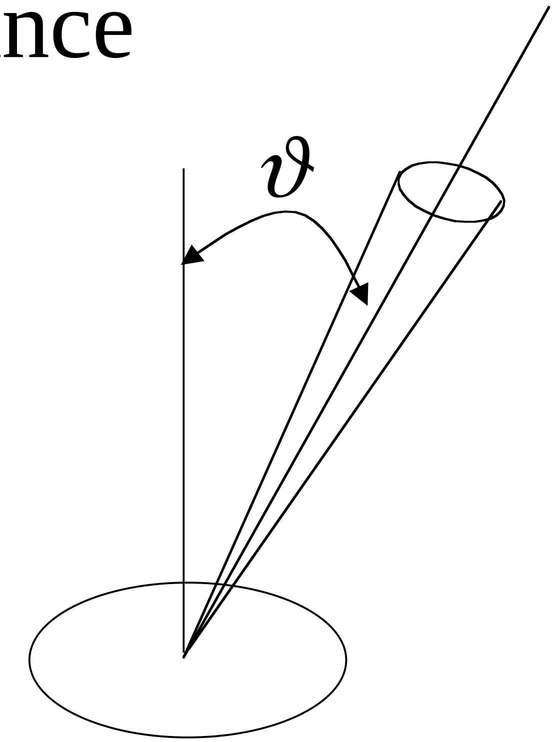
Radiance

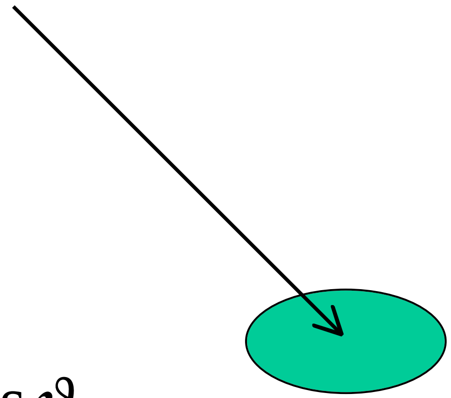
$$L(\underline{x}, \vartheta, \varphi) = \frac{\delta P(\underline{x})}{\delta\omega \delta A \cos\vartheta}$$



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

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



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

BRDF (Bidirectional reflectance distribution function)

- The irradiance at a point due to a particular angle is

$$L_i\left(\underline{x}, \vartheta_i, \varphi_i\right)\cos\vartheta_i d\omega$$

- The energy leaving (reflected) in a particular outgoing direction is given by:

$$L_o\left(\underline{x}, \vartheta_o, \varphi_o\right)$$

- The BRDF is simply the ratio of the output to input.

$$\rho_{bd}\left(\underline{x}, \vartheta_o, \varphi_o, \vartheta_i, \varphi_i,\right) = \frac{L_o\left(\underline{x}, \vartheta_o, \varphi_o\right)}{L_i\left(\underline{x}, \vartheta_i, \varphi_i\right)\cos\vartheta_i d\omega}$$

BRDF

- Units are inverse steradians (sr^{-1})
- Symmetric in incoming and outgoing directions
- The "distribution" part of the name is a hint that we need to integrate the function to get some light.
- To compute the brightness of a surface viewed from a given direction, we add up the contributions from all the input directions:

$$\int_{\Omega} \rho_{bd}\left(\underline{x}, \vartheta_o, \varphi_o, \vartheta_i, \varphi_i,\right) L_i\left(\underline{x}, \vartheta_i, \varphi_i\right) \cos \vartheta_i d\omega_i$$

BRDF

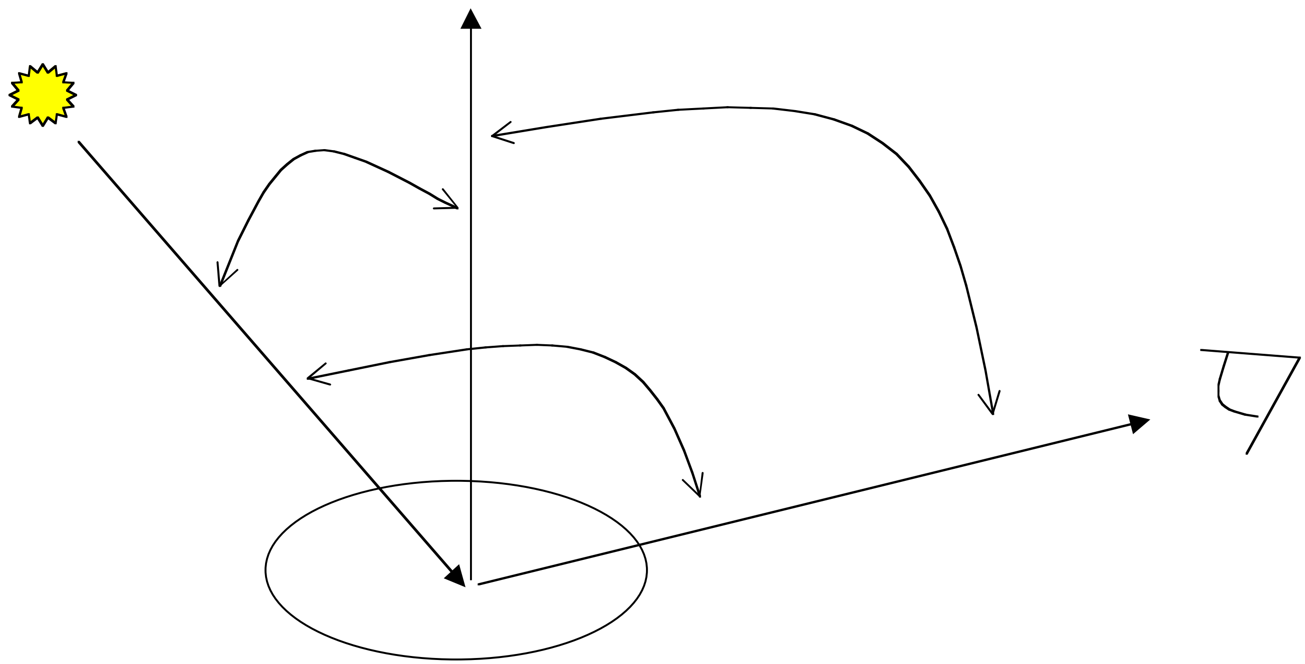
- Note that what we have developed so far is mostly notation, definitions, and descriptions.
- Two approaches to obtaining BRDF’s--measure and model.
- Measuring BRDF is painful (but there is some data available on-line (and more clever ways to collect the have been proposed).
- Developing physics based approximations for the BRDF for simple classes of surfaces is complicated but possible--in general this is still a research area.
- Adding color to the BRDF is easy (one more variable). The full form has additional variables for fluorescence and polarization.

BRDF

- So why do we care about the BRDF?
  - If you have it, then you can compute the effect of any illumination distribution--a photograph only tells you the effect of one illumination distribution
  - Useful abstraction

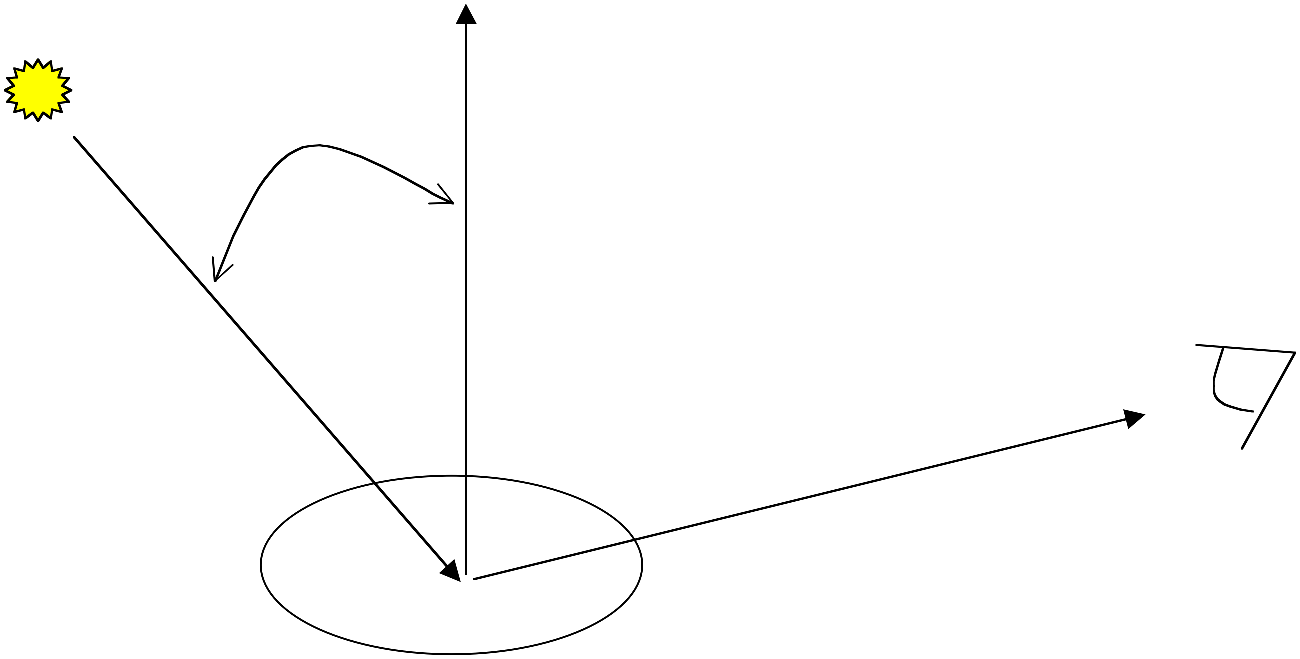
BRDF

- One simplification is possible--the BRDF for many surfaces can be well approximated as a function of 3 variables (angles), not 4. The surface is said to be isotropic.



BRDF

- Even simpler case--the BRDF does not depend on the viewing (output) direction (e.g., Lambertian).



Lambertian surfaces and albedo

- For some surfaces, the percentage of arriving light that leaves is independent of direction in which it arrived
- Lambertian surfaces / ideal diffuse surfaces
  - cotton cloth, carpets, matte paper, matte paints, etc.
- Use radiosity as a unit to describe light leaving the surface (def'n next slide)
- Percentage of light leaving the surface is often called diffuse reflectance, or *albedo* for a Lambertian surface (BRDF is independent of angle too).

Radiosity

- Again, in many situations, we do not need angle coordinates at all
  - e.g. cotton cloth, where the reflected light is not dependent on angle
- Radiometric unit is radiosity
  - total power leaving a point on the surface, per unit area on the surface (Wm^{-2})

- Radiosity from radiance?
  - sum radiance leaving surface over all exit directions

$$B(\underline{x}) = \int_{\Omega} L_o(\underline{x}, \vartheta, \varphi) \cos\vartheta \, d\omega$$

- Note that when the radiance is constant, the above is greatly simplified.

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
  - on real surfaces, energy usually goes into a lobe of directions
  - writing a BRDF approximation is possible, but beyond the scope of this course