PBRT: Reflection Models

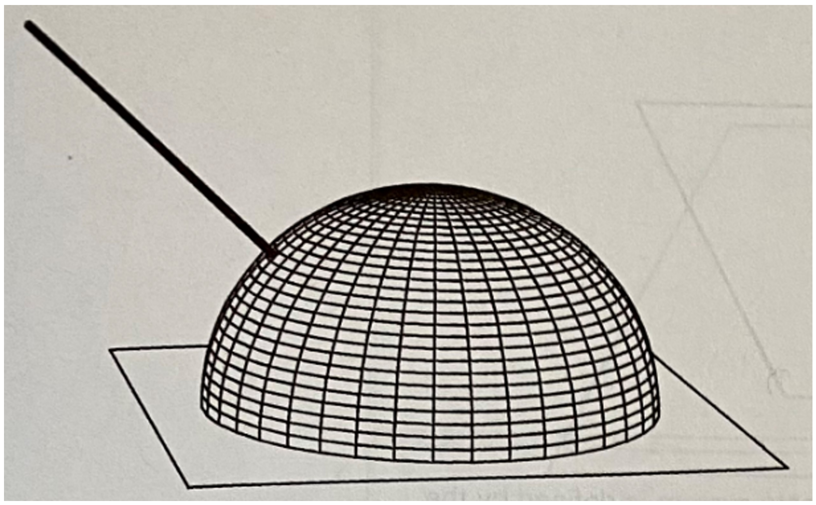
Sunday, January 3, 2021 11:51 AM

8 Reflection models

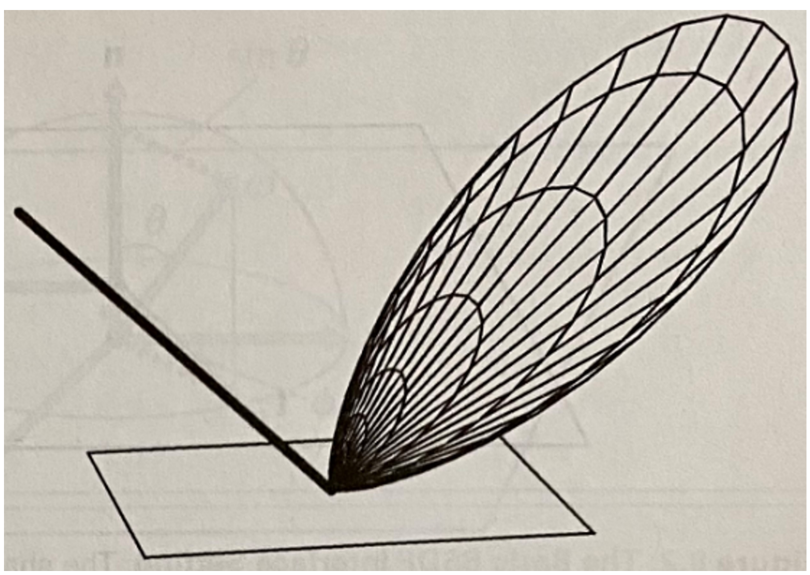
The BRDF describes light ***reflection*** at a surface, the BTDF describes light ***transmission*** at a surface, and the BSDF encompasses ***both*** of these effects described generally as ***scattering***.

Categories of surface reflection **(IMPORTANT:** most surfaces exhibit a ***mixture*** of these 4 types**):**

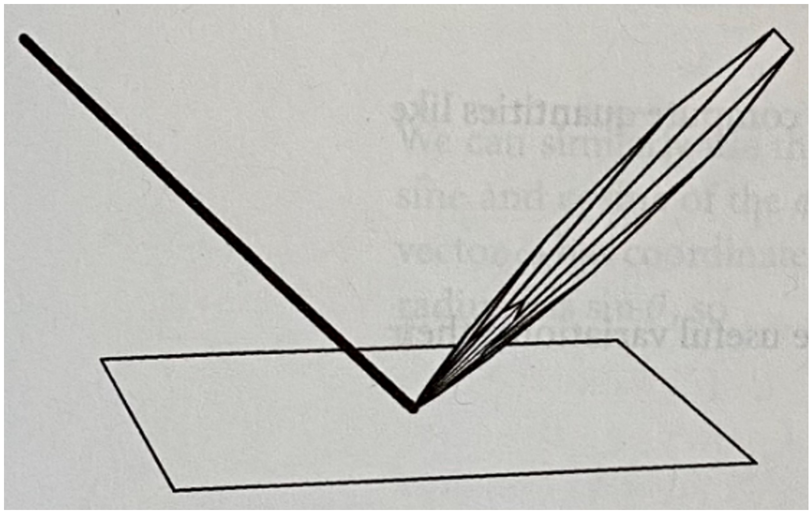
- *Diffuse*: light scatters equally in all directions. Matte paint, dull chalkboards, etc.



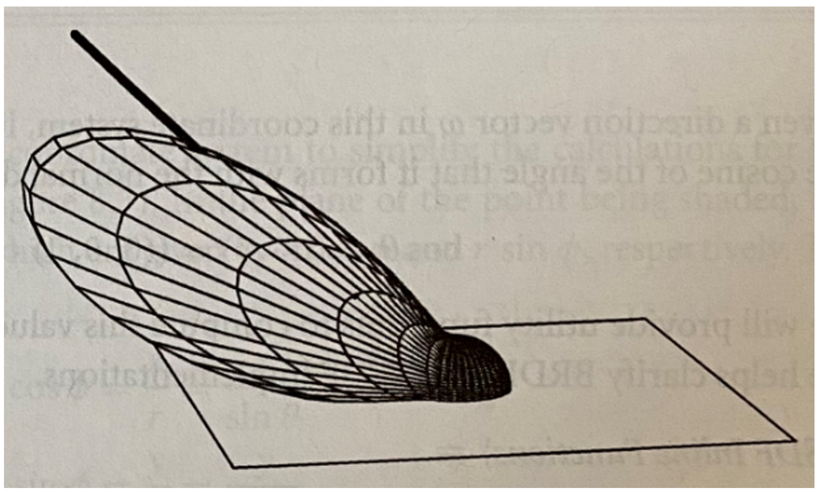
- *Glossy specular*: light scatters preferentially in a set of reflected directions (reflected direction as opposed to back in the incident direction). Plastic, high-gloss paint, etc.



- *Perfect specular*: light scatters in a single reflected direction. Mirrors, glass, etc.



- *Retro-reflective:* light scatters primarily back along the incident direction. Velvet, the moon, etc.

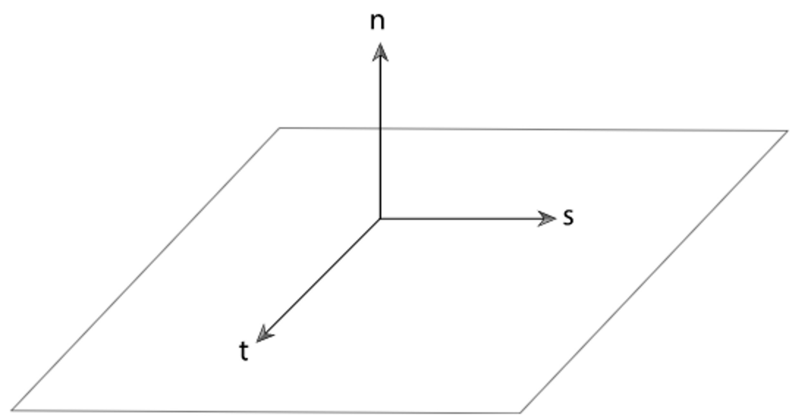


Surface reflection can be further subcategorized as ***isotropic*** or ***anisotropic***:

- *Isotropic:* if you rotate the surface about the normal at one point, the ***reflectance distribution doesn't change***.

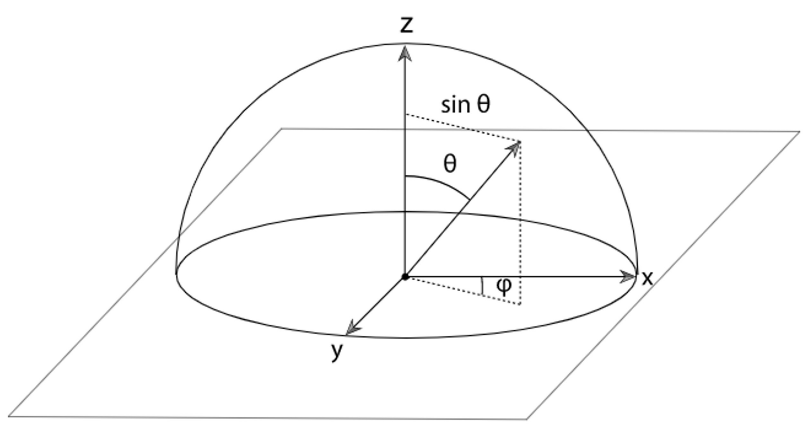
- *Anisotropic:* if you rotate the surface about the normal at one point, the ***reflectance distribution changes***. Brush metal, compact disks, etc.

The ***shading coordinate system***. ***Orthonormal basis*** vectors are 2 vectors tangent to the surface at a point and the normal.



s and t are aligned with x and y, and n with z. (World space x, y, and z? No. Orientation is such that n points up.)

The spherical coordinates of a direction vector ω are expressed relative to this orthonormal basis. (Note that for computing ϕ, ω is first projected to the xy (st) plane.)



The sine, cosine, and tangent of θ and ϕ are computed using various trigonometric and Pythagorean identities (note the triangles). An interesting thing to note is that the length of the projection of ω onto the xy plane is given by $\sin\theta$.

The ω vector in the shading coordinate system:

- Is a linear combination of $\{s, t, n\}$.
- Is normalized.
- Is outward facing, even if it is an incident direction vector.
- Is an incident one when it is in the same hemisphere as n. And n always points away from the object.

8.1 Basic interface

All categories of surfaces (according to how they reflect light) compute the BRDF (and BTDF) differently. But a ***special*** note must be made for ***perfect specular surfaces***: their directional distribution is a Dirac delta function: only a single incident direction contributes to the reflected radiometric quantity in a given outgoing direction (that is to say that the outgoing direction determines the incident direction uniquely). In contrast, the BRDFs (and BTDF) of other surfaces map a given outgoing direction to multiple (or all) incident directions.

The BxDF is the abstract base class / interface of BRDFs and BTDFs. Among other things, it computes the spectral distribution (Spectrum) of a pair of outgoing and incident directions.

8.1.1 Reflectance

See here.

8.2 Specular reflection and transmission

- [ ] TODO

8.3 Lambertian reflection

The ***Lambertian model*** models a ***perfect diffuse*** surface that scatters incident light equally in all directions. Not physically possible.

Its BxDF uses a ***reflectance*** (a distribution, a spectral distribution, Spectrum) that expresses the fraction of incident light that is scattered ("scattering" is a term that stands for "reflection" or "transmission") at each wavelength in the outgoing direction, which is ***equal*** for (or ***constant*** across) all outgoing directions in the hemisphere. (Is the rest of the incident energy absorbed?)

The Lambertian BRDF $f_r(\mathrm{p}, \omega_i, \omega_o)$ is a constant spectral distribution commonly called the ***diffuse color*** c_{diff} or ***albedo***.

Since the BRDF is constant across all outgoing directions, the Lambertian ***directional-hemispherical reflectance*** is constant too:

$$\rho_{dh}(\omega_i)$$

$$= \int_{\Omega=H^2(n):\{\omega_o\}} f_r(p, \omega_i, \omega_o) \, |\cos\theta_o| \, d\omega_o$$

$$= f_r(p, \omega_i, \omega_o) \int_{\Omega=H^2(n):\{\omega_o\}} |\cos\theta_o| \, d\omega_o$$

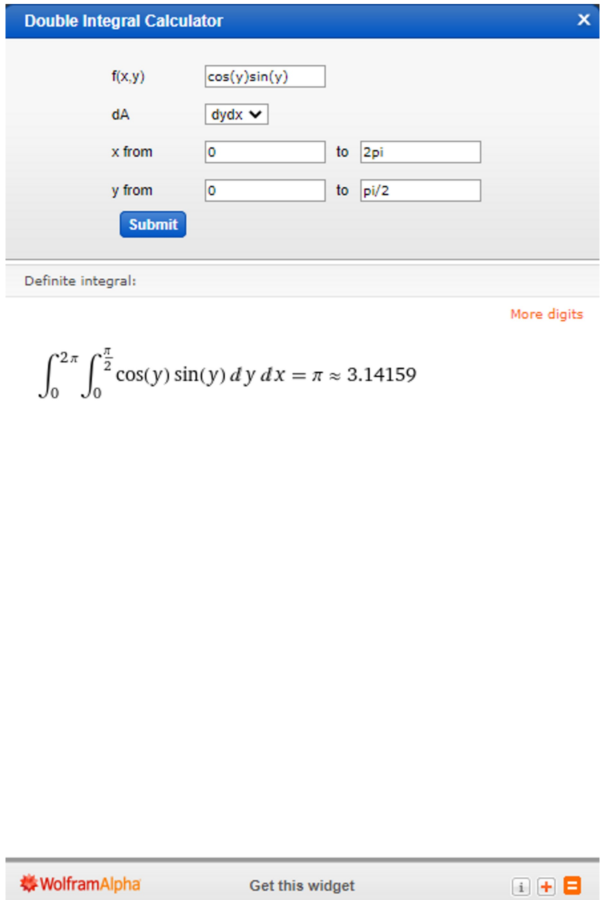
$$= f_r(p, \theta_o, \phi_o, \theta_i, \phi_i) \int_{\phi_i=0}^{2\pi} \int_{\theta_i=0}^{\pi/2} |\cos\theta_i| \, \sin\theta_i \, d\theta_i \, d\phi_i$$

$$= f_r(p, \theta_o, \phi_o, \theta_i, \phi_i) \, \pi$$

$$= \pi \, f_r(p, \omega_i, \omega_o)$$

$$= \pi \, c_{diff}$$

The value of the double definite integral is π:



2 classes implement the Lambertian model: LambertianReflection is the BRDF and LambertianTransmission is the BTDF.

- [ ] TODO: how does Lambertian transmission work? What materials exhibit diffuse transmission?