CSC 4356
Interactive Computer Graphics
Lecture 15: Illumination (Part 2)

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Tue & Thu: 10:30 - 11:50am
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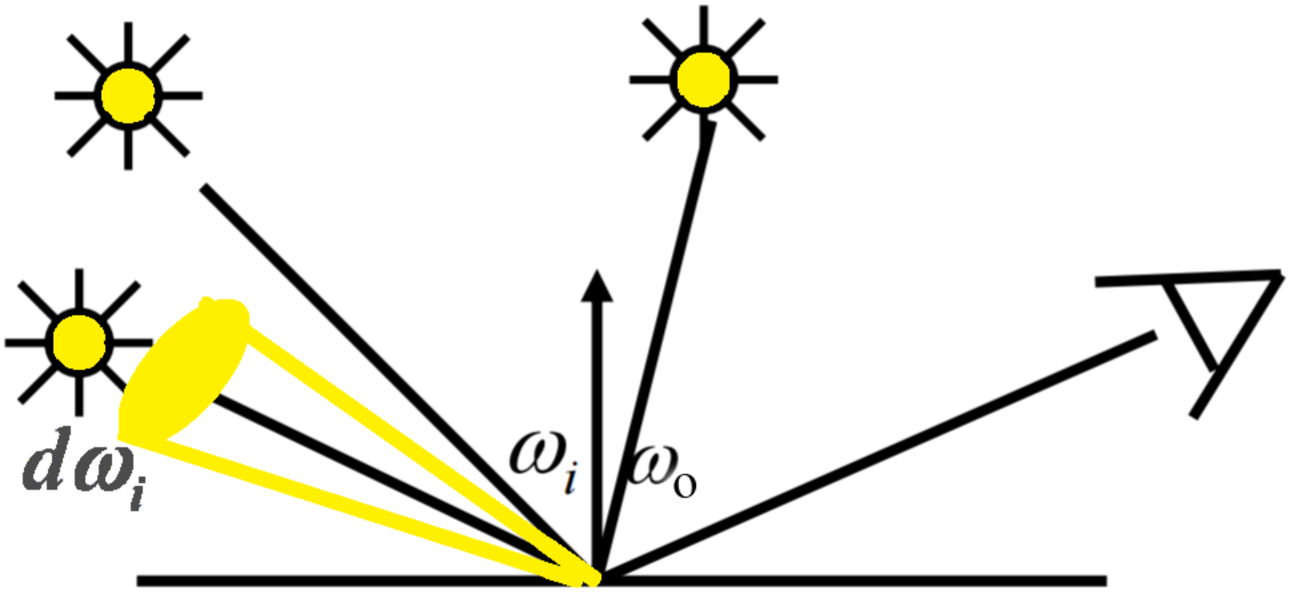
Reflectance Equation



Replace sum with integral

$$L_r(\omega_r) = \int_{\Omega} L_i(\omega_i) f(\omega_i, \omega_r)(\omega_i \cdot n) d\omega_i$$

Reflected Radiance (Output Image)

Incident Radiance (from light soure)

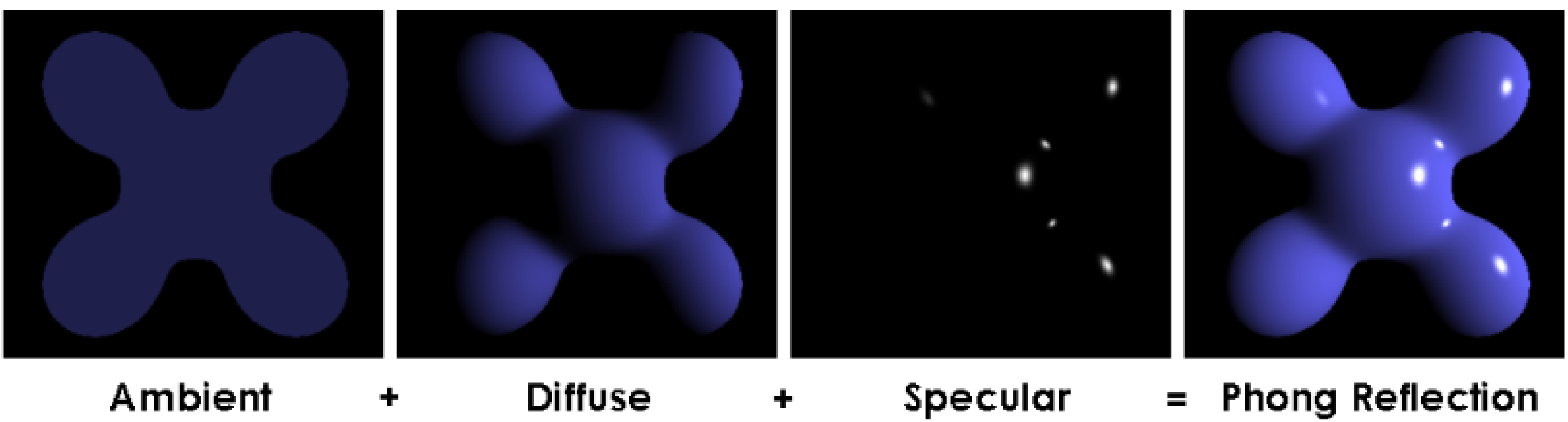
BRDF

Cosine of Incident Angle

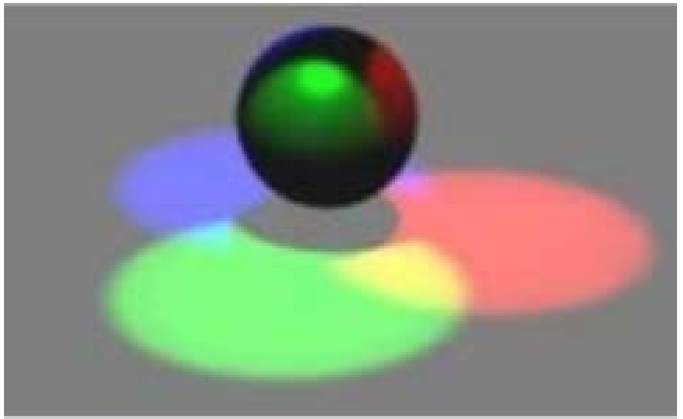
Illumination Model in OpenGL

- Final surface reflectance models as combination of **ambient**, **diffuse**, and **specular** components
  - Simplified empirical illumination model
  - Approximate global lighting effects

$$I_{total} = I_{ambient} + I_{diffuse} + I_{specular}$$



Two Components of Illumination



- Light Sources:
  - Emittance Spectrum (color)
  - Geometry (position and direction)
- Surface Properties:
  - Reflectance Spectrum (color)
  - Geometry (position, orientation, and micro-structure)
- Simplifications often used:
  - Only the direct illumination from the emitters to the reflectors of the scene
  - Ignore the geometry of light emitters, and consider only the geometry of reflectors

Ambient Light Source

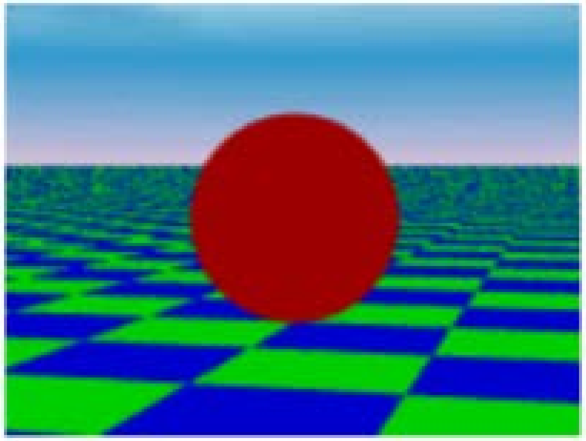
- Even though an object in a scene is not directly lit it will still be visible. This is because light is reflected indirectly from nearby objects
- A simple hack that is commonly used to model this indirect illumination is to use of an ambient light source
- Ambient light source:
  - No spatial or directional characteristics
  - The amount of ambient light incident on each object is a constant for all surfaces in the scene (minimum illumination)
  - An ambient light can have a color

Ambient Reflectance

- The amount of ambient light that is reflected by an object is independent of the object's position or orientation
- Surface properties are used to determine how much ambient light is reflected

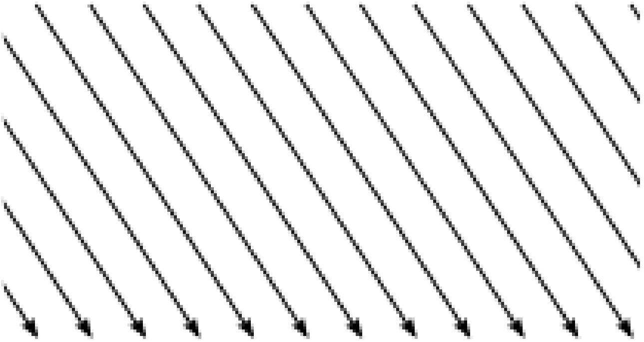
$$I_{ambient} = k_a I_a$$

Ambient Reflectance — **Ambient Reflectivity** — **Ambient Light Intensity**

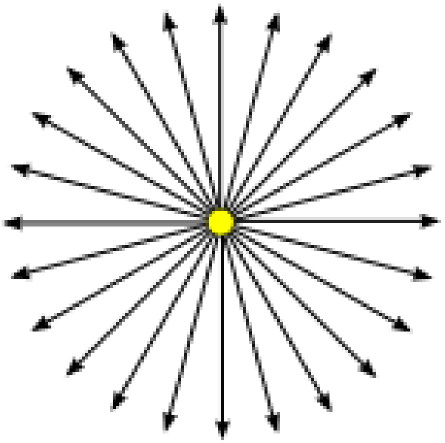


Directional Light Source

- All of the rays from a directional light source have a common direction, and no point of origin
  - As if the light source was infinitely far away from the surface that it is being illuminated
  - Example: sunlight
- Lighting direction is a constant for every surface
- A directional light source have a color



Point Light Source



- The rays emitted from a point light radially diverge from the source
  - Approximate a local light source
  - Example: light bulb
- The lighting direction to each point on a surface changes for a point light source
- How to compute lighting direction?
  - $\mathbf{p}$: surface point position, $\mathbf{p}_l$: light source position

$$\hat{l} = \frac{\mathbf{p} - \mathbf{p}_l}{|\mathbf{p} - \mathbf{p}_l|}$$

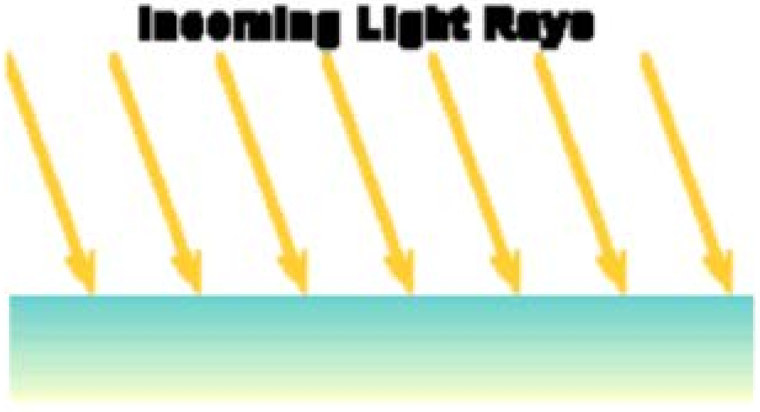
Specify Light Sources in OpenGL

```
// define a directional light
public float [] lightDirection = {1.0f, 1.0f, 1.0f, 0};
glLightfv(GL_LIGHT0, GL_POSITION, lightDirection);
glEnable(GL_LIGHT0);

// define a point light
public float [] lightPoint = {100.0f, 100.0f, 100.0f, 1.0f};
glLightfv(GL_LIGHT1, GL_POSITION, lightPoint);
glEnable(GL_LIGHT1);
```

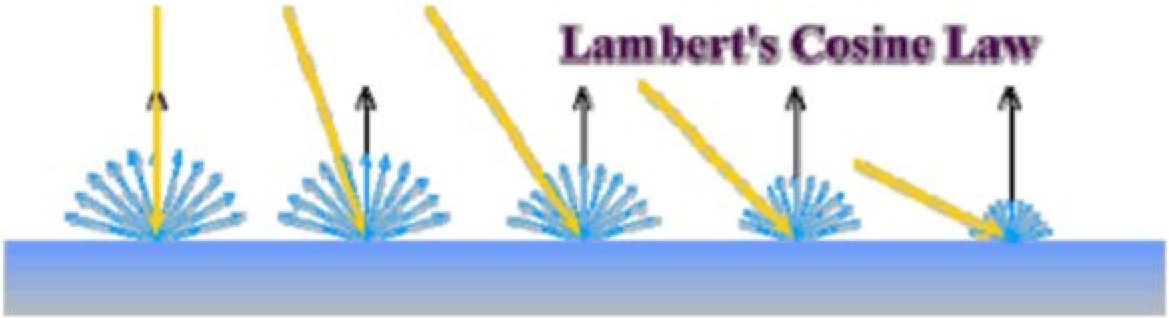
Ideal Diffuse Reflection

- Ideal diffuse reflector (e.g., chalk)
  - Reflect uniformly over the hemisphere
  - Reflection is view-independent
  - Very rough at the microscopic level



Lambert's Cosine Law

- Ideal diffuse reflectors reflect light according to Lambert's cosine law
  - Therefore, such surfaces are also called Lambertian surface/reflector
- Reflectance is proportional to the cosine of the angle between lighting direction and surface normal
  - **Independent of the viewing direction!**



Lambert's Law Derivation

- Irradiance is proportional to cosine of the angle between light direction and surface normal

$$A = A' \cos\theta$$

$$E = \frac{\Phi}{A'} = \frac{\Phi \cos\theta}{A}$$

Computing Diffuse Reflection

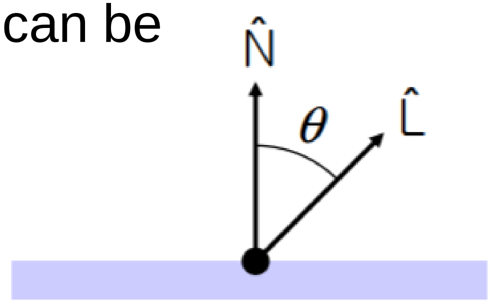
- The angle between the surface normal and the incoming light ray is called the angle of incidence and we can express a intensity of the light in terms of this angle θ

$$I_{diffuse} = k_d I_l \cos\theta$$

Diffuse Reflectance **Diffuse Reflectivity** **Light Intensity** **Incident Angle**

- In practice, we can use dot product to compute cosθ
  - If both the surface normal and the lighting direction are normalized (unit length) then diffuse reflectance can be computed as

$$I_{diffuse} = k_d I_l (\hat{n} \cdot \hat{l})$$



Diffuse Light Examples

- Below are several examples of a spherical diffuse reflector with a varying lighting angles.
  - Why consider a spherical surface?
  - We need only consider angles from 0 to 90 degrees
  - Greater angles (where the dot product is negative) are blocked by the surface and the reflectance is zero

Next Time …

- Continue with more discussions on the illumination model
- Surface material
- Reading:
  - Textbook: 17-1 to 17-6