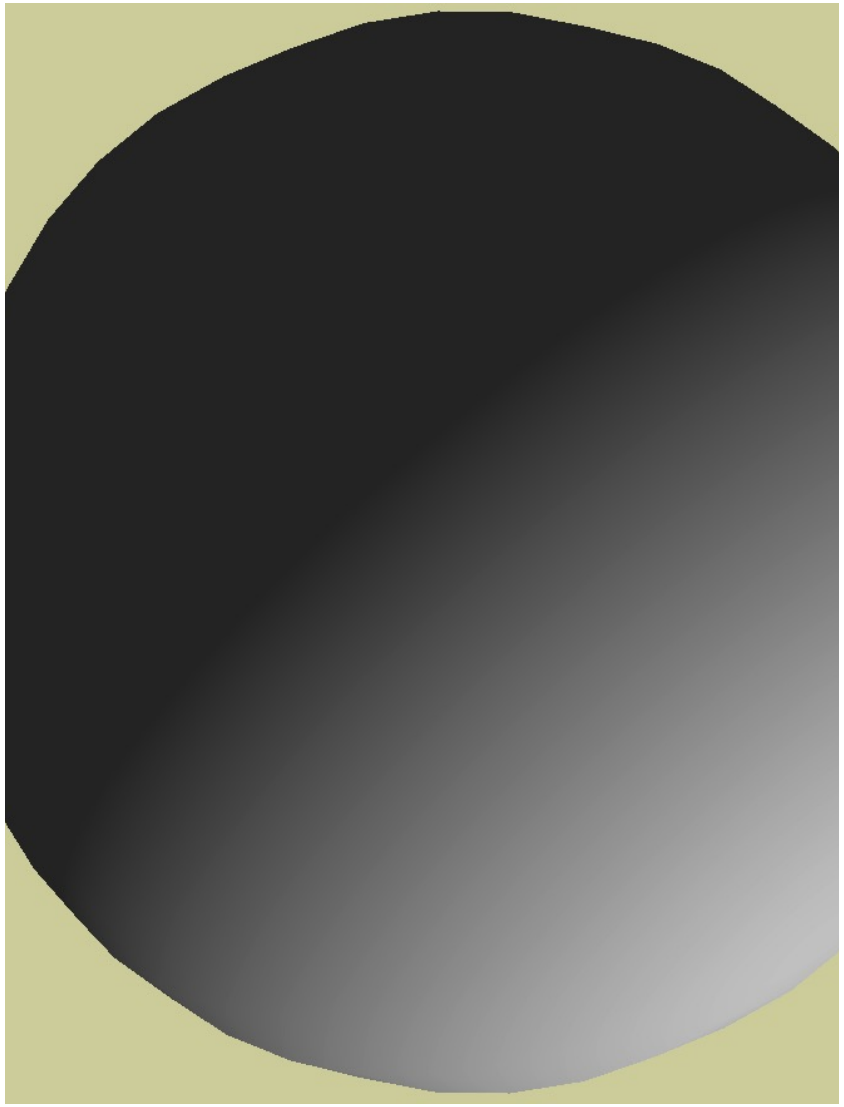
9. GLSL

- Shaders & SPIR-V
- Shader compilation, language & I/O
- Types, I/O & Descriptors
- Uniform buffers for constants

```
// Again, this is needed for the compiler
#version 450
#extension GL_ARB_separate_shader_objects: enable

// the fragment colour (input)
layout(location = 0) vec3 fragColor;

// the output colour
layout(location = 0) vec3 outColor;

// and the main routine
void main()
    { // main()
    // just copy the input colour to the output
    // note that interpolation has already happened
    // in the rasteriser
    // also notice the 1.0 set for the opacity
    outColor = vec4(fragColor, 1.0);
    } // main()
```

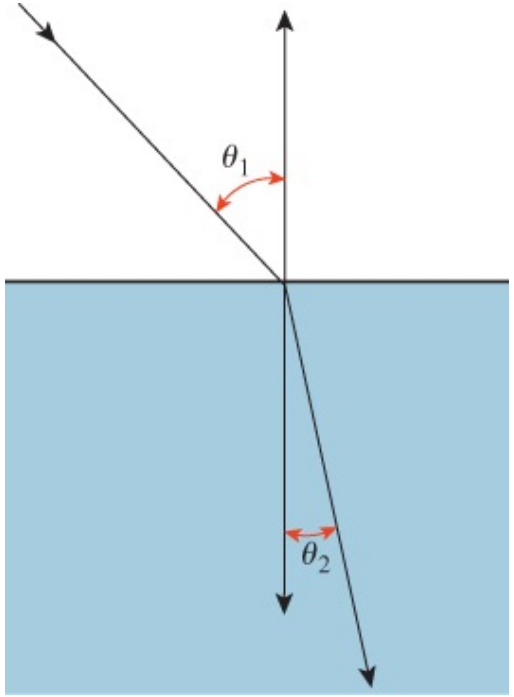
10. Phong Shader

- Vertex shader transforms & outputs normals
- Rasteriser interpolates normals
- Fragment shader computes Blinn-Phong
- GLSL example
- Geometry Shader example for splats



11. Physics of Light

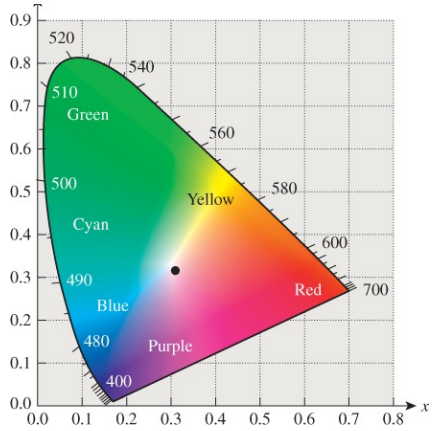
- Photons: Orbitals, Absorption, Emission
- Wave-Particle Duality
- Diffraction, Polarisation, Reflection, Refraction
- Integrating Radiance (5-deep integral)
- Angular Dependence
- Lambertian Reflectance

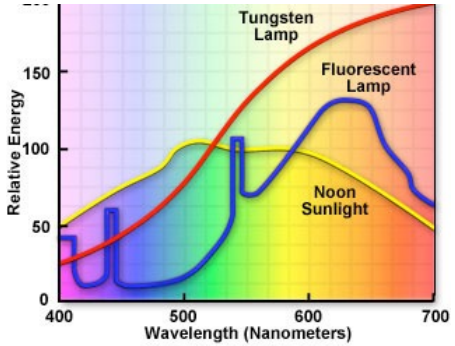


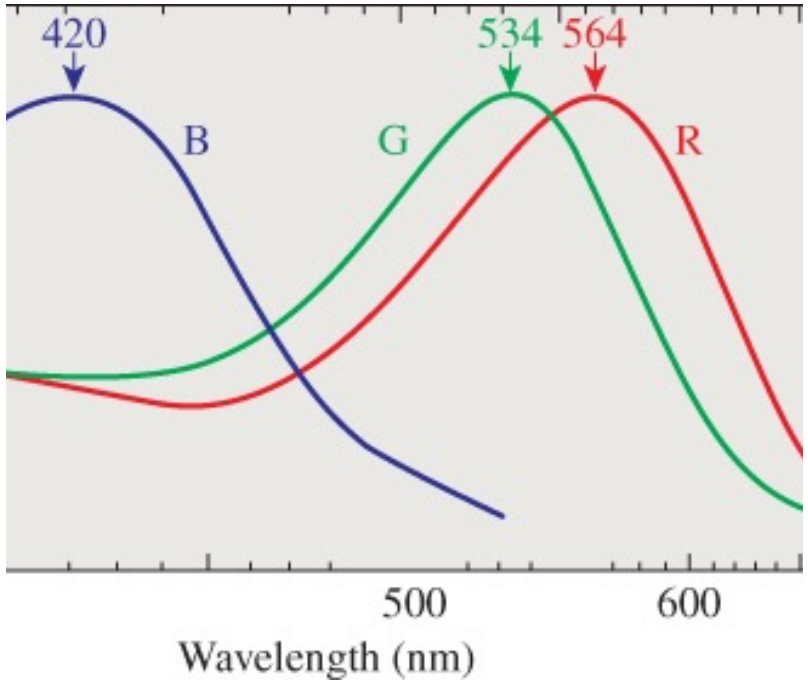
$$energy \approx \int_{t_0}^{t_1} \int_{x_0}^{x_1} \int_{y_0}^{y_1} \int_{\omega \in \Omega} \int_{\lambda_0}^{\lambda_1} L(t, (x, y, 0), -\omega, \lambda)\, d\lambda\, d\omega\, dy\, dx\, dt. \quad (26.39)$$

11. Colour & Perception

- Spectral Distribution
- Rods & Cones
- Luminance
- Tri-Stimulus Theory
- Gamma Encoding
- Colour Spaces

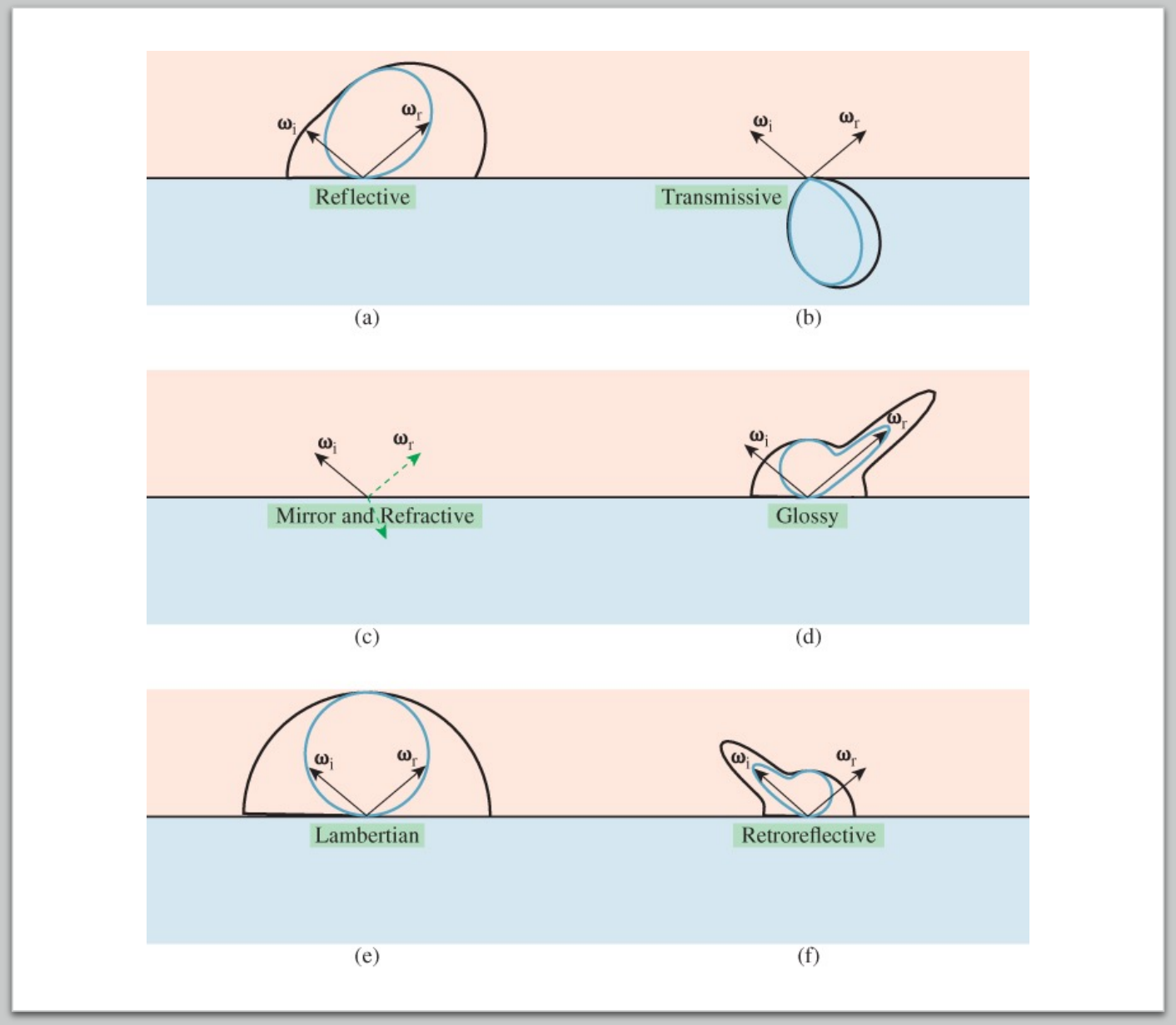






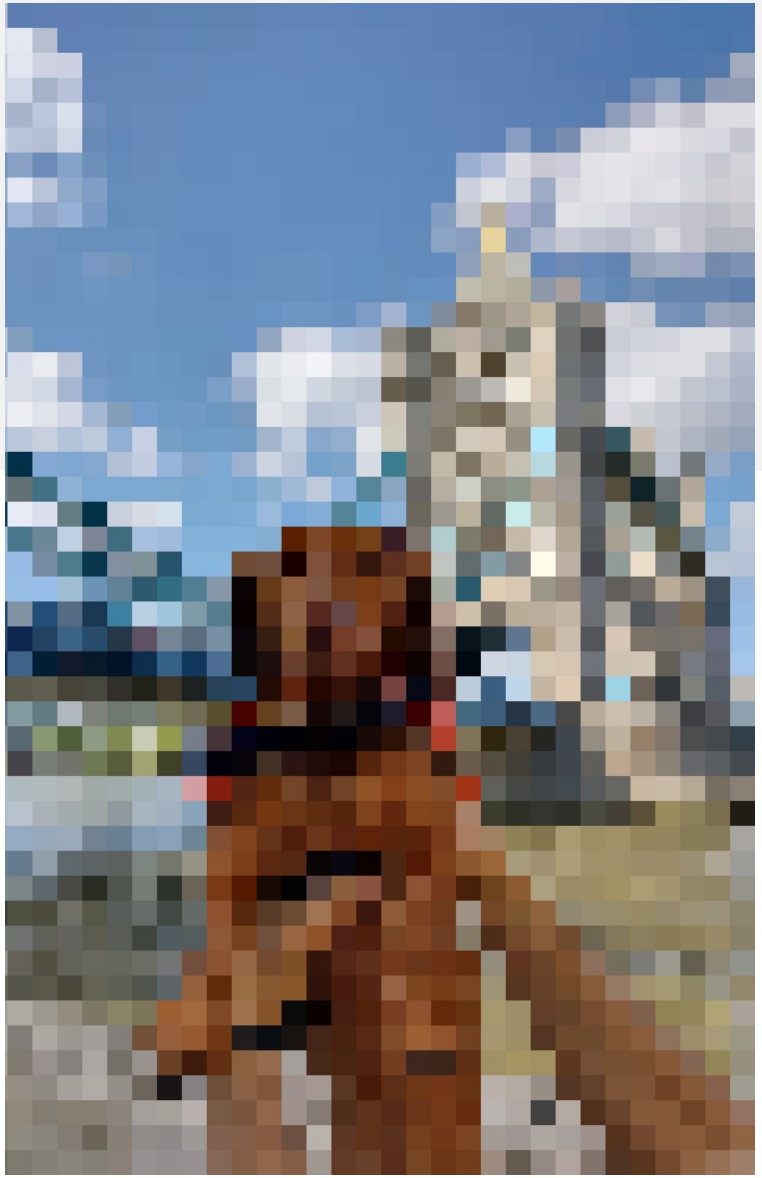
12. Materials & Scattering

- Scattering Functions (BSDFs)
- Finding Surface Frames
- Sources of BSDFs
- Blinn-Phong Shading
  - Add Specular Reflection / Refraction
  - Replace Ambient
- Translucency & Opacity



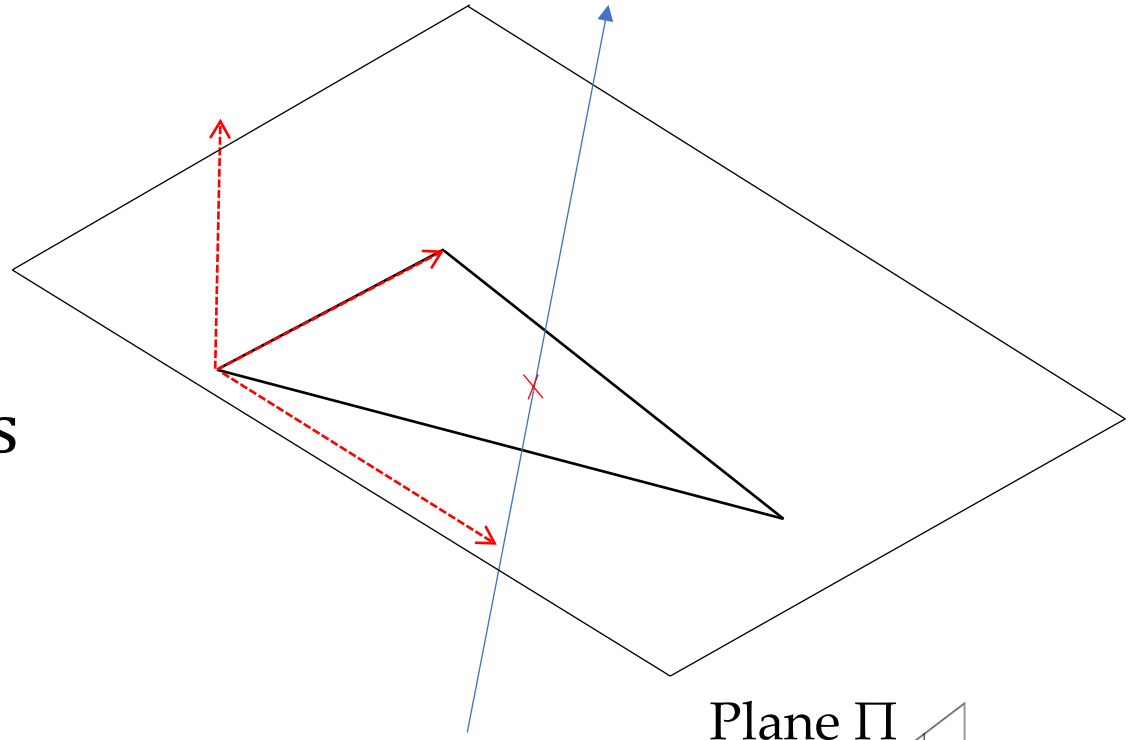
13. Filtering & Scaling

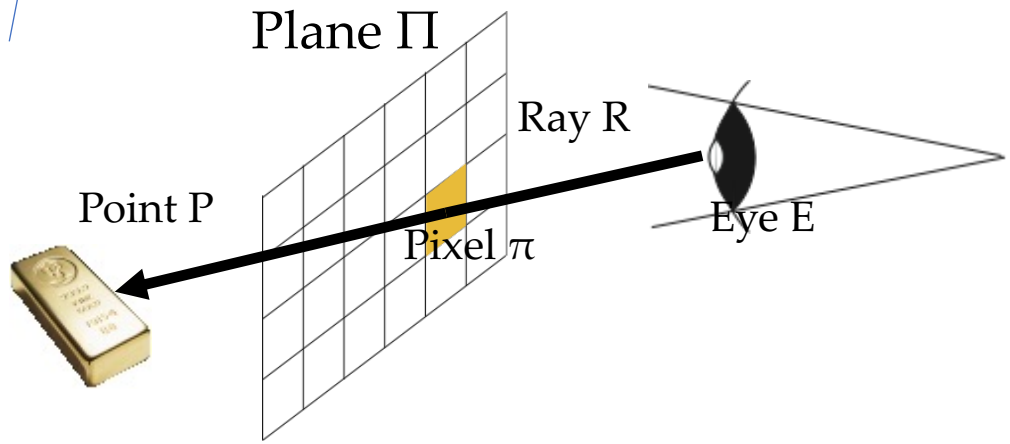
- Continuous vs. Discrete Images
- Reconstruction, Aliasing & Filtering
- Convolution
- Blurring
- Fourier Analysis
- Frequency Filtering
- Scaling Down / Up



14. Raytracing / Intersection

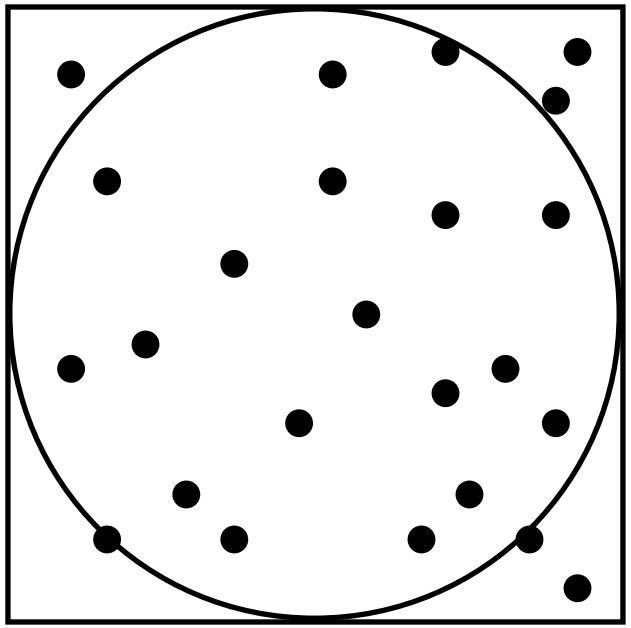
- Ray Casting & Visibility
- Shadow Rays
- Geometric Intersections
  - Line-Sphere
  - Line-Plane
  - Line-Triangle
  - Triangle-Triangle





15. Monte Carlo Sampling

- Random Numbers
- Mean, Variance & Standard Deviation
- Importance Sampling
- Monte Carlo Sampling
- Weighting Sampling Directions



$f: [0,1]\times[0,1] \rightarrow H: (u, v) \rightarrow (\cos(2\pi u), v, \sin(2\pi u))$

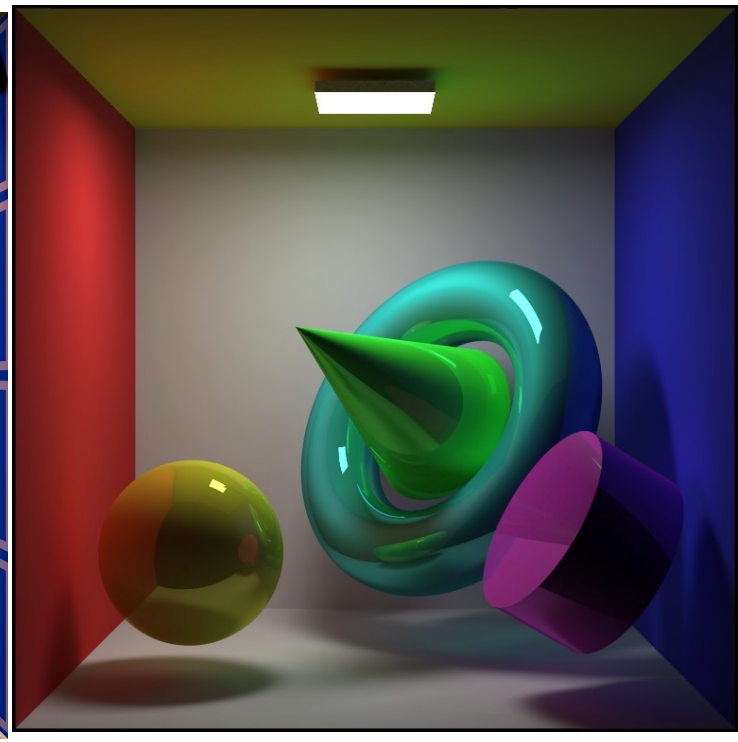
16. Practical Raytracing

- Rendering Equation
- Basic Path Tracer
  - Direct Point Lights
  - Indirect Point Lights
  - Recursive Scattering
  - Transmissive Terms
- Recursive Path Tracer
  - Emissive Term for Area Lights
  - Direct Term for Point Lights
  - Direct Monte Carlo Term for Area Lights
  - Impulse Scatter for Reflection/Transmission
  - Indirect Light for Everything Else
    - Randomised Direction & Extinction Factor

- $L^{ref}(P, \omega_0) = \int_{\omega_i \in \boldsymbol{S}^2_+(P)} L(P, -\omega_i) f_r(P, \omega_i, \omega_0) \left(\omega_i \cdot \overrightarrow{n_p}\right) \mathrm{d}\omega_i$

17. Alternative Rendering Solutions

- Radiosity
- Path Tracing (Kajiya)
- Bidirectional Path Tracing
- Metropolis Light Transport
- Photon Mapping
- Image-Space Photon Mapping
- All of the stuff we don't use



18. NPR

- Style, Intent, Message, Abstraction
- Role of Strokes
- Simplify, Factorise, Schematise
- Silhouette Detection from Normals
- Curvature Lines
- Cel (Toon) Shading

19. Volume Rendering

- Volumetric Functions
- Meshes & Interpolation
- Isosurfaces
- Normal Vectors & Central Differencing
- Volume Rendering Integral
- Transfer Functions
- Pseudocode