Shading

Course web page:

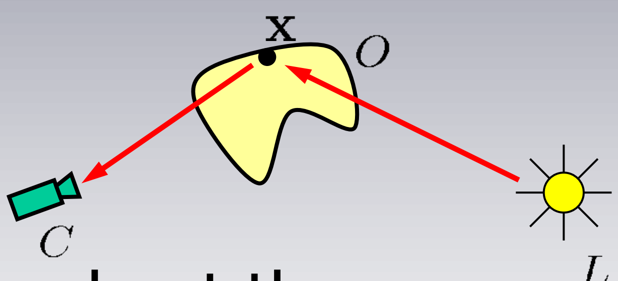
http://goo.gl/EB3aA

Outline

- Radiometry
- Surface properties
  - Diffuse/matte/Lambertian
  - Specular
- Simplified local model

Shading

- Geometry of perspective projection explains location of scene point in image, but what about its intensity and color?

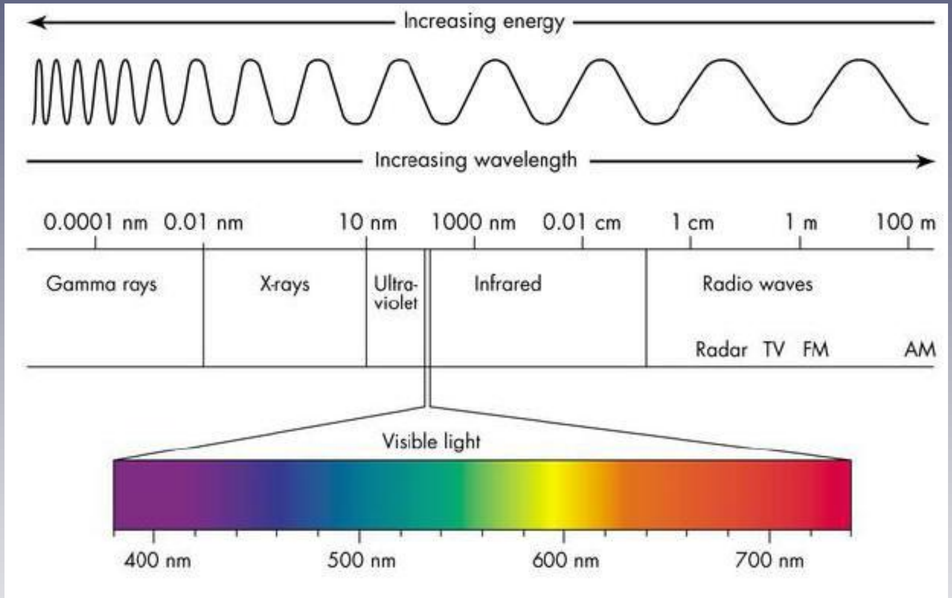


- **Radiometry** is about the measurement of electromagnetic radiation, in this case optical (Shirley, Chap. 20-20.2)
- **Photometry** quantifies camera/eye sensitivity (Shirley Chap. 20.3)

Lighting Objects

What is Light?

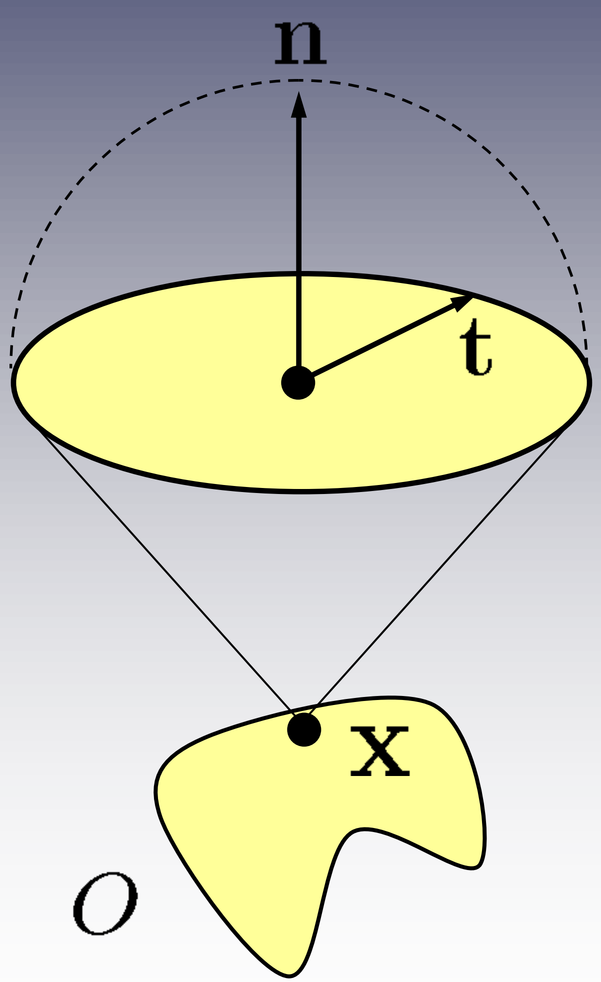
- A *photon* is a quantum of light with a:
  - 3-D position
  - 3-D direction of propagation
  - Wavelength λ
- *Energy q* carried by one photon is proportional to $1/\lambda$



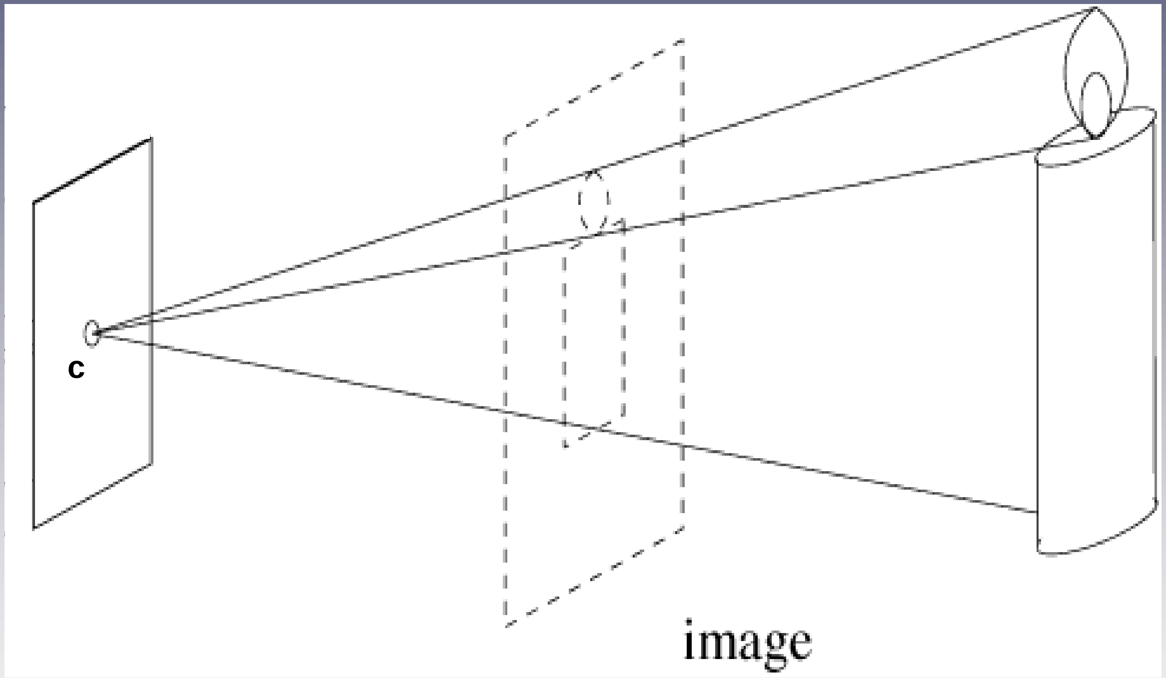
- *Power* is energy per unit of time; units are watts W
- *Spectral power* is watts per unit of wavelength
  - In the following slides this is the kind of power we are talking about unless otherwise noted

Incoming and Outgoing Light at a Surface

- **Irradiance** *E* (Wm^{-2})
  - Light power (watts) arriving at a point on a surface from all visible directions
  - An image samples the irradiance at the pinhole
  - Book uses variable *H*
- **Radiosity** *B* (Wm^{-2})
  - Light leaving a surface in all directions (per patch)
  - Also called "radiant exitance"



Perspective Projection



from Forsyth & Ponce

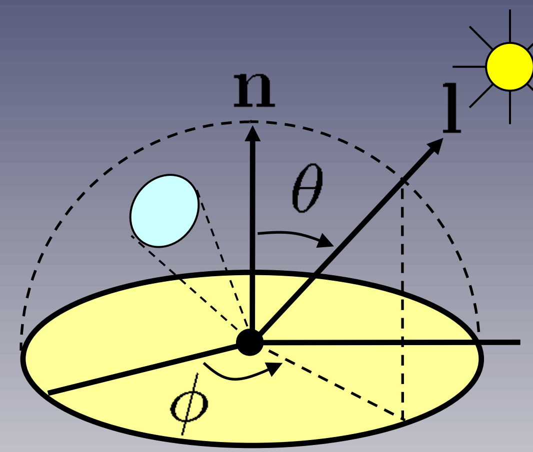
Instead of single direction **d** characteristic of parallel projections, rays emanating from single point **c** define perspective projection

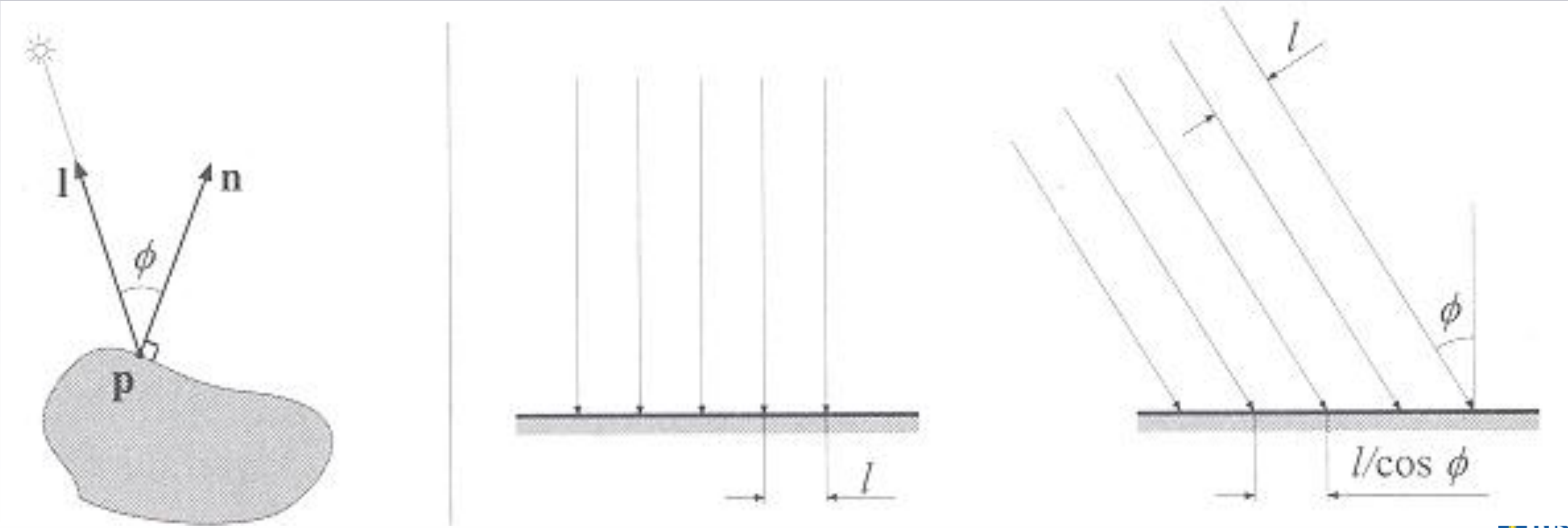
Radiance

- Irradiance doesn't tell us **where** light came from
- **Radiance** L ($Wm^{-2}sr^{-1}$)
  - Power at a point in space in a given direction, per solid angle, foreshortened
  - Can be incoming or outgoing
  - Does not attenuate with distance in vacuum
- What is stored in **one** pixel—the light energy arriving along a particular ray at a particular point
  - After photometric considerations

Foreshortening

- The more a surface is tilted away, the larger the area light energy is distributed over (and therefore is "diluted")
  - In 2-D, received intensity is proportional to **cosine** of angle between light direction **l** and surface normal **n**
  - Received intensity is greatest when **l** and **n** are parallel
- 3-D foreshortening factor for light coming from direction (θ, φ) is $\cos\theta$

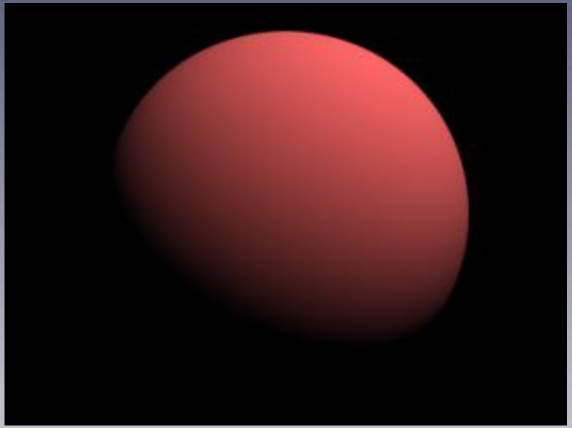


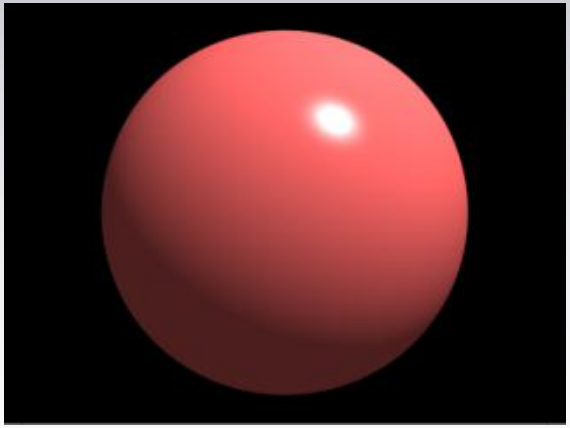


from Akenine-Moller & Haines

Object surface properties

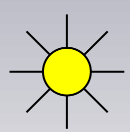
- General
  - Light/dark/color
  - Reflectivity (e.g., matte/ Lambertian vs. shiny)
- Space-varying pattern
  - I.e., are above characteristics different in different locations?
  - We'll get to this when we cover texture-mapping



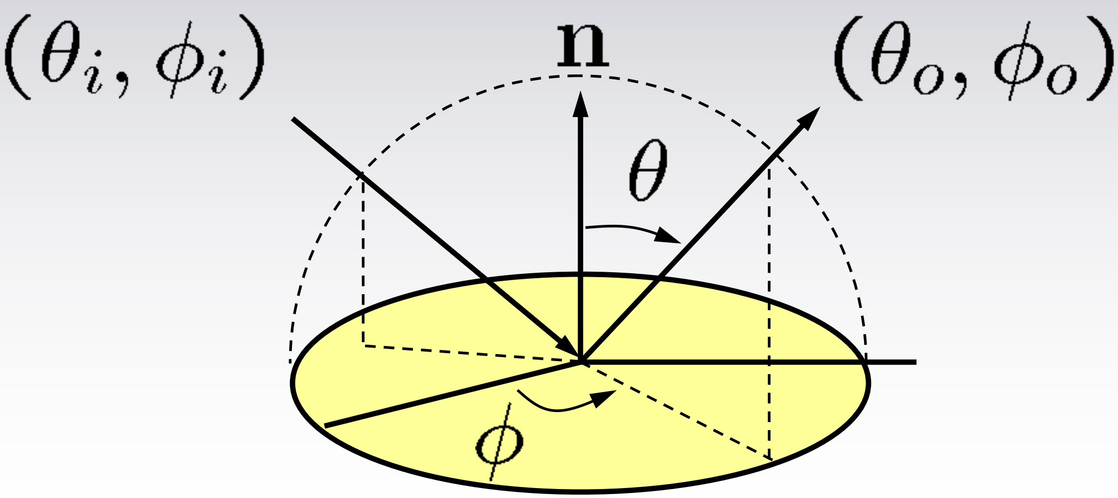


Capturing Surface Properties: BRDF

- **Bidirectional Reflectance Distribution Function** (BRDF): Ratio of outgoing radiance in one direction to incident irradiance from another

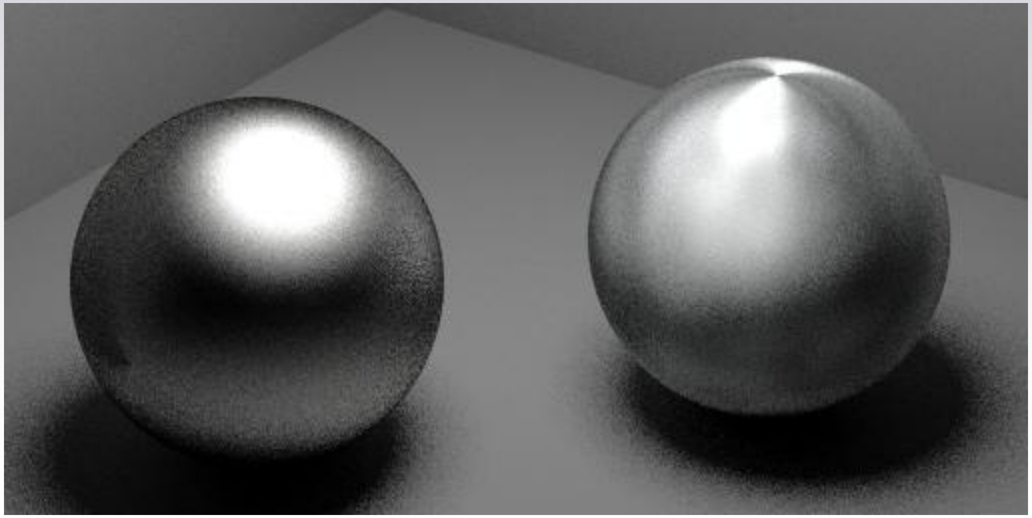


$$f(\theta_o, \phi_o, \theta_i, \phi_i) = \frac{L(\theta_o, \phi_o)}{dE(\theta_i, \phi_i)}$$



BRDF Properties

- Energy leaving ≤ Energy arriving (**albedo** is fraction reflected)
- For a perfectly diffuse/Lambertian surface, the BRDF is a constant—incoming light is scattered equally in all directions
- Generally, only the **difference** between incident and emitted angle Φ (as well as polar angles) is significant
  - Dependence on absolute Φ → *Anisotropy* (e.g., brushed metal, fur)



Reflectance equation

- Radiance for a viewing direction given all incoming light (also called *rendering* equation in Shirley 20.2):

$$L_o(\mathbf{x}, \theta_o, \phi_o) = \int_\Omega f(\theta_o, \phi_o, \theta_i, \phi_i) L_i(\mathbf{x}, \theta_i, \phi_i) \cos \theta_i d\omega$$

- This is expensive to compute in general, so the standard local approach is approximation:
  - Approximate incoming light as **ambient** (whole hemisphere) + set of point light sources
  - Approximate BRDF of surface as combination of **diffuse** (matte) and **specular** (shiny) factors

Illumination models

- Interaction between light sources and objects in scene that results in perception of intensity and color at eye
- Local vs. global models
  - Local illumination: Perception of a particular primitive only depends on light sources **directly** affecting that one primitive
    - Geometry
    - Material properties
  - Global illumination: Also take into account **indirect** effects on light of other objects in the scene
    - Shadows cast
    - Light reflected/refracted
    - More when we get to ray tracing