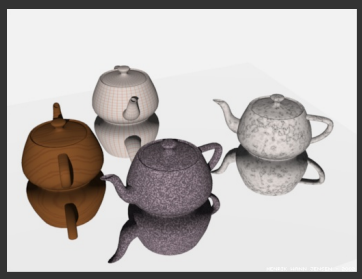
CSE168: Rendering Algorithms
Basic Shading



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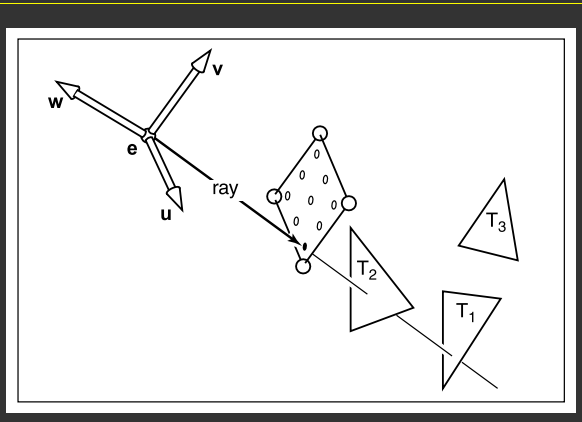
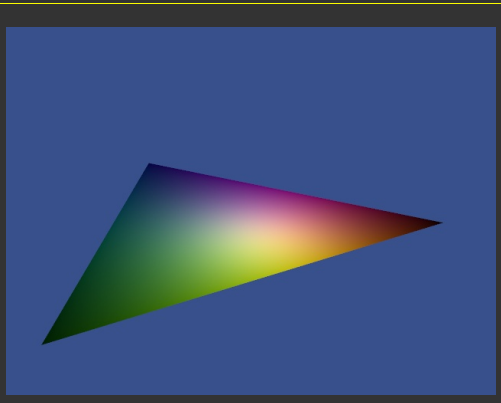
Practical details

- Assignment 1 due April 24

Ray Tracing



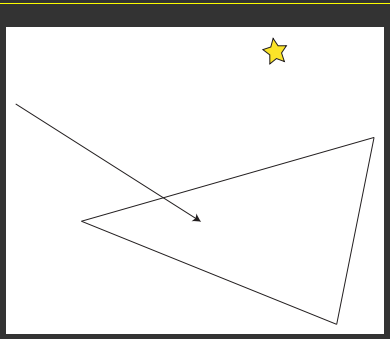
Basic Shading



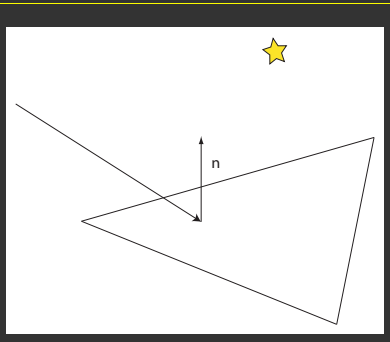
Basic Shading

- Diffuse shading
- Shadow rays
- Floating point issues
- Specular reflection
- Refraction
- Fresnel term
- A full illumination model

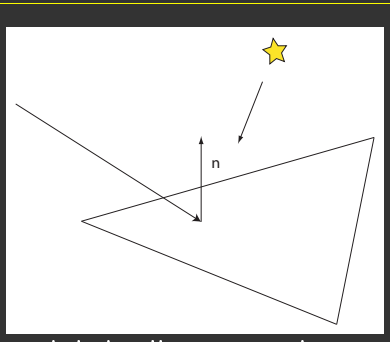
Basic Shading



Basic Shading

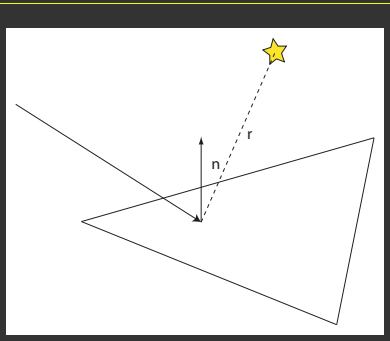


Basic Shading



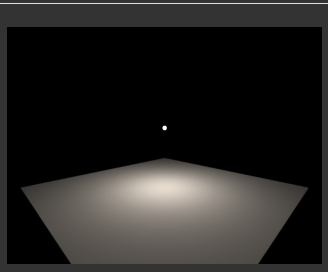
How much light illuminates the triangle?

Basic Shading



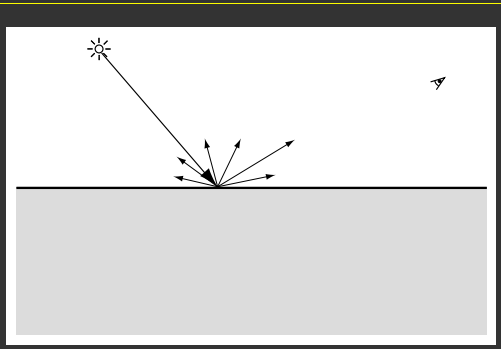
$$E = \frac{\Phi(\vec{n} \cdot \vec{l})}{4\pi r^2}$$

Direct Illumination



$$E = \frac{\Phi(\vec{n} \cdot \vec{l})}{4\pi r^2}$$

The BRDF



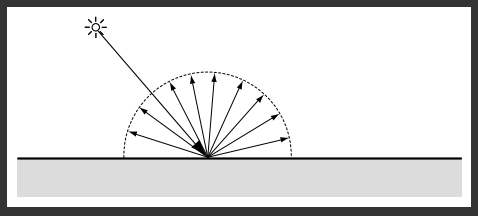
BRDF: $f_r(x, \vec{\omega}, \vec{\omega}') = \frac{dL(x,\vec{\omega})}{dE(x,\vec{\omega}')}$

Basic Physics

L = Radiance
E = Irradiance

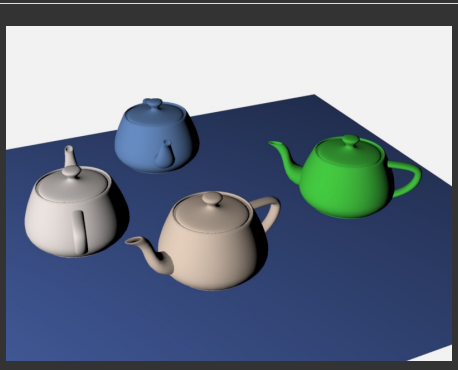
- A ray transports radiance L
- A light source illuminates an object with irradiance E

Diffuse Shading



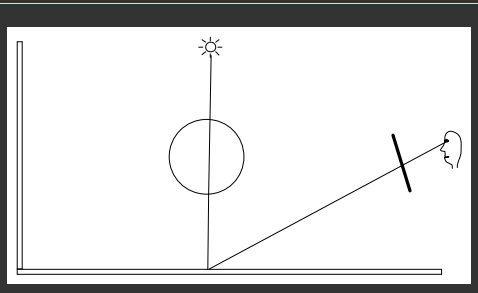
$$L_d(x, \vec{\omega}) = R_d * E$$

Diffuse Shading

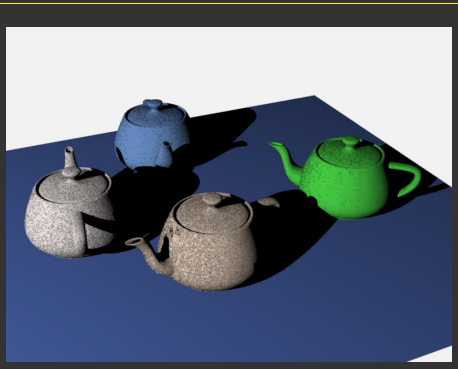


$$L_d(x, \vec{\omega}) = R_d * E$$

Shadows

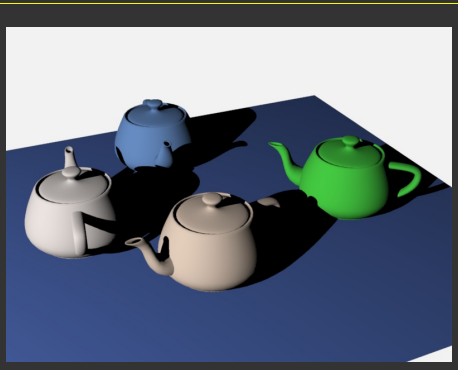


Shadows



Only accept intersections if $t > \epsilon$, $\epsilon \approx 0.0001$.

Shadows



Everything is Diffuse

Arnold Rendering

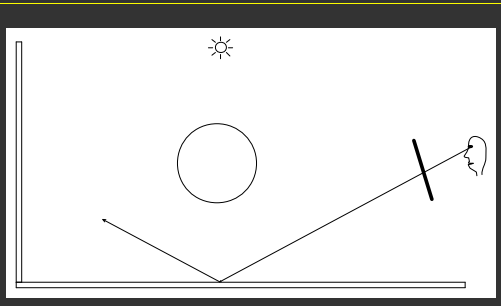
Everything is Diffuse!

Arnold Rendering

Everything is Diffuse!

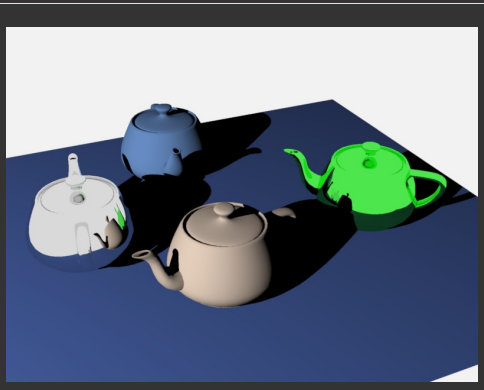
Arnold Rendering

Specular Reflection

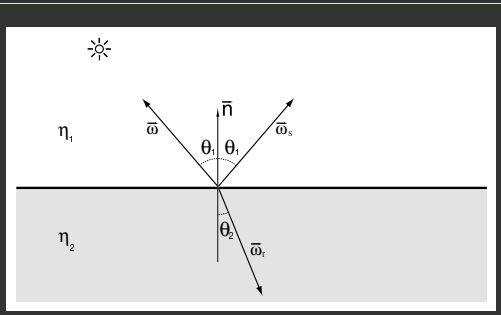


$$L_s(x,\vec{\omega}) = R_s * L_i(x,\vec{\omega_r})$$
$$\vec{\omega_r} = -2(\vec{\omega}\cdot\vec{n})\vec{n} + \vec{\omega}$$

Specular Reflection

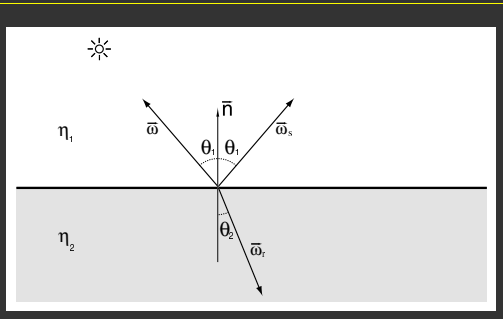


Specular Refraction



Specular Refraction

Snell's Law



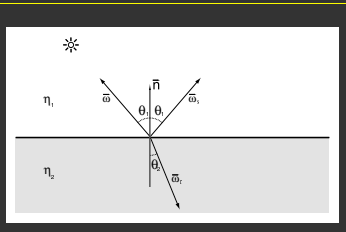
$$\eta_1 \sin\theta_1 = \eta_2 \sin\theta_2$$

The Index of Refraction

Some values for η:

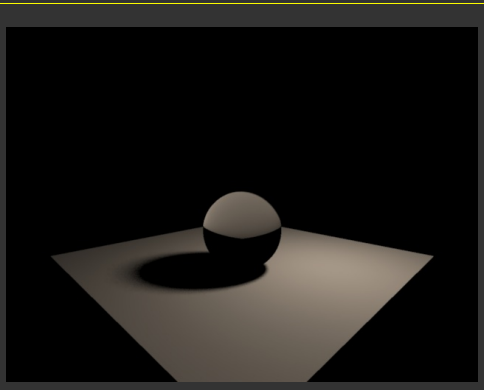
Vacuum	1.00000
Air at STP	1.00029
Ice	1.31
Water	1.33
Crown glass	1.52 - 1.65
Diamond	2.417

Specular Refraction



$$\vec{\omega}_t = -\frac{\eta_1}{\eta_2}(\vec{\omega} - (\vec{\omega}\cdot\vec{n})\vec{n}) - \left(\sqrt{1 - \left(\frac{\eta_1}{\eta_2}\right)^2 (1 - (\vec{\omega}\cdot\vec{n})^2)}\right)\vec{n}$$

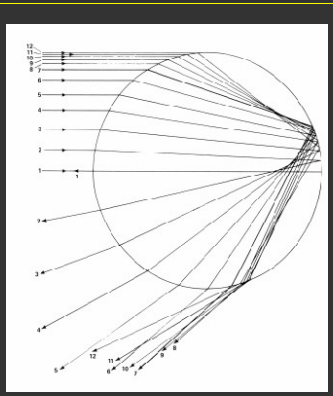
Specular Refraction



Rainbows

Rainbow caused by refraction through waterdrops

Ray Tracing a Waterdrop

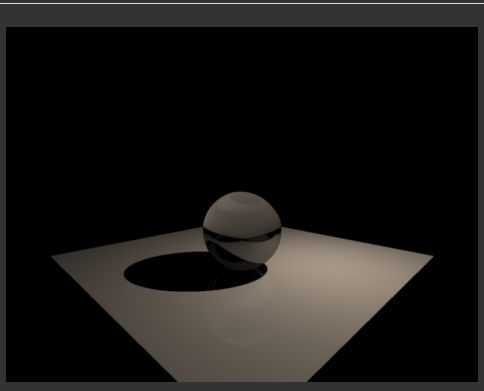


Analysis of refraction in a waterdrop by Descartes ~1650

An Illumination Model

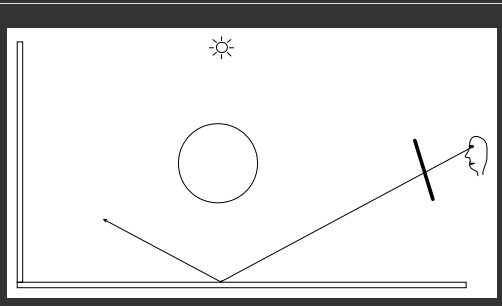
$$L = R_d * E + R_s * L_s + R_t * L_t$$

An Illumination Model



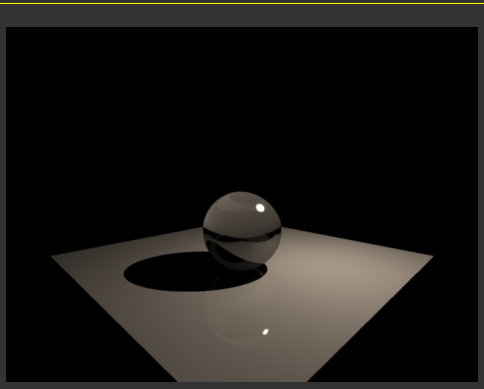
Marble Spheres

Simulating Highlights



$$L = R_s * \frac{(\vec{\omega}_s \cdot \vec{l})^n}{(\vec{n} \cdot \vec{l})} * E$$

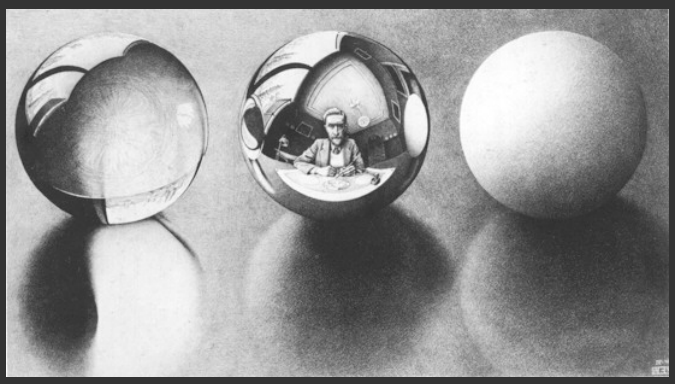
Simulating Highlights



An Illumination Model

$$L = R_d * (\vec{n} \cdot \vec{l}) * E + R_s * \frac{(\vec{\omega}_s \cdot \vec{l})^n}{(\vec{n} \cdot \vec{l})} * E + R_s * L_s + R_t * L_t$$

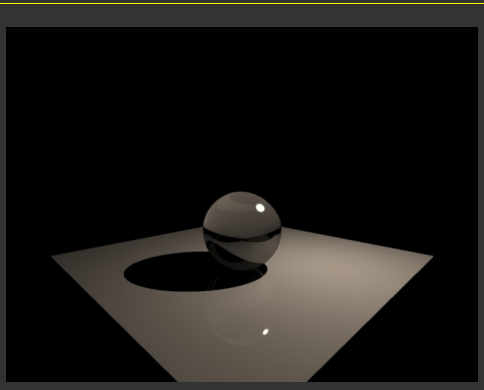
Three Spheres



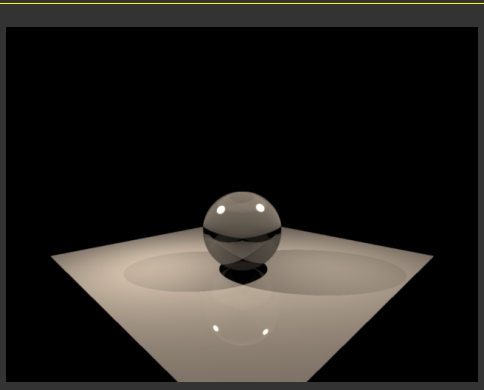
Direct Illumination

What happens when there are two lights in the scene?

One Light



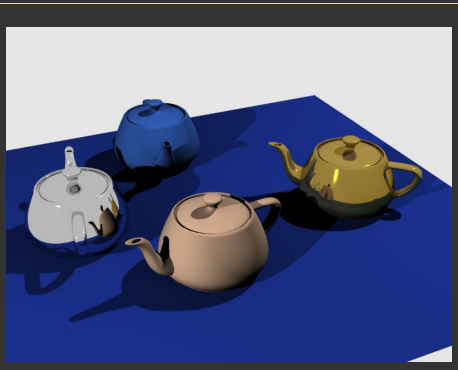
Two Lights



An Illumination Model

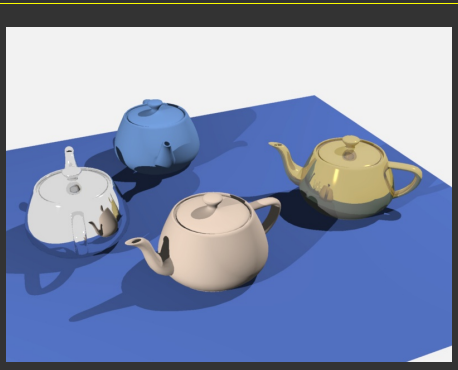
$$L = \sum_{l}^{N_l} \left(R_d * E_l + R_s * \frac{(\vec{\omega}_s \cdot \vec{l})^n}{(\vec{n} \cdot \vec{l})} * E_l \right) + R_s * L_s + R_t * L_t$$

An Illumination Model



Still something missing?

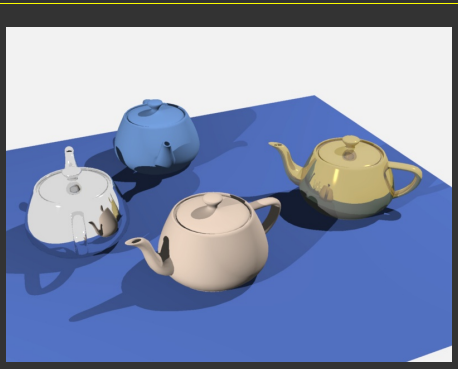
Ambient Term



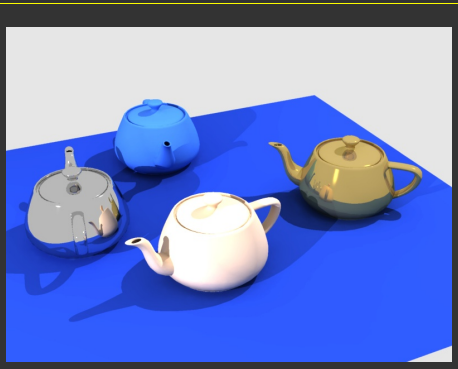
Ambient Term

$$L = \sum_{l}^{N_l} \left(R_d * E_l + R_s * \frac{(\vec{\omega}_s \cdot \vec{l})^n}{(\vec{n} \cdot \vec{l})} * E_l \right)$$
$$+ R_s * L_s + R_t * L_t + R_d * E_A$$

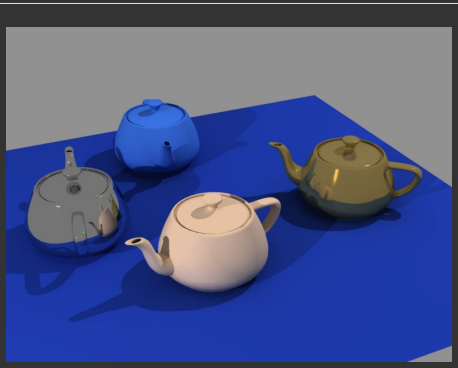
Ambient Term



Global Illumination



Tone Mapping

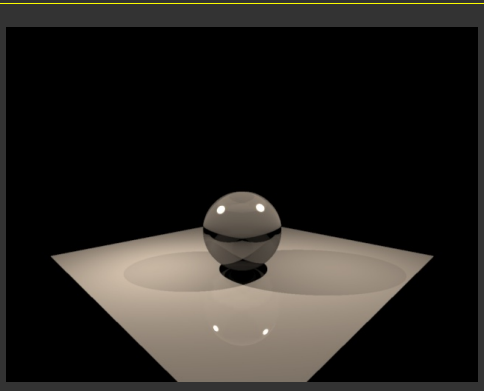


Energy Balance

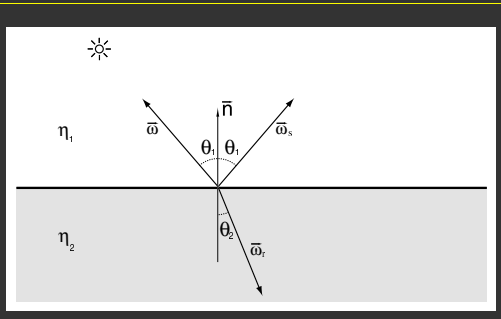
$$L = Reflected + Transmitted + Absorbed$$

$$R_d \geq 0 \quad , \quad R_s \geq 0 \quad , \quad R_t \geq 0$$
$$R_d + R_s + R_t \leq 1$$

A Glass Sphere



Fresnel Reflection



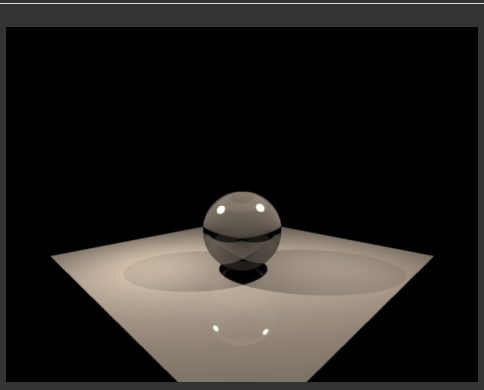
How much light is reflected and refracted ??

Fresnel Reflection

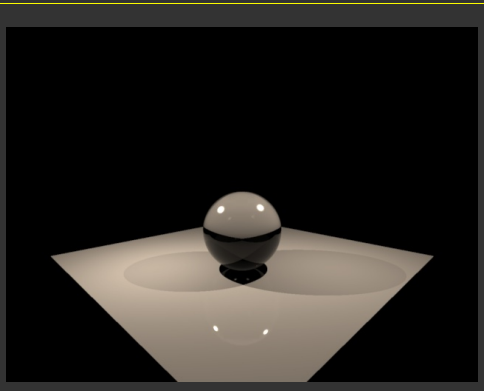
$$\rho_{\parallel} = \frac{\eta_2 \cos\theta_1 - \eta_1 \cos\theta_2}{\eta_2 \cos\theta_1 + \eta_1 \cos\theta_2}$$
$$\rho_{\perp} = \frac{\eta_1 \cos\theta_1 - \eta_2 \cos\theta_2}{\eta_1 \cos\theta_1 + \eta_2 \cos\theta_2}$$

$$F_r(\theta) = \frac{1}{2}\left(\rho_{\parallel}^2 + \rho_{\perp}^2\right) = \frac{d\Phi_r}{d\Phi_i}$$

No Fresnel Reflection



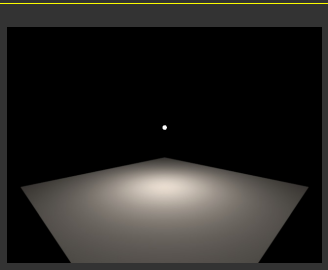
Fresnel Reflection



Fresnel Reflection

$$F_r(\theta) \approx F_0 + (1 - F_0)(1 - \cos\theta)^5$$

Illumination Model



$$L = \sum_{l}^{N_l} \left(\left(R_d + R_s * \frac{(\vec{\omega}_s \cdot \vec{l})^n}{(\vec{n} \cdot \vec{l})} \right) * \frac{\Phi(\vec{n} \cdot \vec{l})}{4\pi r^2} \right)$$
$$+ R_d * E_A + R_s * L_s + R_t * L_t$$

Torrance-Sparrow Model

$$f_r = \frac{FGP(\omega_f)}{4 \cos\theta_i \cos\theta_r}$$

$$S(V) = \frac{2(N \cdot H)(N \cdot V)}{H \cdot V}$$

$$G = min\{\ 1,\ S(E),\ S(L)\ \}$$

Teapot Series

Teapot Series

Teapot Series

Teapot Series

Next time

Acceleration structures