# CSE 167:
# Introduction to Computer Graphics
# Lecture #7: Lights

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# Announcements

- Thursday in-class: Midterm
  - Can include material up to and including today's lecture
- Project 3 late grading deadline this Friday
  - Grading starts at 12:30pm, ends at 1:30pm

# Lecture Overview

- OpenGL Light Sources
  - Directional Lights
  - Point Lights
  - Spot Lights

# Light Sources

- Real light sources can have complex properties
  - Geometric area over which light is produced
  - Anisotropy (directionally dependent)
  - Reflective surfaces act as light sources (indirect light)

- OpenGL uses a drastically simplified model to allow real-time rendering

# OpenGL Light Sources

- At each point on surfaces we need to know
  - Direction of incoming light (the $\mathbf{L}$ vector)
  - Intensity of incoming light (the $c_l$ values)
- Standard light sources in OpenGL
  - Directional: from a specific direction
  - Point light source: from a specific point
  - Spotlight: from a specific point with intensity that depends on direction

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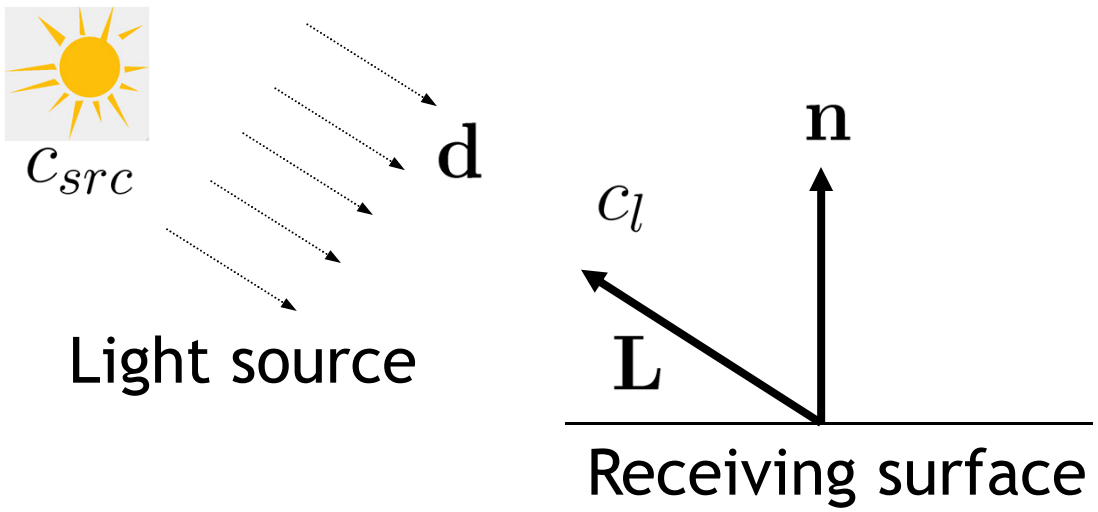
# Directional Light

- Light from a distant source
  - Light rays are parallel
  - Direction and intensity are the same everywhere
  - As if the source were infinitely far away
  - Good approximation of sunlight
- Specified by a unit length direction vector, and a color




$$\mathbf{L} = -\mathbf{d}$$

$$c_l = c_{src}$$

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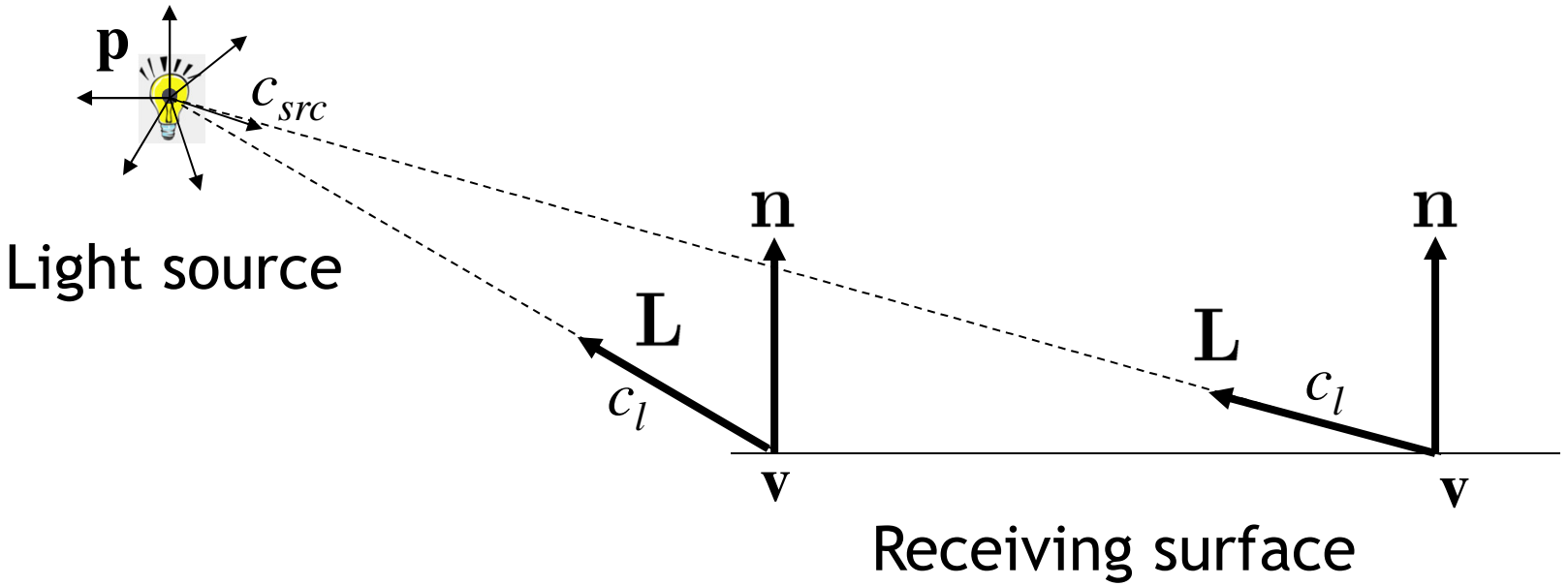
# Point Lights

- Similar to light bulbs
- Infinitely small point radiates light equally in all directions
  - Light vector varies across receiving surface
  - What is light intensity over distance proportional to?
  - Intensity drops off proportionally to the inverse square of the distance from the light
    - Reason for inverse square falloff:
      Surface area A of sphere:
      $A = 4 \pi r^2$

# Point Lights in Theory




At any point v on the surface:

$$\mathbf{L} = \frac{\mathbf{p} - \mathbf{v}}{\|\mathbf{p} - \mathbf{v}\|}$$

$$c_l = \frac{c_{src}}{\|\mathbf{p} - \mathbf{v}\|^2}$$

# Point Lights in OpenGL

- OpenGL model for distance attenuation:

$$c_l = \frac{c_{src}}{k_c + k_l |\mathbf{p} - \mathbf{v}| + k_q |\mathbf{p} - \mathbf{v}|^2}$$

- Attenuation parameters:
  - $k_c$ = constant attenuation, default: 1
  - $k_l$ = linear attenuation, default: 0
  - $k_q$ = quadratic attenuation, default: 0
- Default: no attenuation: $c_l = c_{src}$
- Change attenuation parameters with:
  - GL_CONSTANT_ATTENUATION
  - GL_LINEAR_ATTENUATION
  - GL_QUADRATIC_ATTENUATION

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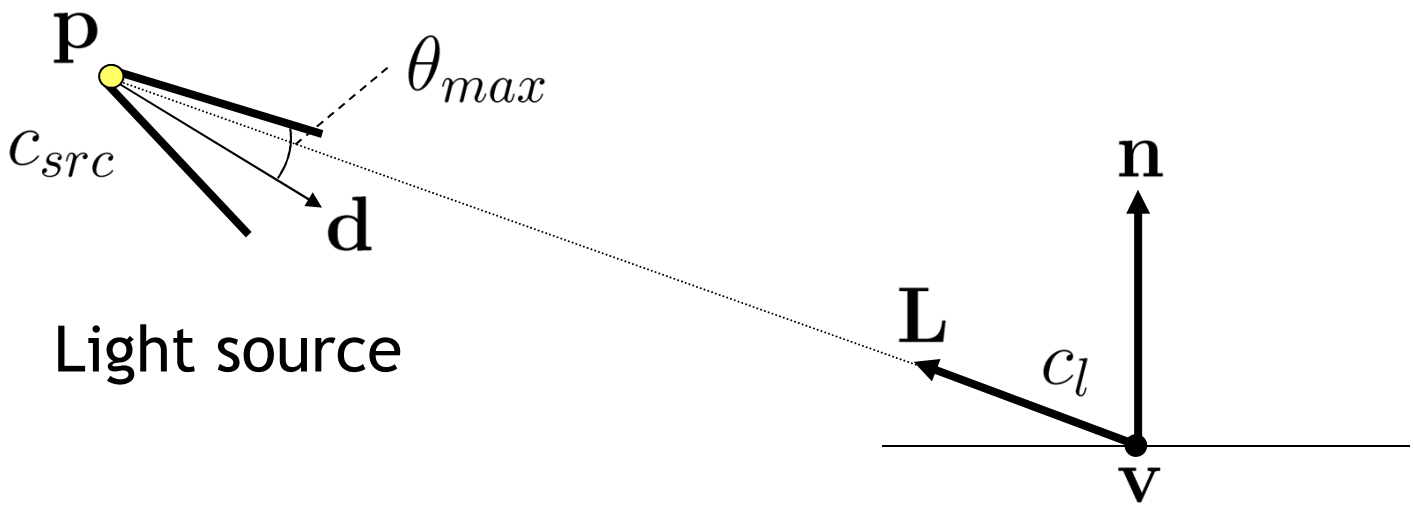
# Spotlights

- Like point source, but intensity depends on direction

**Parameters**

- Position: location of light source
- Spot direction: center axis of light source
- Falloff parameters:
  - Beam width (cone angle)
  - The way the light tapers off at the edges of the beam (cosine exponent)

# Spotlights

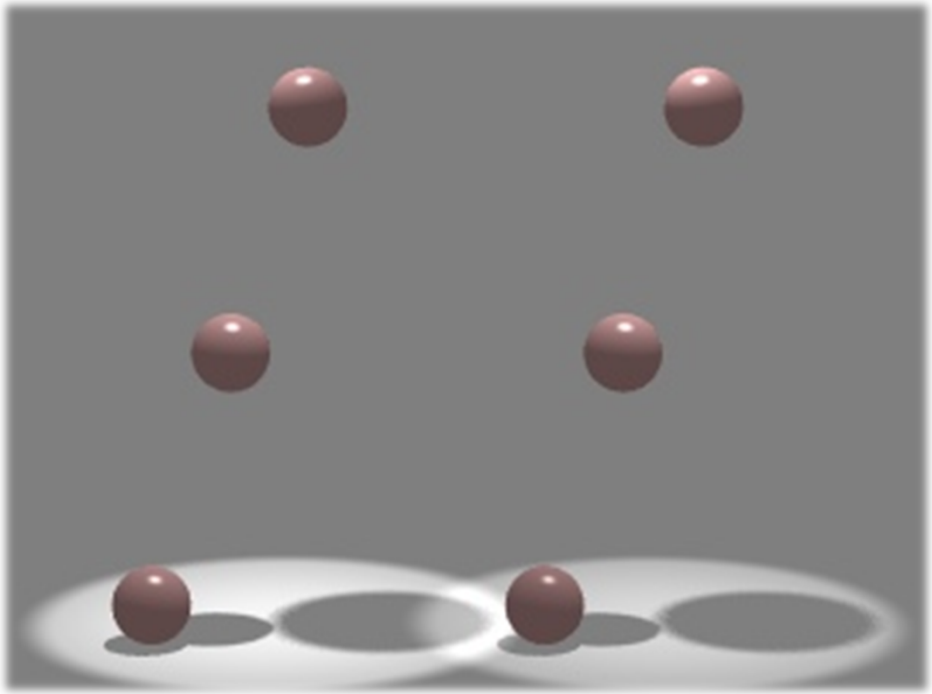



$$\mathbf{L} = \frac{\mathbf{p} - \mathbf{v}}{\|\mathbf{p} - \mathbf{v}\|}$$

$$c_l = \begin{cases} 0 & \text{if} \quad -\mathbf{L} \cdot \mathbf{d} \leq \cos(\theta_{max}) \\ c_{src} \left(-\mathbf{L} \cdot \mathbf{d}\right)^f & \text{otherwise} \end{cases}$$

# Spotlights

Photograph of real spotlight



Spotlights in OpenGL

# Video

- C++ OpenGL Lesson on Basic Lighting
  - http://www.youtube.com/watch?v=g_0yV7jZvGg