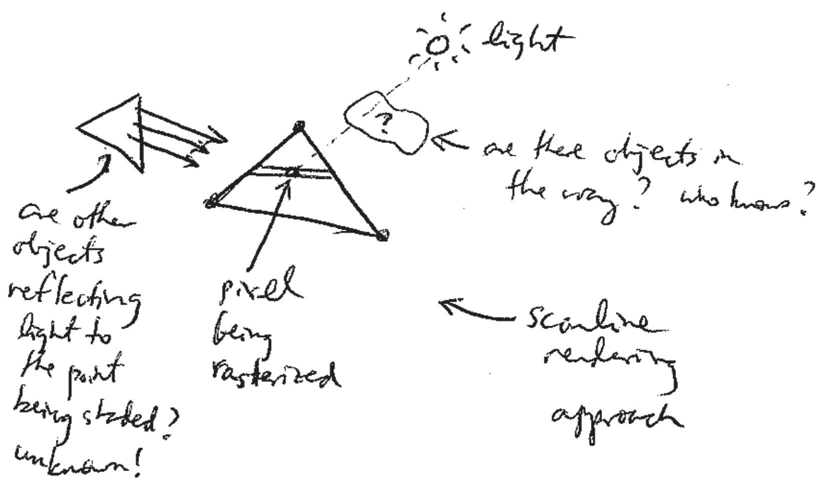
Introduction to Illumination

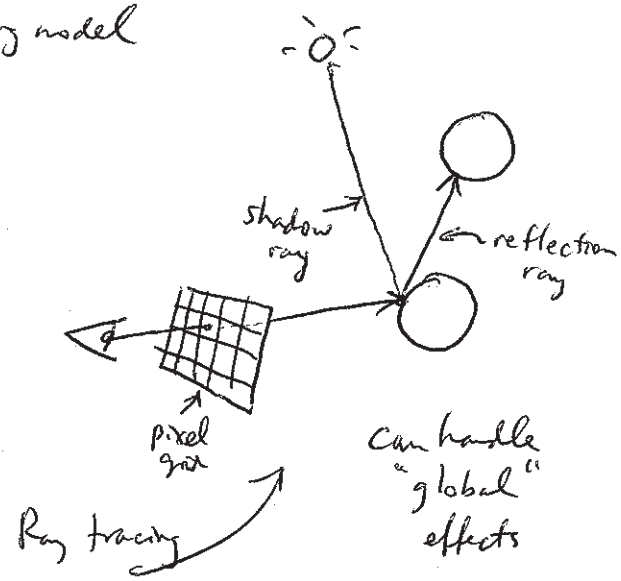
Goal: Model the interaction of light with materials.

1) Must be fast

2) Must look good
   doesn't have to be physically correct!

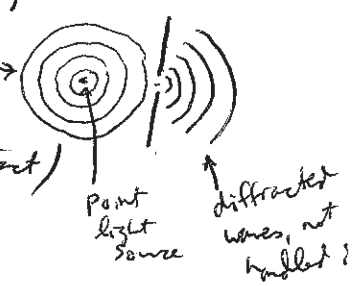
Our scan-line rendering system is using a "local" shading model
- no information about other objects in the scene!





Assumptions of light transport in computer graphics (scan-line rendering)

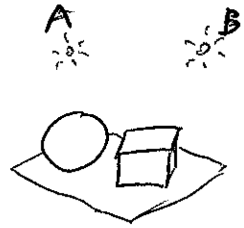
1. Geometrical optics
   - Light travels in straight lines
   - No diffraction
   - No interference
     (light rays do not interact)



2. Steady state assumption
   - Light travels ∞ fast! ← not correct, but who can tell? (see goal #2)

3. No propagation media
   - No atmospheric effects (fog can be approximated by attenuating proportional to distance from viewer)
   - No participating media

4. Linearity of light
 - Superposition :



Scene with 2 light sources. Say $I(A)$ is image with light source A on and $I(B)$ is image w/ light B.
then $I(A+B) = I(A) + I(B)$

5. Discrete wavelength approx
 - Not continuous wavelength, but RGB.

Radiometric terms (we've covered them before, see Lecture 2 (8/23/07))

Flux: Φ : radiated power (W) or $\left(\frac{J}{sec}\right)$

Irradiance: E : irradiance incident on a surface
 - flux (power)/unit area $\left(\frac{W}{m^2}\right)$

Radiant Intensity I : power / unit solid angle
W/sr

Radiance: L : Flux density per unit solid angle per unit ~~sr~~ area
$\frac{W}{m^2 sr}$

- How many photons/sec does a 100W bulb give out?

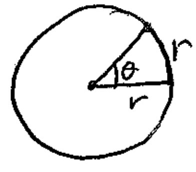
We can find energy/sec.
Assume photons have wavelength λ.

energy of a single photon → $E = hf = \frac{hc}{\lambda}$ (h ← Planck's constant, c ← speed of light, λ ← wavelength)

if $\lambda = 630$ nm (red light)
$c = 3 \times 10^8$ m/s
$h = 6.626 \times 10^{-34}$ J·s
$\approx 3.2 \times 10^{-19}$ J/photon
$(3.2 \times 10^{20}$ photons/sec !$)$

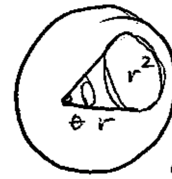
sr = steradians
unit of solid angle

similar to radians, which are defined on a circle, steradians are defined on a sphere:



$\theta = 1$ radian
A radian is defined as the angle of an arc of length r on a circle with radius r.

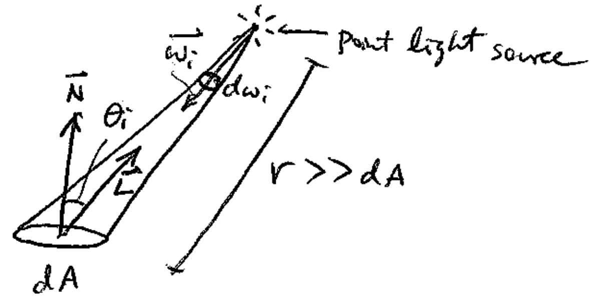
perimeter = $2\pi r$
1 radian length r so 2π radians on a circle



$\theta = 1$ steradian
A steradian is defined as the solid angle subtended by a patch of size r^2 in area on a sphere of radius r.
Surface area of sphere $4\pi r^2$
$1\ sr = r^2$
so 4π sr in a sphere!

I. Illumination

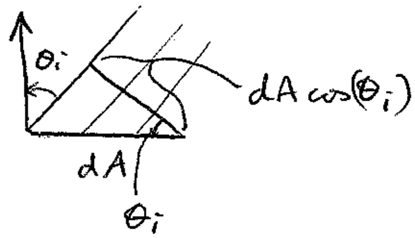
Point → area

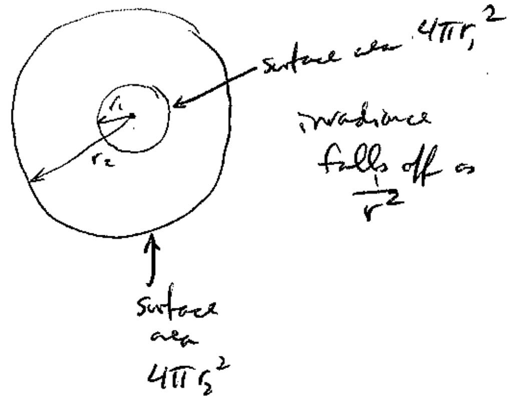


Irradiance at point on surface:

$$E = \frac{d\Phi}{dA} = \frac{\overbrace{I(\omega_i)}^{\text{intensity of light } \left(\frac{W}{sr}\right)} \, \overbrace{d\omega}^{\text{angle } (sr)}}{\underset{(m^2)}{dA}}$$

E: $\left(\frac{W}{m^2}\right)$



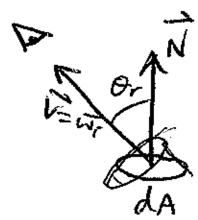


so $\displaystyle d\omega = \frac{dA\cos(\theta_i)}{r^2}$

$$E = \frac{I(\omega_i)\,\cancel{dA}\cos(\theta_i)}{\cancel{dA}\,r^2} = \frac{I(\omega_i)\cos(\theta_i)}{r^2} \qquad 0 \le \theta_i \le 90^\circ$$

II Reflection

Ideal Diffuse Illumination: AKA Lambertian



Radiant intensity:

$$dI(\vec{\omega_r}) = \underbrace{E}_{\frac{W}{m^2}} \, \underbrace{dA}_{\frac{1}{m^2}} \, \underbrace{k_d \cos(\theta_r)}_{\left(\frac{1}{sr}\right)}$$

Radiance:

$$\underset{\left(\frac{W}{sr\,m^2}\right)}{L(\vec{\omega_r})} = \frac{dI(\vec{\omega_r})}{\underbrace{dA_p}_{\substack{\text{projected} \\ \text{area} \\ (m^2)}}} = \frac{E\,\cancel{dA}\,k_d\,\cancel{\cos(\theta_r)}}{\cancel{dA}\,\cancel{\cos(\theta_r)}} = \frac{I(\omega_i)\cos(\theta_i)\,k_d}{r^2}$$

note the $\cos(\theta_r)$ terms cancel!

⇒ no dependency on view direction

In OpenGL this is often written as:

$$L_{diff} = \underbrace{f_{att}}_{\text{distance fall-off}} \underbrace{I_p}_{\text{intensity of the light}} \underbrace{k_d}_{\text{color diffuse attenuation}} \underbrace{(\vec{N} \cdot \vec{L})}$$

if $|\vec{N}| = |\vec{L}| = 1$ then

$$\vec{N} \cdot \vec{L} = |\vec{N}||\vec{L}| \cos\theta_i = \cos\theta_i$$

(often expanded to:

$$\frac{1}{\underbrace{c_1 + c_2 r + c_3 r^2}_{\text{works and looks better for most apps}}}$$
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