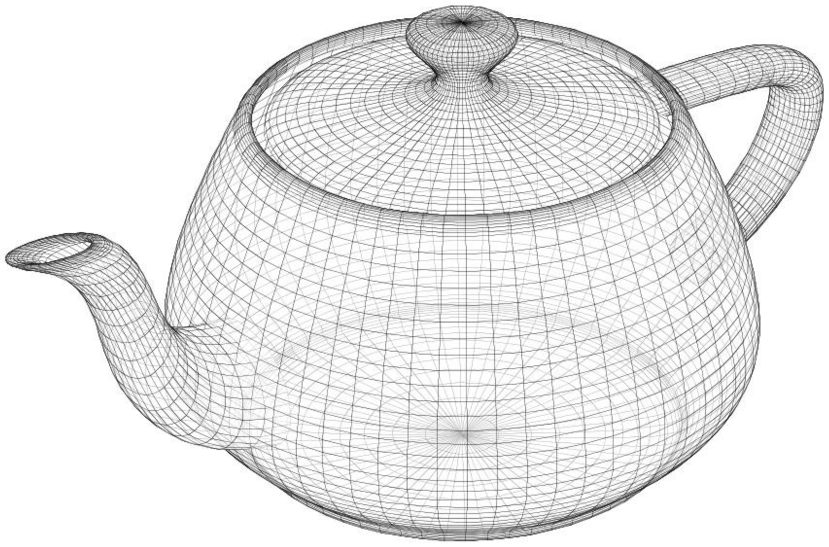

Area Lights

Production Computer Graphics

Eric Shaffer

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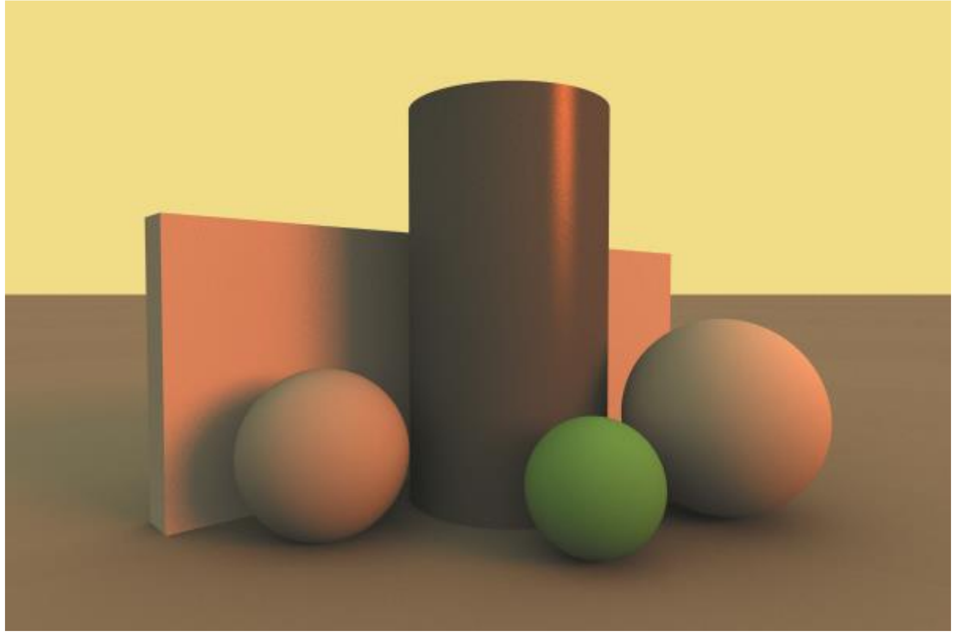
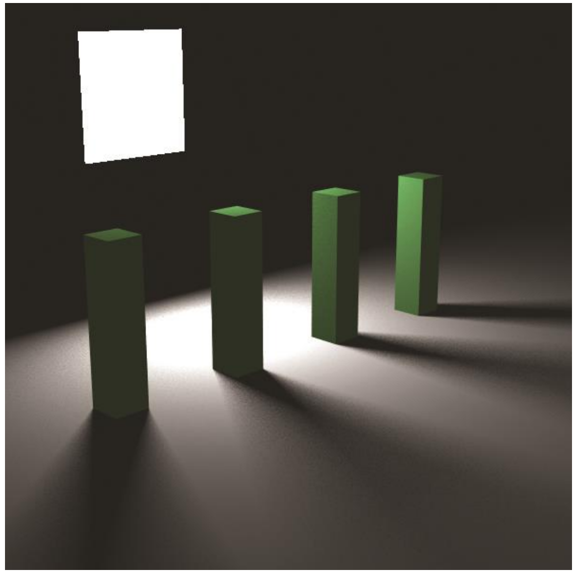
Objectives

- Understand how area lights are modeled and rendered
- Understand the idea of an environmental light
- Be able to implement both



What is an area light?

- An area light has a finite area
  - In addition to position, orientation, color, and luminance
- Adding area lights greatly increases the realism in a lit scene
  - You get soft shadows as opposed to just hard-edged shadows
- Area lights require more sampling per pixel
  - Longer render times



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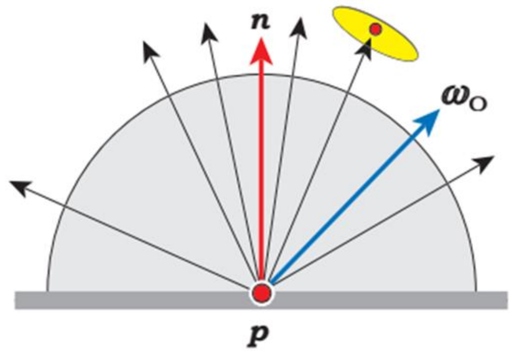
Implementing Area Lights

Area lights can have different geometries

- Circle, rectangle, sphere, etc.
- Need to be able to sample the surface and generate normals

How do we use this information computationally?

- Need to estimate the incident radiance from the light on a point ***p***
- Three possible techniques
  - Shoot shadow rays to points sampled on the light surface
  - Shoot shadow rays in the solid angle subtended at ***p***
  - Shoot rays by sampling the BRDF at the point ***p***



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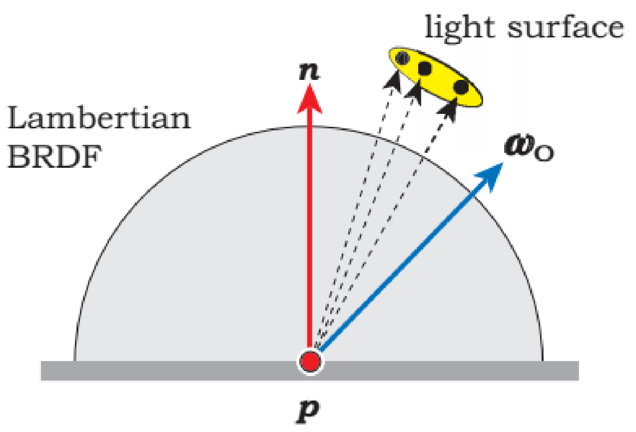
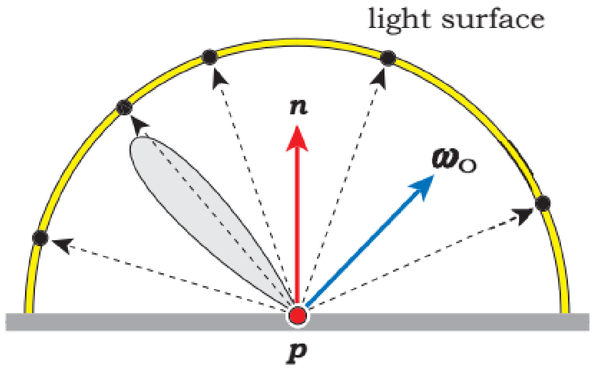
Sampling the Light Surface

- To determine incident radiance at a hit point ***p***
  - Generate shadow rays
    - Originating p
    - Directed to a sample point $\boldsymbol{s}_i$ on the surface of the light
- Examples →
- The light must be able to provide
  - Uniformly sampled points $\boldsymbol{s}_i$
  - The normal at the point $\boldsymbol{s}_i$





$$L_o(p,\omega_o) = L_e(p,\omega_o) + \int_A f_r(p,\omega_i,\omega_o) L_o(p',-\omega_i) V(p,p') G(p,p')\, dA$$

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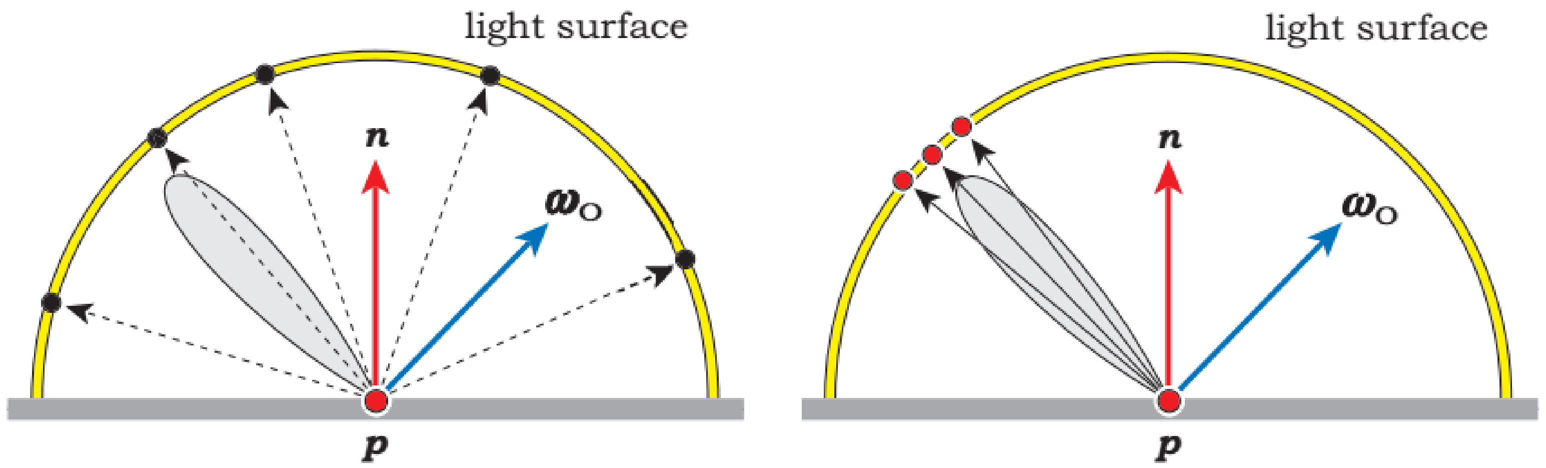
Sampling the BRDF

To determine incident radiance at a hit point ***p***

- Generate rays
  - Originating p
  - Directions distributed according to the BRDF
    - i.e. sample hemisphere around ***p*** possibly non-uniformly

Why do this? example: (a) is uniform and undersamples, (b) samples BRDF



$$L_o(p,\omega_o) = L_e(p,\omega_o) + \int_{2\pi^+} f_r(p,\omega_i,\omega_o) L_i(p,\omega_i) \cos\theta_i \, d\omega_i$$

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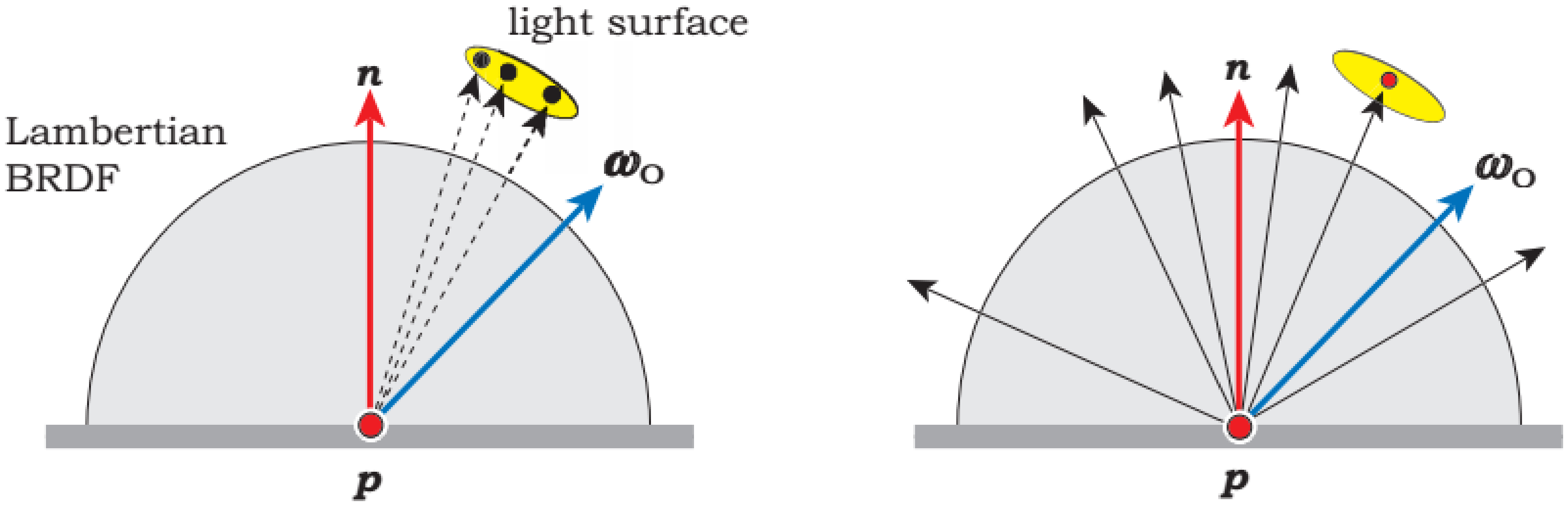
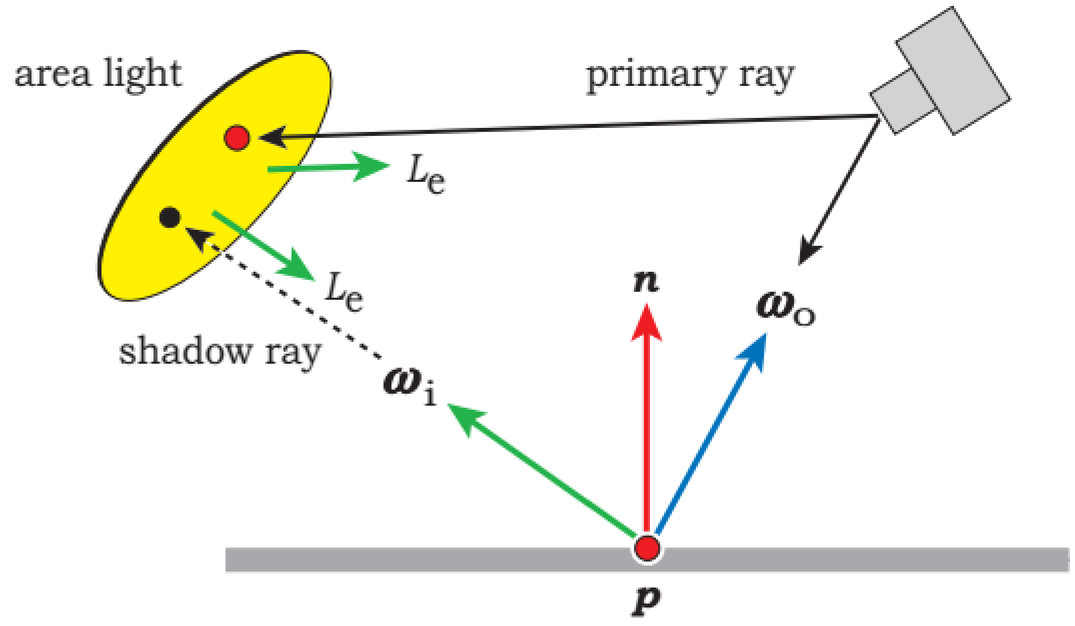
Importance Sampling Revisited

There are situations in which sampling the BRDF is less efficient



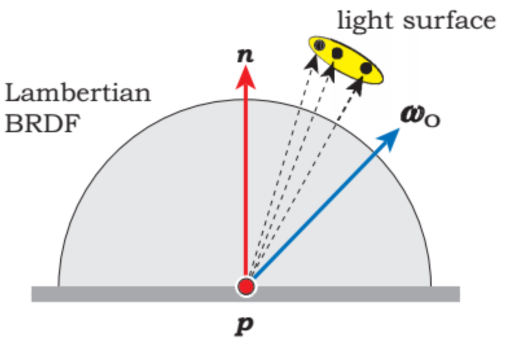
What to do?

- Sample the light for rectangular, circular, and spherical lights
- Sample the BRDF for hemisphere light
- We also need to be able to render the light itself



Estimating Direct Illumination

- We need to compute exitant radiance at point ***p'***
- For direct illumination, we gather only illumination from lights
  - We neglect indirect light reflected off other surfces
- Using the area form of the rendering equation:



$$L_o(p,\omega_o) = L_e(p,\omega_o) + \int_A f_r(p,\omega_i,\omega_o) L_o(p',-\omega_i) V(p,p') G(p,p')\, dA,$$

- For a single area light the Monte Carlo estimator for the integral is

$$\langle L_r(p,\omega_o)\rangle = \frac{1}{n_s}\sum_{j=1}^{n_s} \frac{f_r(p,\omega_{i,j},\omega_o) L_e(p'_j,-\omega_{i,j}) V(p,p'_j) G(p,p'_j)}{p(p'_j)},$$

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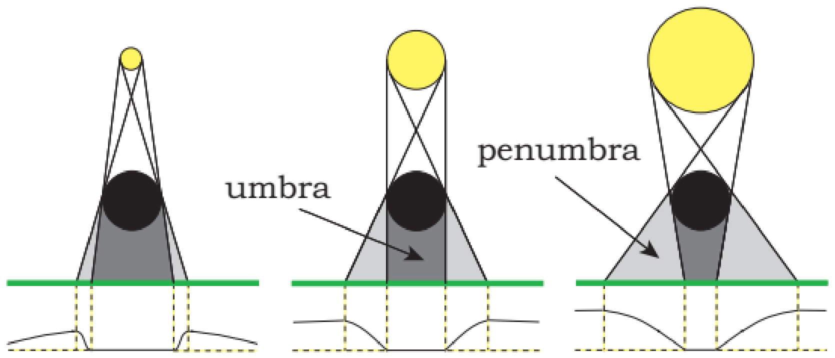
Estimating Direct Illumination

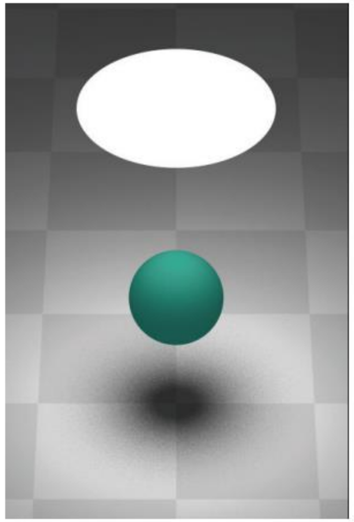
$$\langle L_r(p,\omega_o)\rangle = \frac{1}{n_s}\sum_{j=1}^{n_s} \frac{f_r(p,\omega_{i,j},\omega_o)L_e(p'_j,-\omega_{i,j})V(p,p'_j)G(p,p'_j)}{p(p'_j)},$$

- We have n sample points
- p() is the probability distribution function over the light surface
- p() can be hard to determine in general
- In practice use uniform distribution $p(p'_j) = \frac{1}{A_j}$

Sources of Noise with Area Lights

Penumbra can be noisy





- Why?
- If a hit point is in a penumbra, requires a large number of samples to resolve correctly

If the area light is large, the estimator can exhibit a lot of variation

- So it will take a lot of samples to converge
- Why? It has to do with $G(p,p') = \dfrac{\cos\theta_i \cos\theta'}{\left\| p' - p \right\|^2}$

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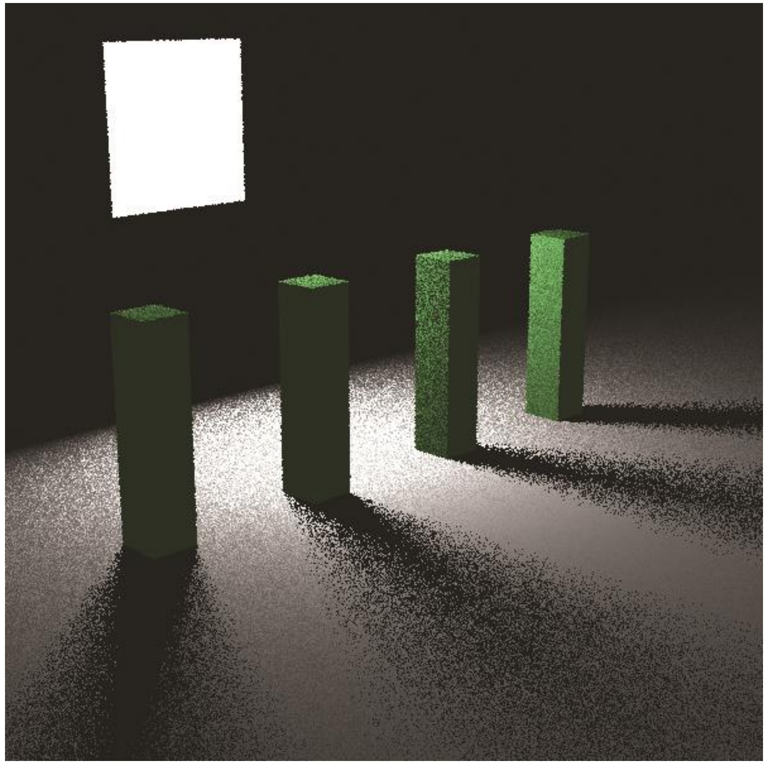
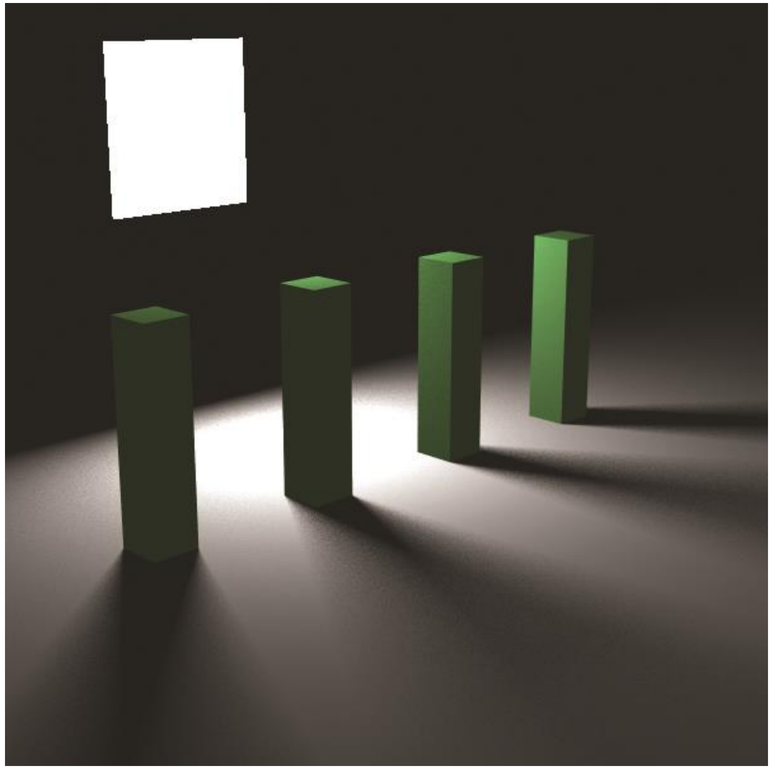
Example

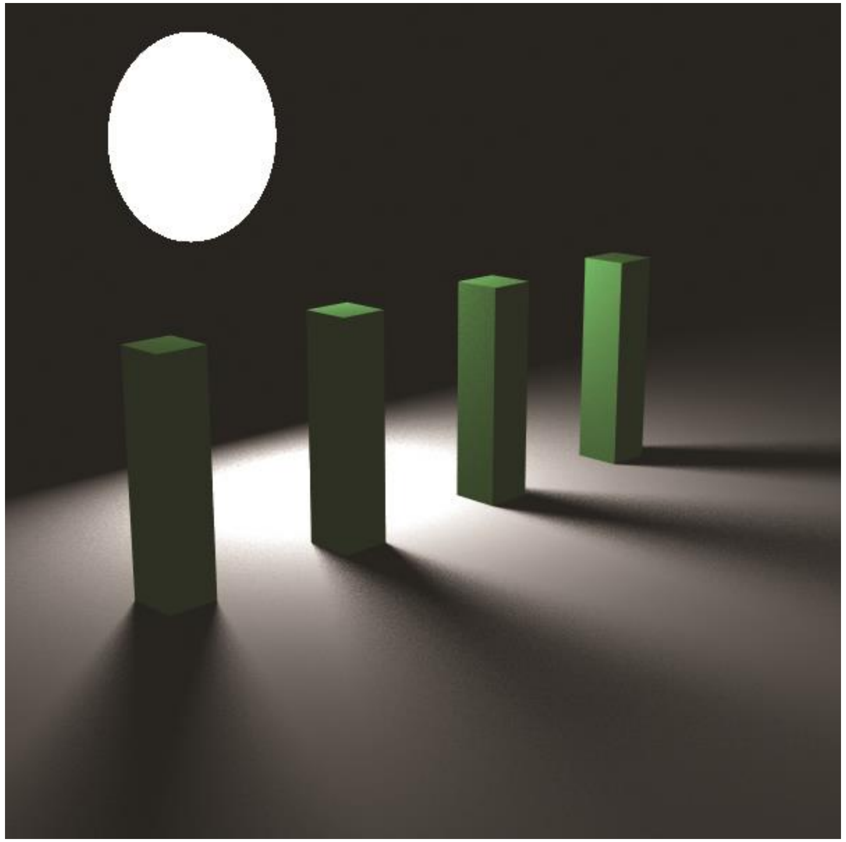


(a) 1 ray per pixel

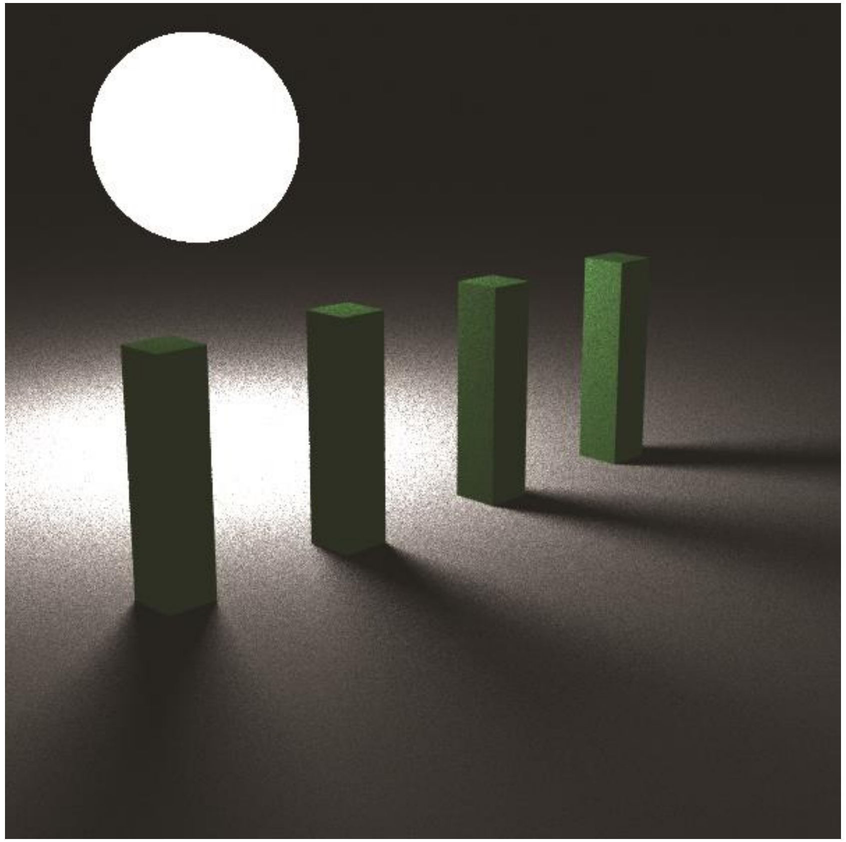


(b) 100 rays per pixel

Example



(a) Disc Light



(b) Spherical Light

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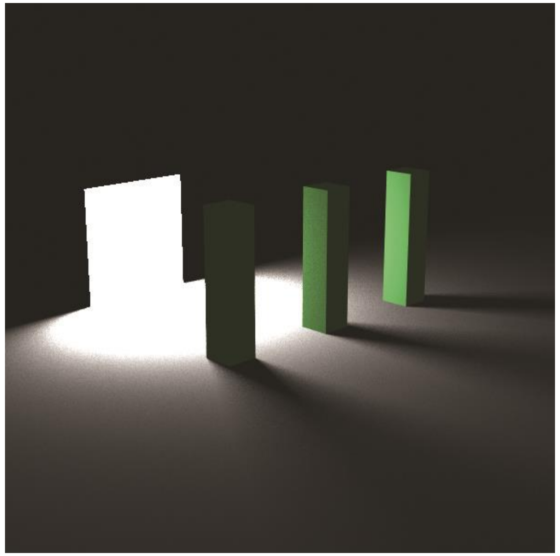
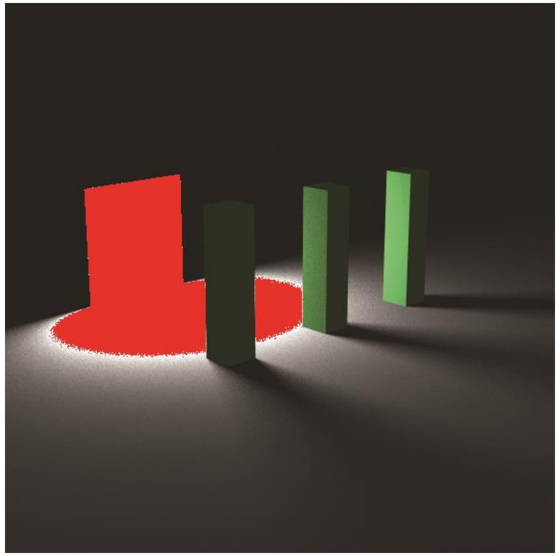
Overflow





The area light touches the plane

Note that overflow occurs around the light….

Can fix this in several ways

- Keep lights away from objects
- Use a PDF that includes a $1/d^2$ term
- Use the hemisphere rather than area form of the rendering equation

$$G(p,p') = \frac{\cos\theta_i \cos\theta'}{\|p' - p\|^2}$$

Environment Light

An Environment Light

- Is an infinitely large spherical (or hemispherical) light
- Surrounds the scene
- Emissive material with possibly spatially varying color

Shoot shadow rays using cosine distribution

- Use hemisphere form of the rendering equation

Monte Carlo Estimator is:

$$\langle L_r(p,\omega_o)\rangle = \frac{1}{n_s}\sum_{j=1}^{n_s}\frac{f_r(p,\omega_{i,j},\omega_o)L_i(p,\omega_{i,j})\cos\theta_{i,j}}{p(\omega_{i,j})}$$

$\cos\theta_i = n \bullet \omega_i, \quad p = \cos\theta_i/\pi.$

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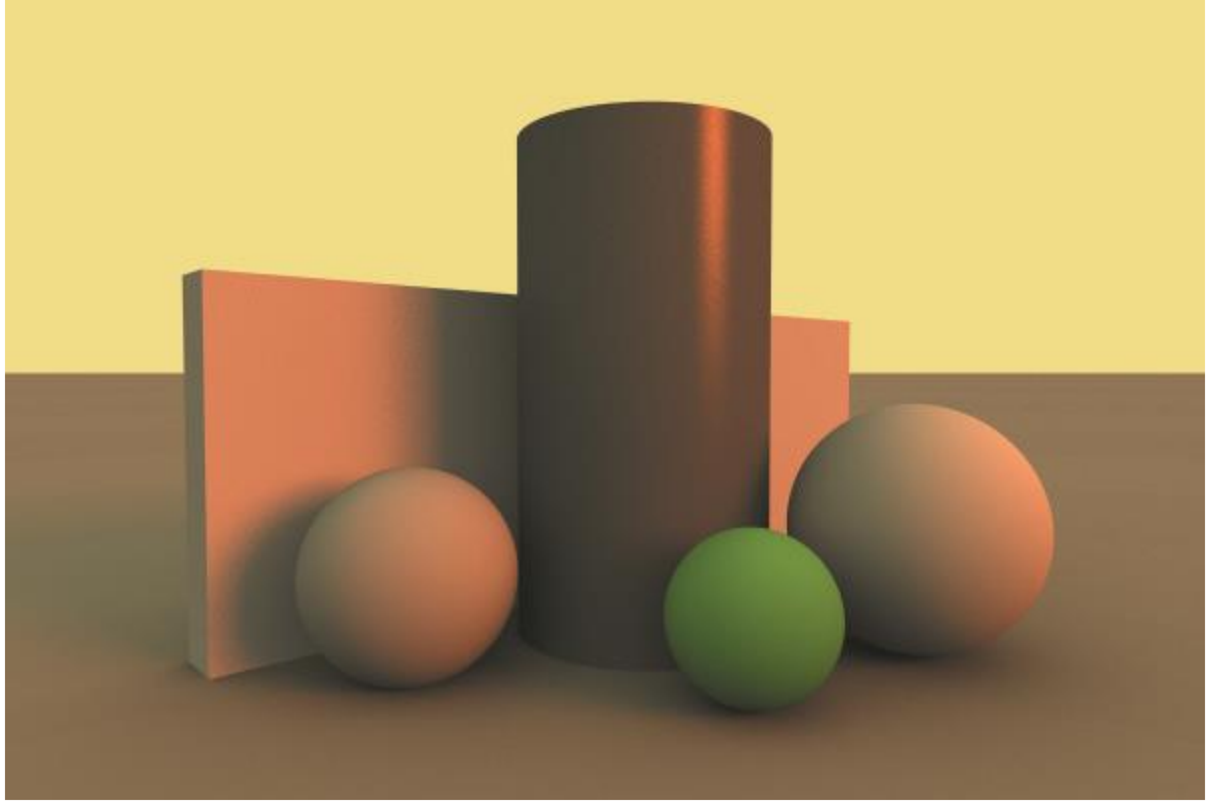
Example



Here we have

- yellow environment light
- orange directional light
- ambient occlusion