


Lighting affects appearance


Light

Source emits photons

Photons travel in a straight line

When they hit an object they:

- bounce off in a new direction
- or are absorbed
- (exceptions later).

And then some reach the eye/camera.

Reflectance

- Model how objects reflect light.
- Model light sources
- Algorithms for computing
  - Shading: computing intensities within polygons
  - Determine what light strikes what surfaces.

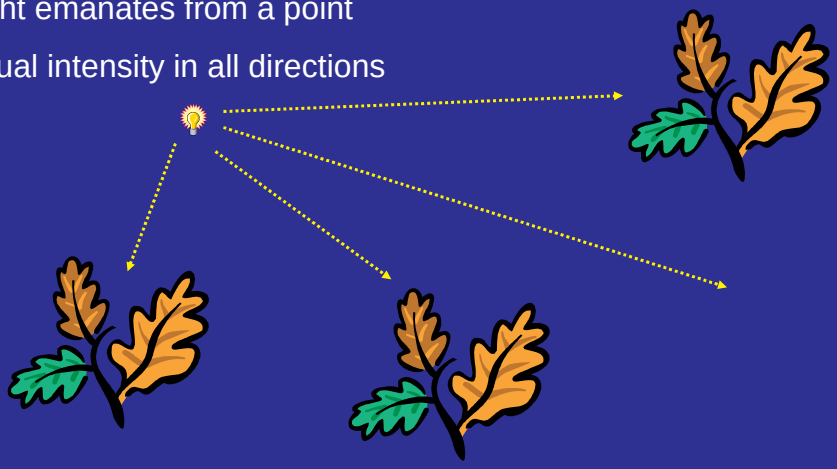
Basic fact: Light is linear

- Double intensity of sources, double photons reaching eye.
- Turn on two lights, and photons reaching eye are same as sum of number when each light is on separately.
- This means we can render lights separately

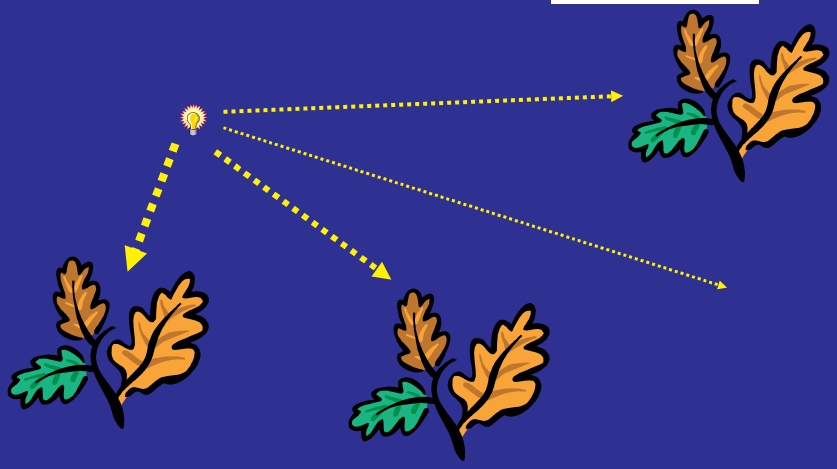
Light Model: Point Source

•Light emanates from a point

•Equal intensity in all directions

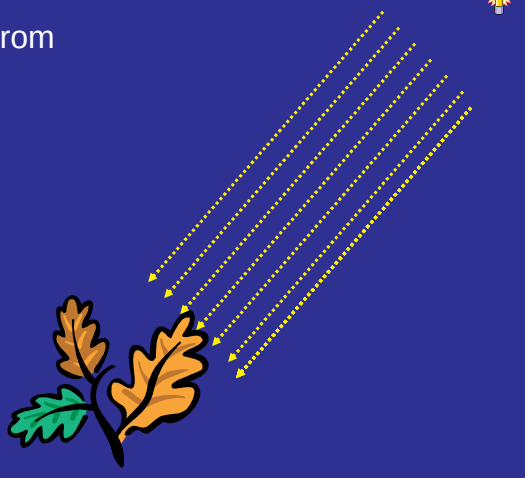


- Intensity drops off with distance.
- With square of distance: $\frac{1}{d^2}$
- To simulate effects of non-point sources: $\frac{1}{a_0 + a_1 d + a_2 d^2}$



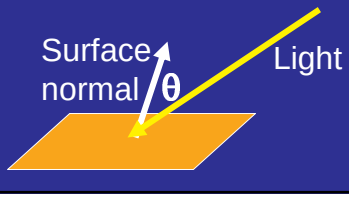
Light model: distant point source

- All light in scene comes from same direction.
- With same intensity



Surfaces reflect light: Lambertian

- Amount of light striking surface proportional to cos θ
  - Angle between light direction and surface.
- Equal brightness in all directions
- Albedo is fraction of light reflected.
- Diffuse objects (chalk, cloth, matte paint).
- Brightness doesn't depend on viewpoint.



Lambertian + Point Source

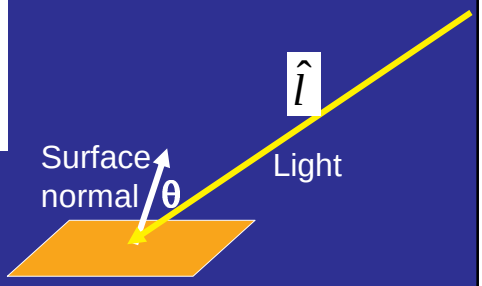
$\vec{l} = l \bullet \hat{l}$ $\begin{cases} \hat{l} \text{ is direction of light} \\ l \text{ is intensity of light} \end{cases}$

$i = \max(0, \lambda(\vec{l} \bullet \hat{n})$

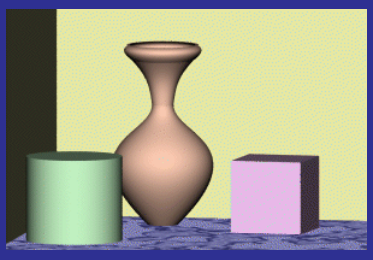
i is radiance

λ is *albedo*

$\hat{n}$ is surface normal

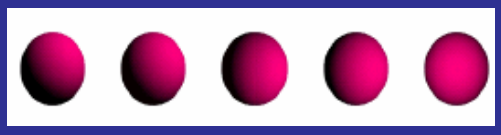


Lambertian Examples



Scene

(Oren and Nayar)



Lambertian sphere as the light moves.

(Steve Seitz)

Ambient

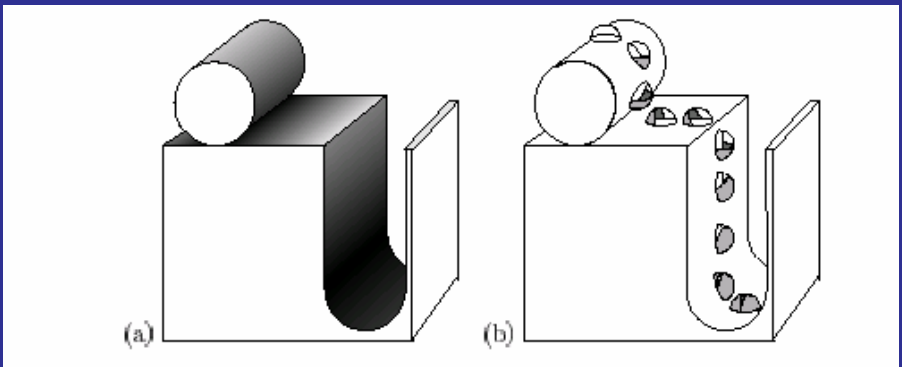
- Assume Lambertian surface normal receives equal light from all directions.

$$i = a\lambda$$

- Diffuse lighting, no cast shadows.
- Ambient (and point) light can be colored

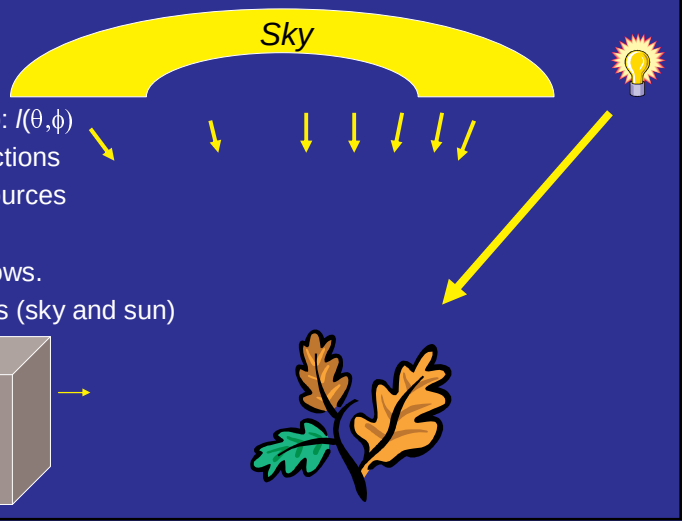
Ambient + Point Source

- Needed to avoid artifacts
  - Make sure shadows aren't black.
- Reasonable approximation to general
  - Sun + sky.
  - Lamp + light reflected by walls
  - In fact, it's a 1st order approximation.
- But doesn't handle many effects
  - Sources of other shapes.
  - Shadows of ambient light in concave objects.



Shadow example

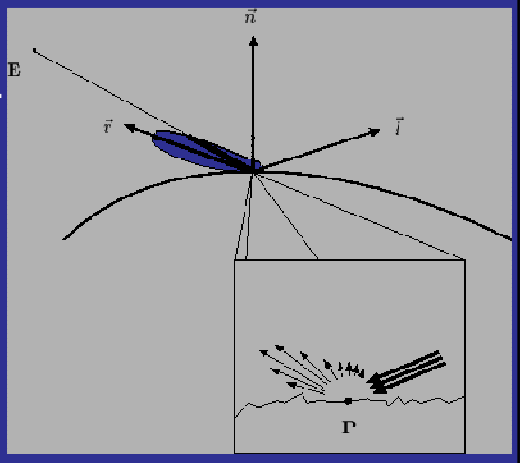
Environment Map



- Environment map: $I(\theta,\phi)$
  - Light from all directions
  - Diffuse or point sources
  - Still distant
  - Still no cast shadows.
  - Example: outdoors (sky and sun)

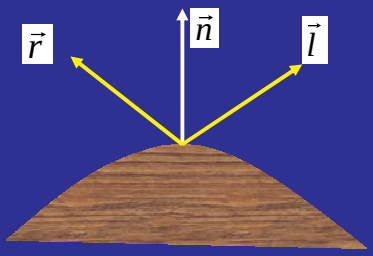
Specular surfaces

- Another important class of surfaces is specular, or mirror-like.
  - radiation arriving along a direction leaves along the specular direction
  - reflect about normal
  - some fraction is absorbed, some reflected
  - color depends on color of incoming light, not of surface.



(http://graphics.cs.ucdavis.edu/GraphicsNotes/Shading/Shading.html)

Specular Direction

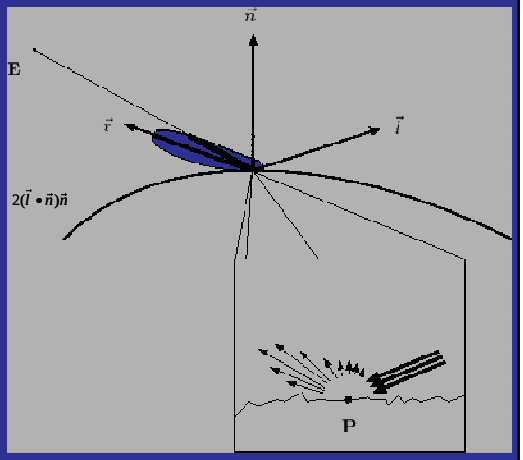


$$\vec{r} + \vec{l} = 2(\vec{l} \bullet \vec{n})\vec{n}$$

$$\vec{r} = 2(\vec{l} \bullet \vec{n})\vec{n} - \vec{l}$$

Specular surfaces

- Brightness depends on viewing direction.
- Specularity is spread out.
  - Mirror, smooth light all bounces same way.
  - Slightly rougher, direction of bounce varies.
  - Diffuse, many bounces



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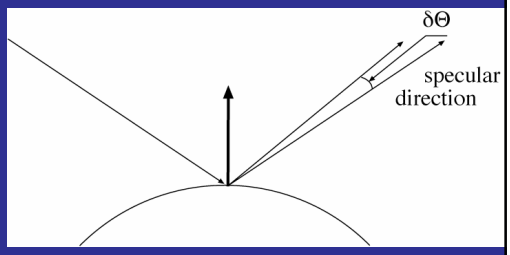
Phong's model

- Empirical model (*eg.,* hack)
- Phong's model
  - reflected energy falls off as: $\cos^n(\delta\vartheta)$
    - n very big, this is like mirror.
    - As n gets smaller, specularity more spread out.
    - Good model for plastic
    - Specularity color of source.

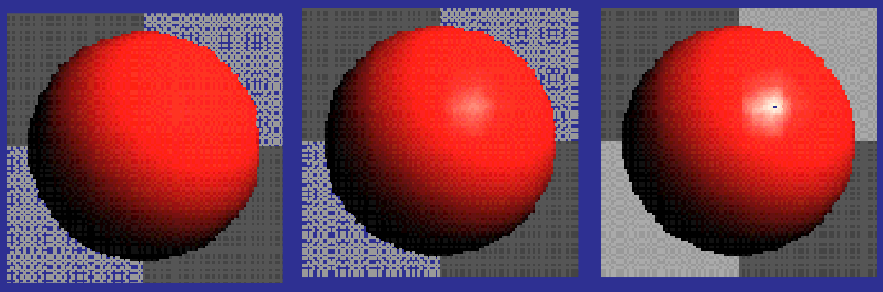


(Forsyth & Ponce)

Lambertian + specular

- Two parameters: how shiny, what kind of shiny.
  - Many objects combine shiny and diffuse material
    - Wood with veneer; glossy paint, plastic, greasy skin.

Lambertian+Specular+Ambient



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More complex reflectances

- Physically realistic models
  - Torrance Sparrow models roughness of surfaces and shadowing of microfacets.
- Models built from observation.
  - Measurement for every lighting direction and viewing direction.

BRDF Not Always Appropriate

BRDF

BSSRDF

http://graphics.stanford.edu/papers/bssrdf/
(Jensen, Marschner, Levoy, Hanrahan)

Luminescence

- Surface shifts color of light.
- Can reflect more light of a color than is present in source.
- This is why objects can glow in “black” light.