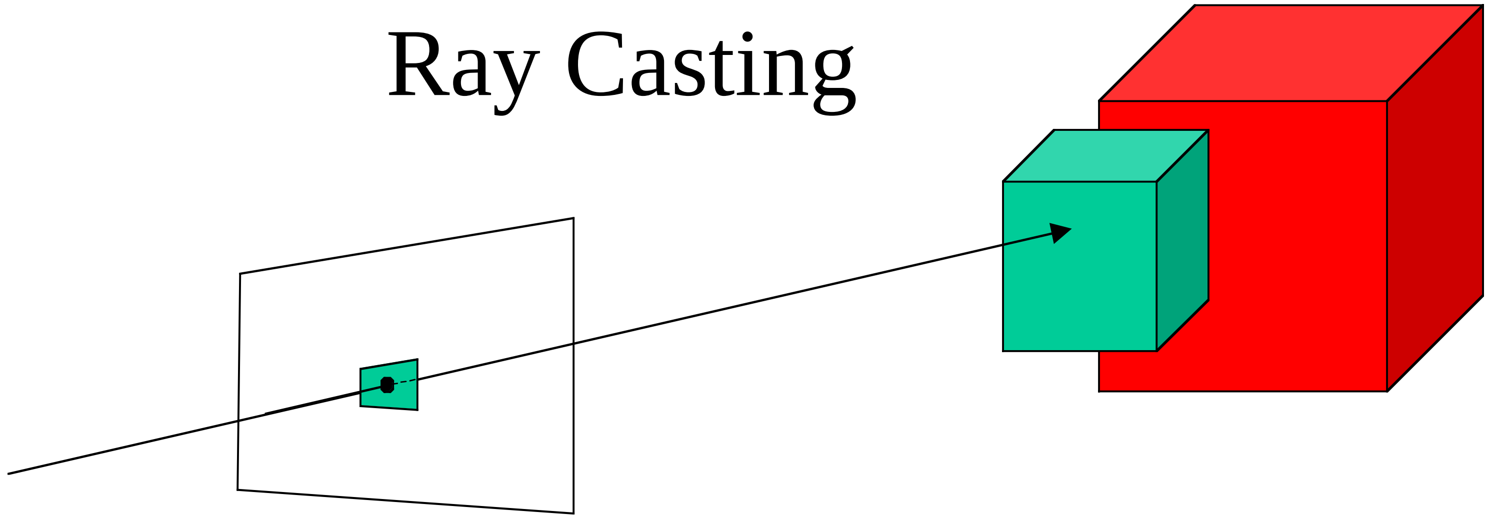
Ray Casting



- Image precision algorithm
- For each pixel cast a ray into the world
  - For each surface
    - determine intersection point with ray
  - Render pixel based on closest surface

Ray Casting

- First step in ray tracing algorithm
- Expensive
- Good performance usually requires clever data structures such as bounding volumes for object groups or storing world occupancy information in octrees.
- Other main problem is computing intersection.
- See §13.4 for discussing regarding intersection with spheres in perspective space.
- For polygons, we can use the standardized orthographic space where we can work in 2D.
- Useful for “picking”--not expensive here (why?)

Ray Tracing--teaser

- Idea is very simple--follow light around
- Following all the light around is intractable, so we follow the light that makes the most difference
- Work backwards from what is seen
- Simple ray tracer
  - Cast a ray through each pixel (as in ray casting for visibility)
  - From intersection point cast additional rays to determine the color of the pixel.
  - For diffuse component, must cast rays to the lights
  - We may also add in some “ambient” light
  - For mirrors, must cast ray in mirror direction (recursion--what is the stopping condition)

Current state of intro students graphic's ability

Know how to draw polygons

Know about cameras

Know how to map 3D polygons onto the screen

Know how to draw the bits closest to the cameras

Issues

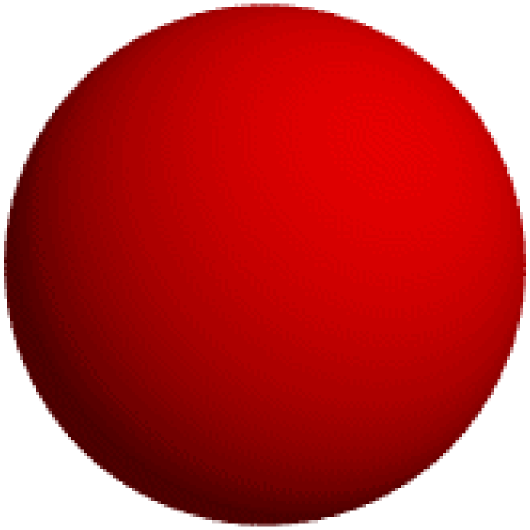
- Should we live in a polygonal world?
- How do you get polygons for complex objects?
- What color should each pixel be?

Coloring pixels

Need to model light and surface

Simplest model

Point light source and Lambertian (diffuse) reflection. Gives basic shader--makes things look 3D



Point light source

Modeled by single light direction (key attribute, more than "point-like"--e.g., the sun is essentially a point source

Lambertian Reflection

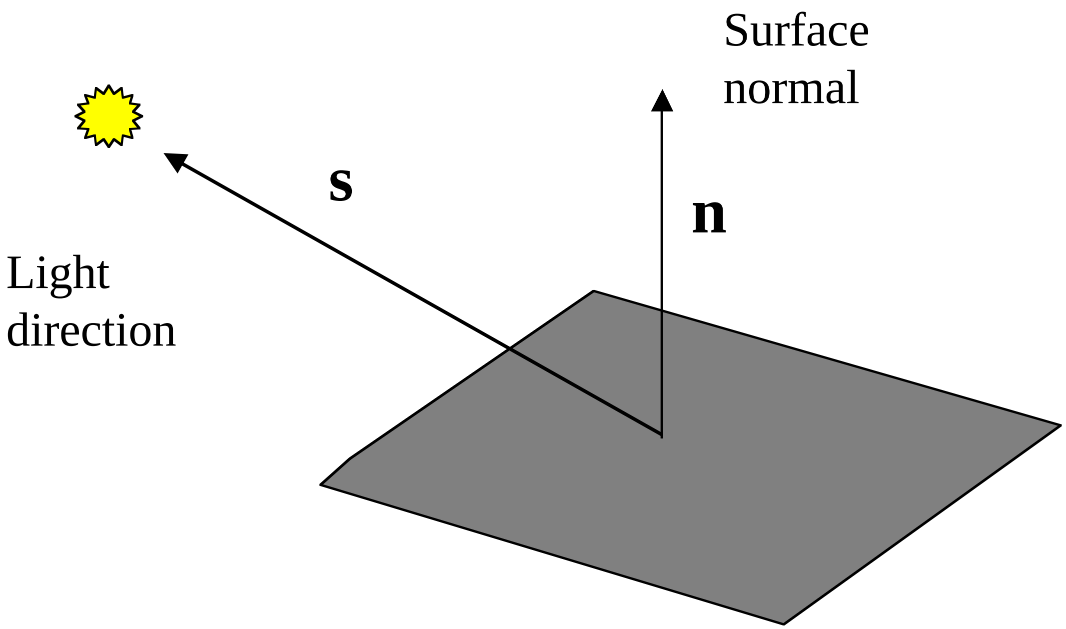
- Light is scattered equally in all directions
- Brightness is independent of viewing direction
- Example--non-shiny paper
- Simple rule--attenuate brightness by

$$\mathbf{n} \bullet \mathbf{s}$$

Surface normal

Light source direction

Lambertian Reflection



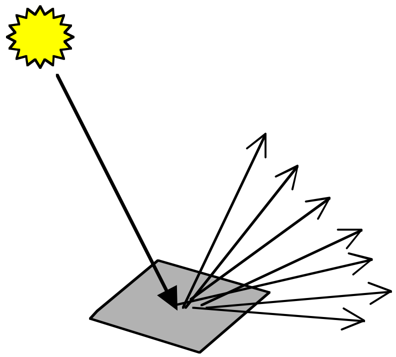
Why is brightness proportional to **n•s** ?

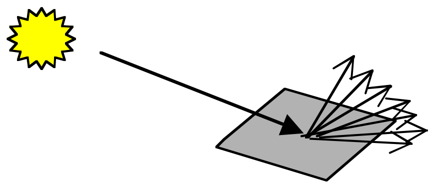
What about more than one light?

Lambertian Reflection

Why is brightness proportional to **n•s** ?

Intuitive argument: The surface scatters light in all directions equally, but as the angle of the light becomes oblique, the amount of light per unit area is reduced (foreshortening) by a factor of the cosine of the angle.





Lambertian Reflection

What about more lights?

If they are point sources, just add them up. Note that this means that extended sources can be approximated by multiple point sources and/or integration.

Applies to non-Lambertian surfaces also.

Special cases to be handled later: Very long thin source and large, planer source.

Lambertian Reflection

Most the world is not Lambertian

Lambertian assumption failures

- Rough surfaces--important example--the moon is not Lambertian
- Dielectrics (plastics, many paints)
- Metallic surfaces
- Skin

More General Reflection

- Many effects when light strikes a surface -- could be:
  - absorbed
  - transmitted
  - reflected
  - scattered
- Assume that
  - surfaces don’t fluoresce
  - surfaces don’t emit light (i.e., they are not sources)
  - all the light leaving a point is due to that arriving at that point

More General Reflection

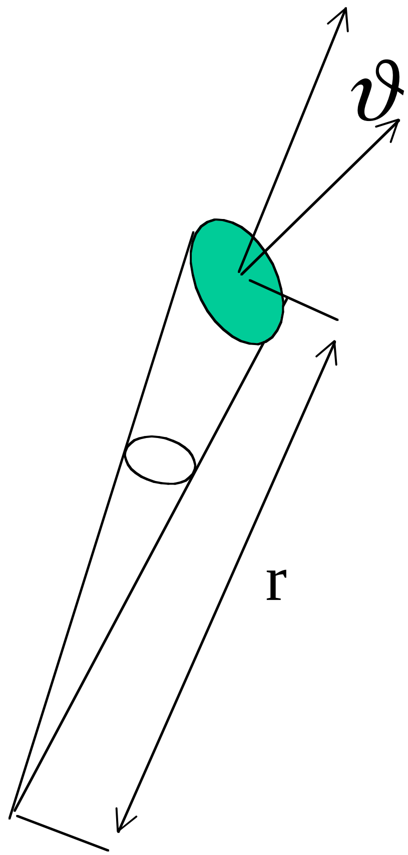
- Can model this situation with the Bidirectional Reflectance Distribution Function (BRDF)
- This is the ratio of what comes out to what came in
- What comes out <--> “radiance”
- What goes in <-->”irradiance”

Solid Angle

- Analogous tome measuring angles radians
- The solid angle subtended by a patch area dA is given by

$$d\Omega = \frac{dA\cos\vartheta}{r^2}$$

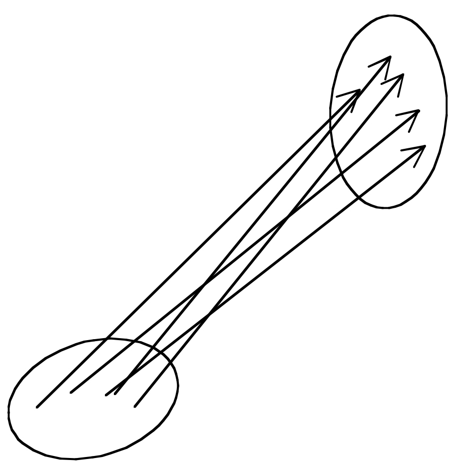
- Units are steradians (sr)



Radiance

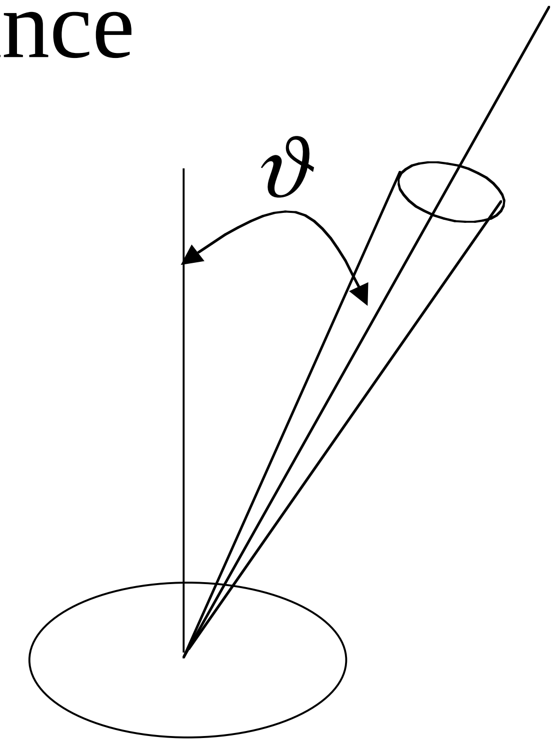
- Amount of light at a point in a particular direction
- Think of a small area either emitting or collecting the light
- Property is: *Radiant power per unit foreshortened area per unit solid angle*
- Units: watts per square meter per steradian ($wm^{-2}sr^{-1}$)
- Usually written as:

$$L(\underline{x}, \vartheta, \varphi)$$



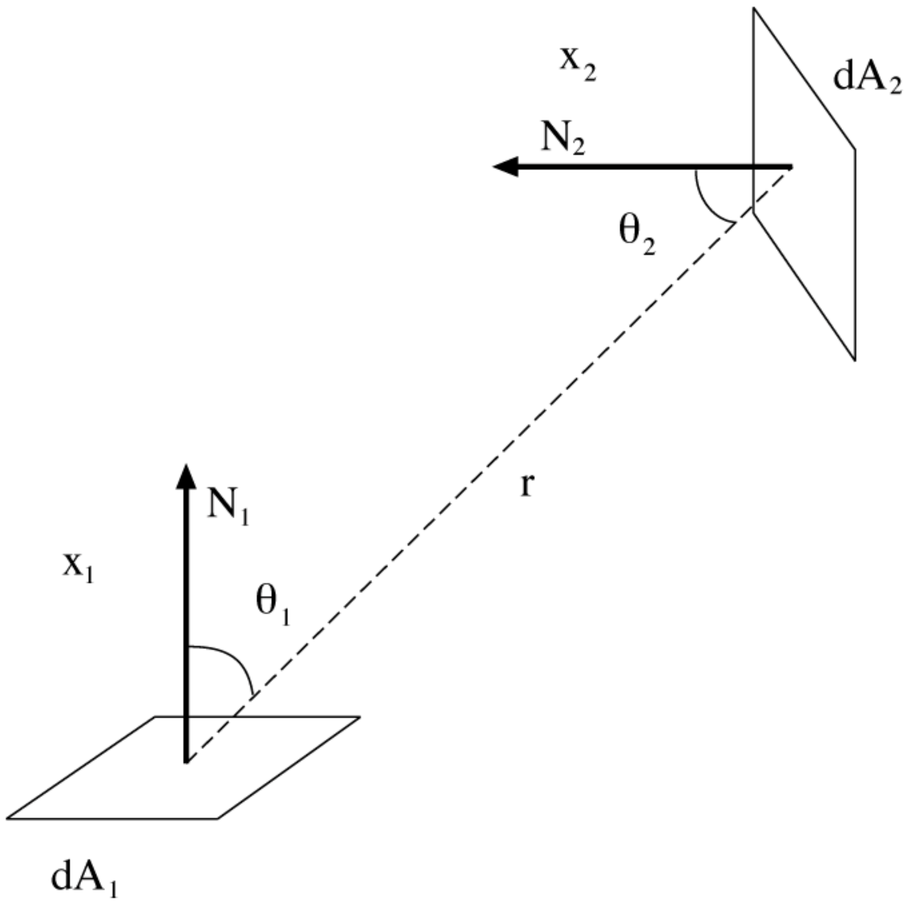
Radiance

$$L\left(\underline{x},\vartheta,\varphi\right)=\frac{\delta P(\underline{x})}{\delta\omega\delta A\cos\vartheta}$$



- Crucial property: In a vacuum, radiance leaving p in the direction of q is the same as radiance arriving at q from p

Radiance is constant along straight lines



- Power 1->2, leaving 1:

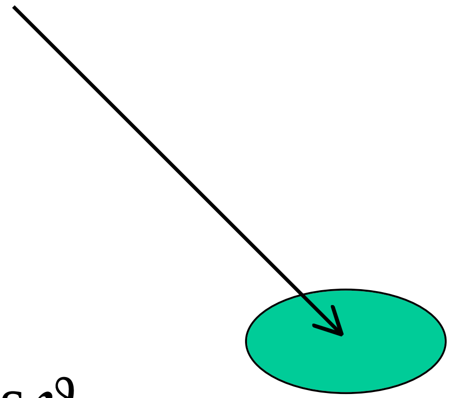
$$L(\underline{x}_1,\vartheta,\varphi)(dA_1\cos\vartheta_1)\left(\frac{dA_2\cos\vartheta_2}{r^2}\right)$$

- Power 1->2, arriving at 2:

$$L(\underline{x}_2,\vartheta,\varphi)(dA_2\cos\vartheta_2)\left(\frac{dA_1\cos\vartheta_1}{r^2}\right)$$

Irradiance

- Irradiance is the amount of light (power) falling on a surface per unit area.
- Units are watts/m^2
- Generally a function of direction



$$E(\underline{x},\vartheta,\varphi)=\frac{\delta P(\underline{x})}{\delta A}=L(\underline{x},\vartheta,\varphi)\delta\omega\delta A\cos\vartheta$$

Irradiance

- Note that irradiance is the incident power per unit area *not foreshortened*.
- A surface experiencing radiance L(x,θ,ϕ) coming from dω experiences irradiance

$$L(\underline{x},\vartheta,\varphi)\cos\vartheta d\omega$$

- Total power arriving at the surface is given by adding irradiance over all incoming angles.
- Total power is:

$$\int_{\Omega} L(\underline{x},\vartheta,\varphi)\cos\vartheta\sin\vartheta d\vartheta d\varphi$$

For integration in polar coords