Computer Graphics (CS 4731)
Lighting

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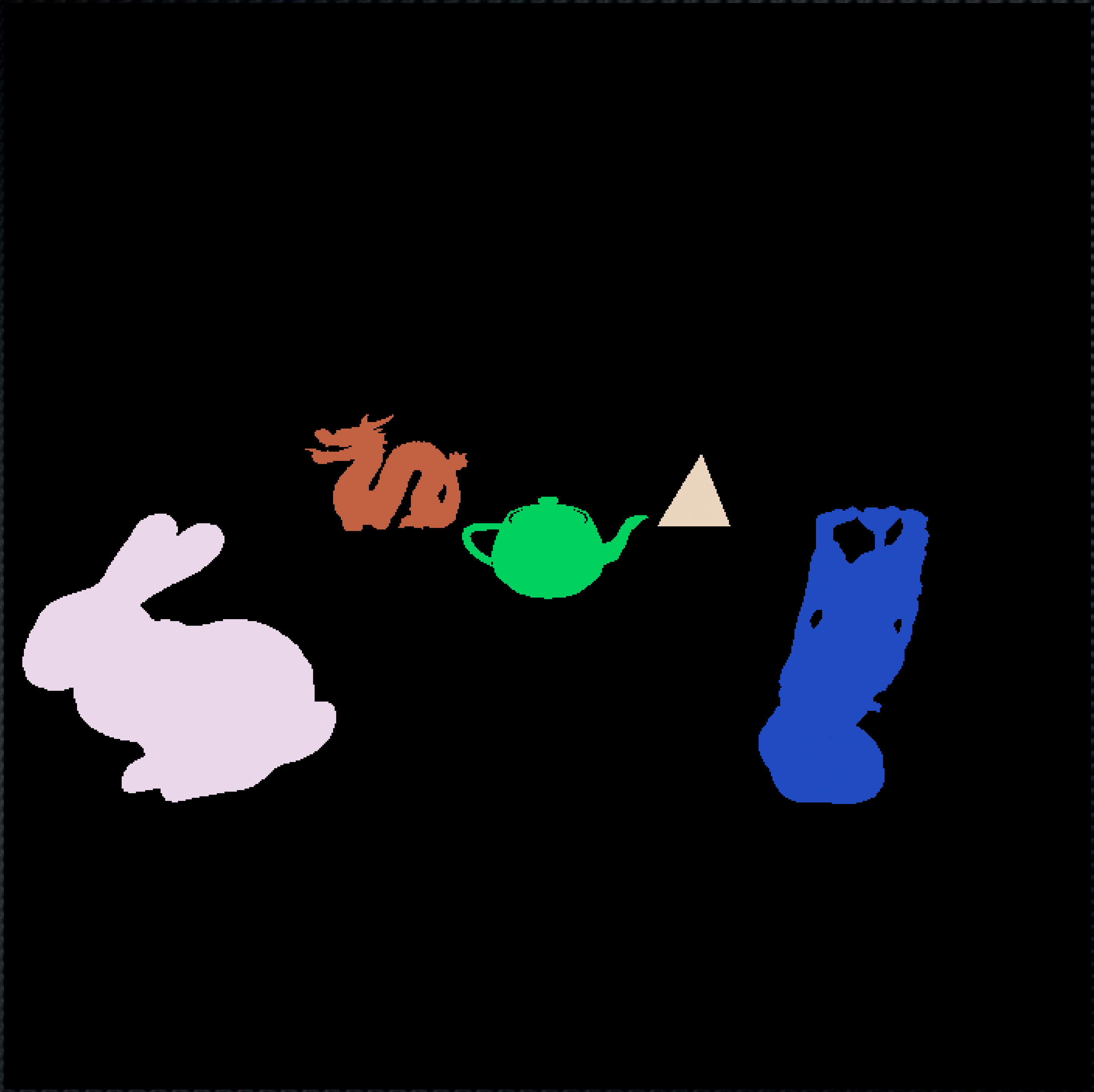
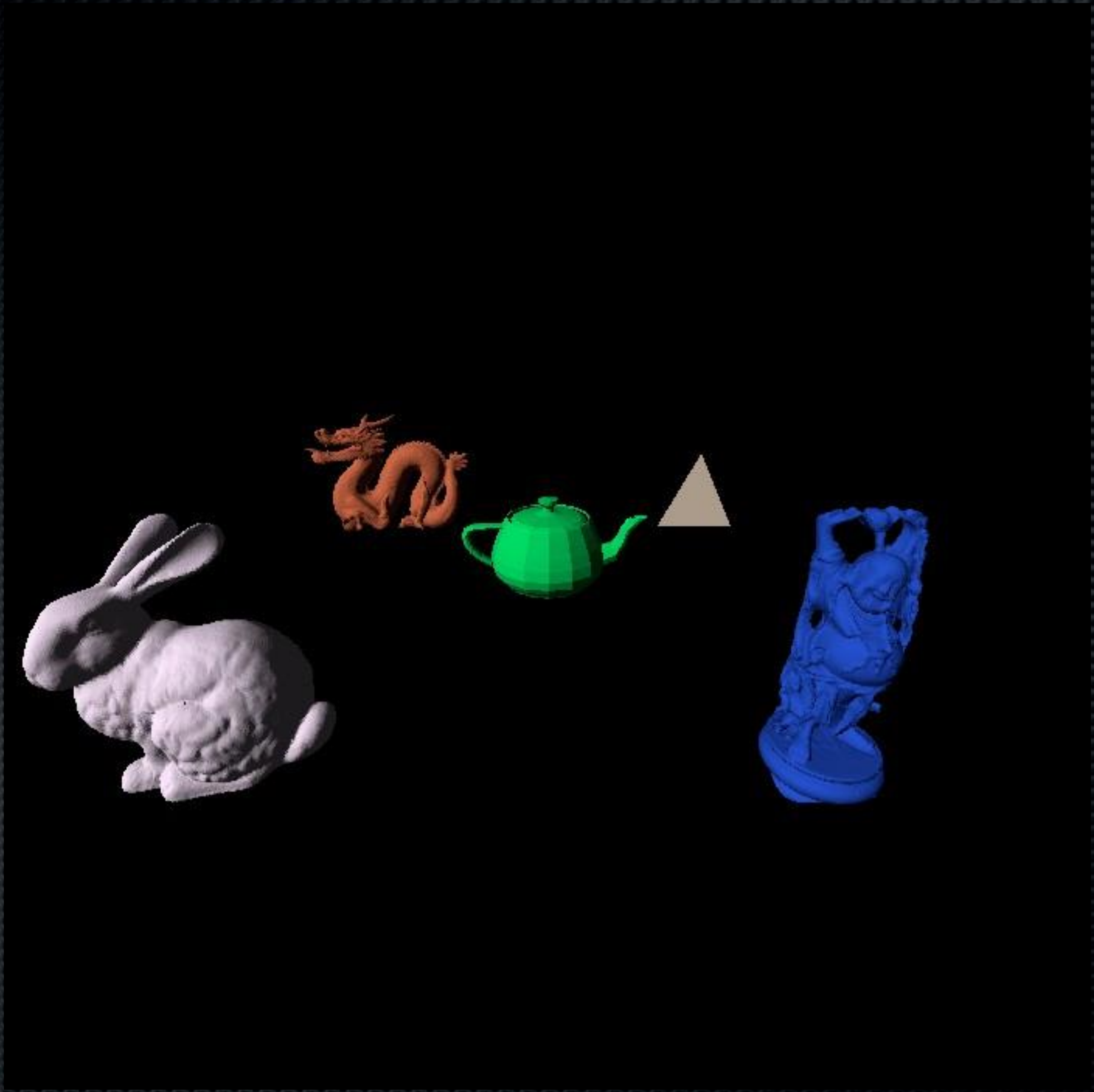
Slides Courtesy of Emmanuel Agu (WPI) and Matt Stoker (Utah)





Lighting

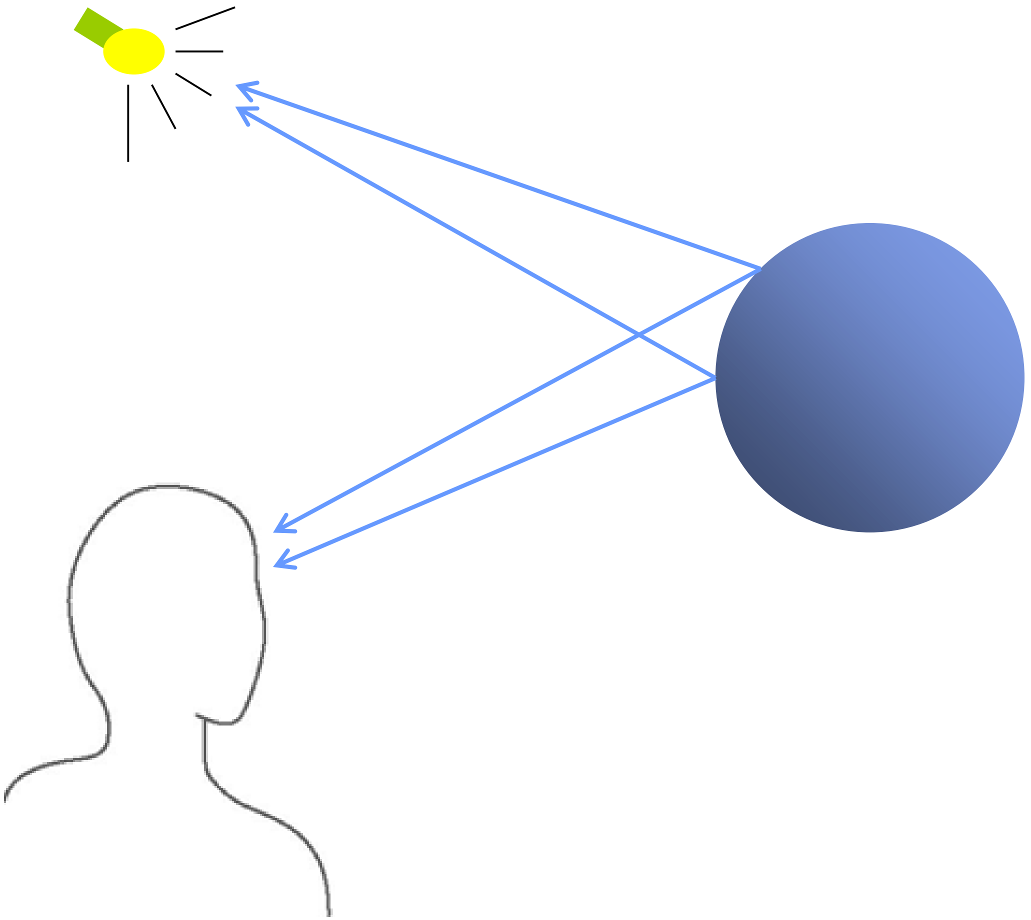

Variation in the color of an object gives perception of structure.

This variation in color is due to the changing light conditions on the object's surface.

The orientation of the surface relative to the light source(s) is what makes up most color variation.

How can lighting be modeled in tessellated geometry?

What Causes Shading?



Lighting

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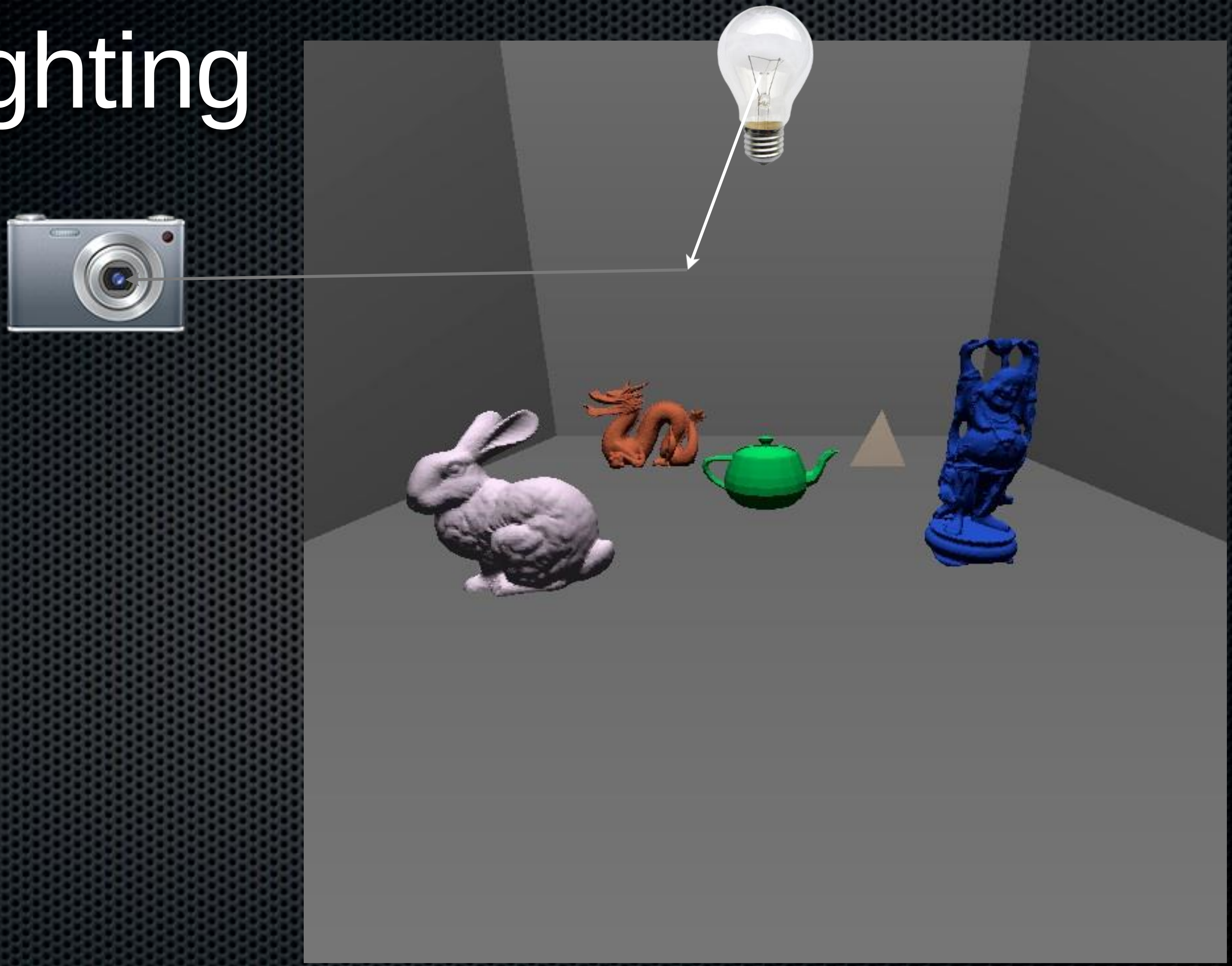
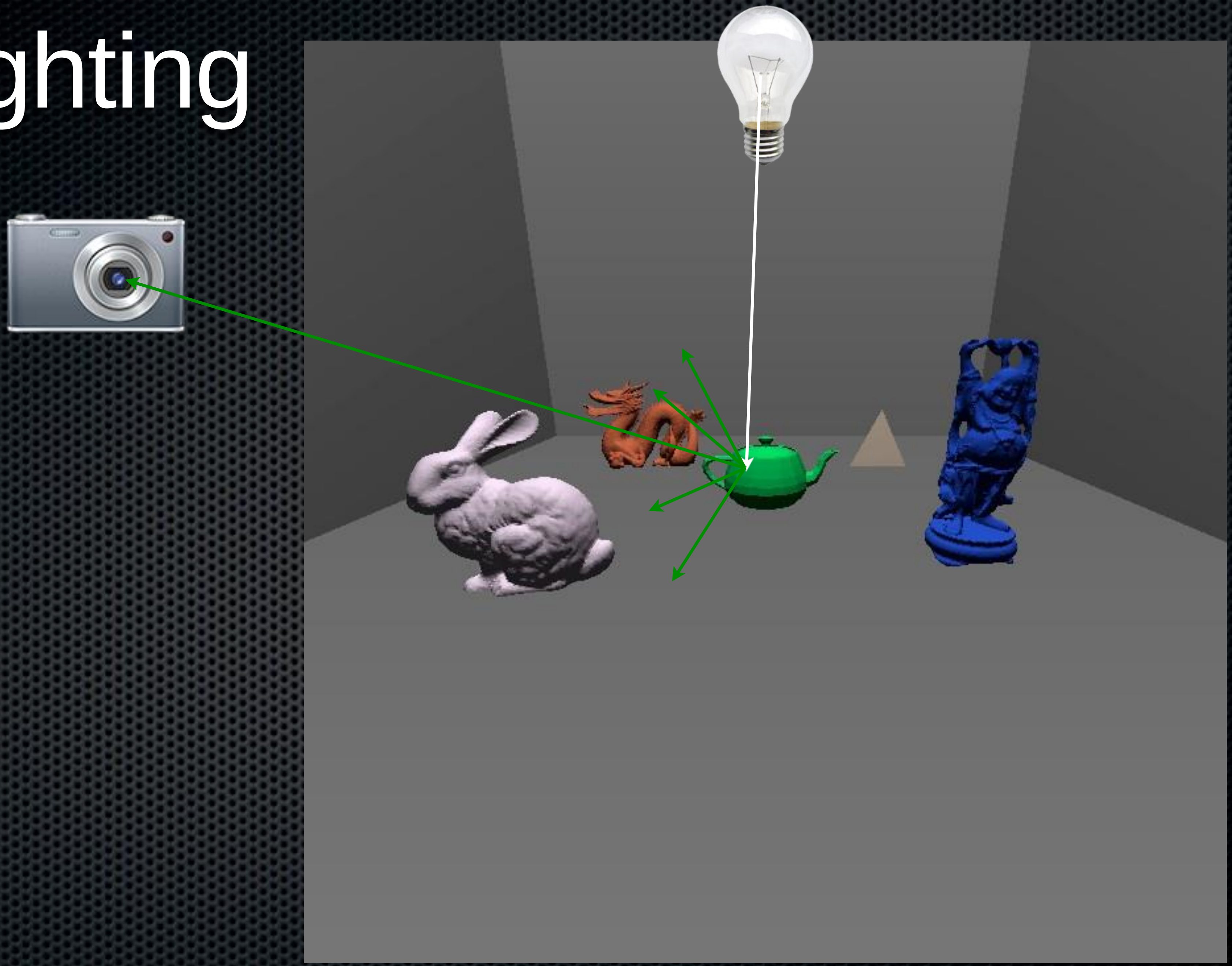
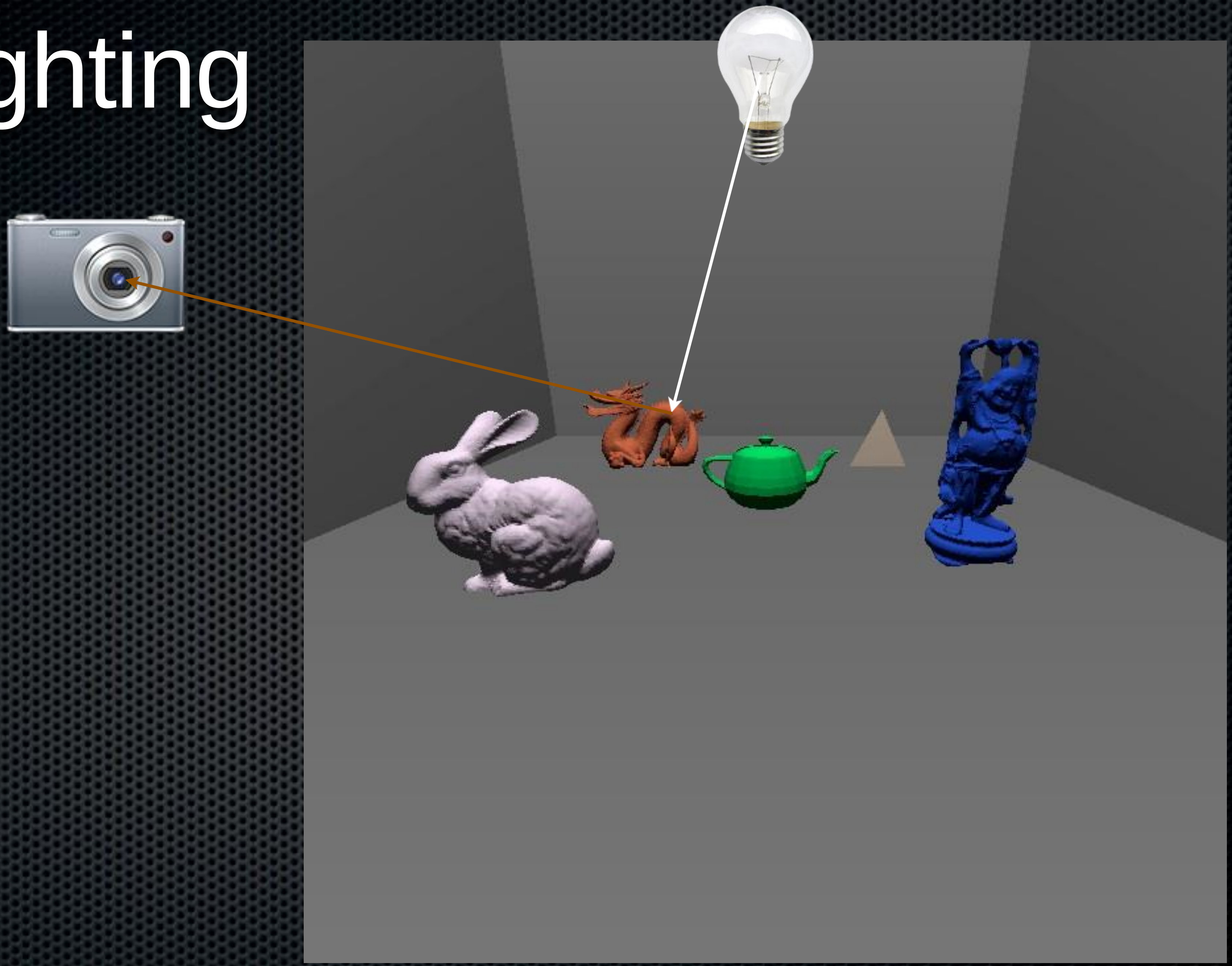


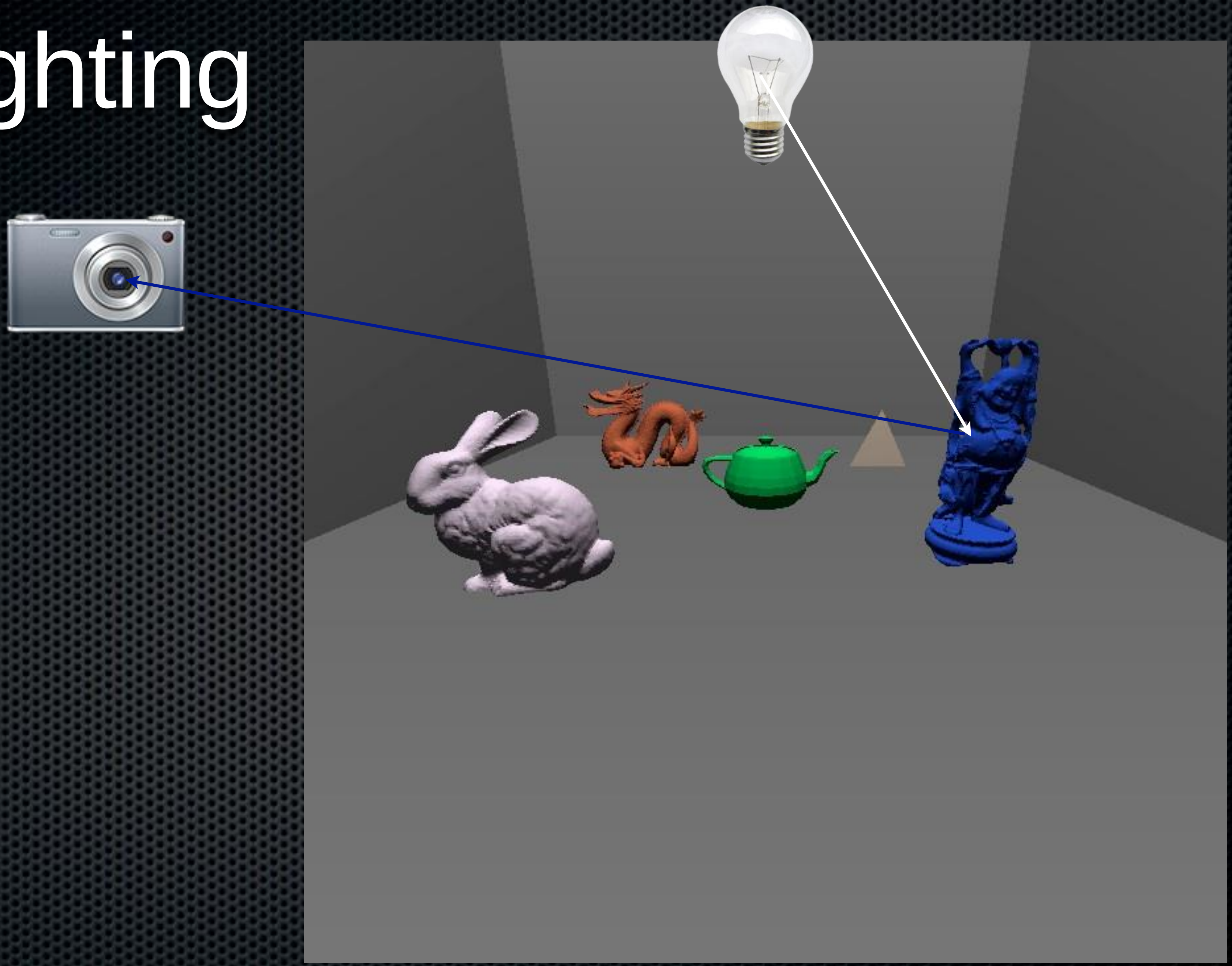
Lighting



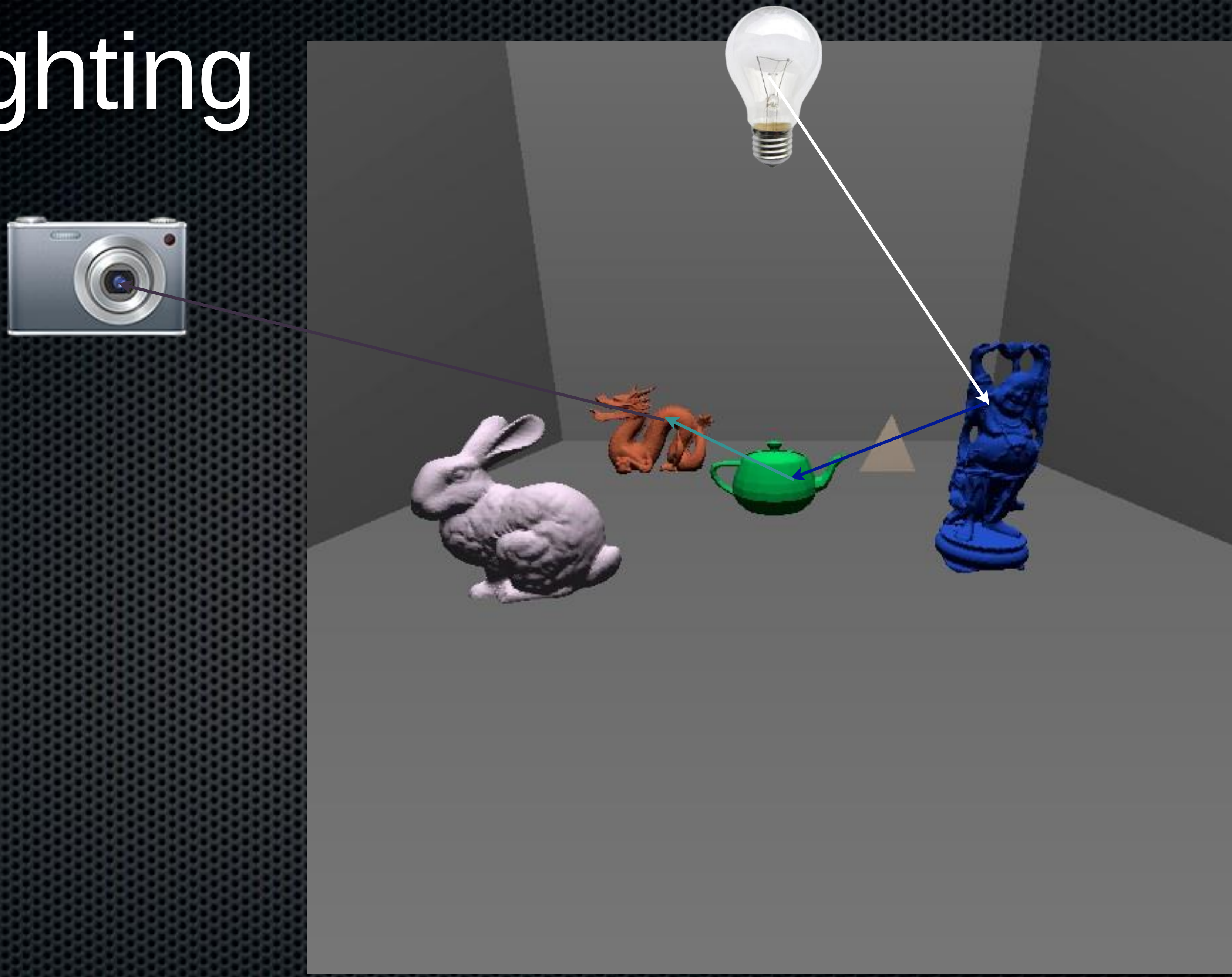
Lighting



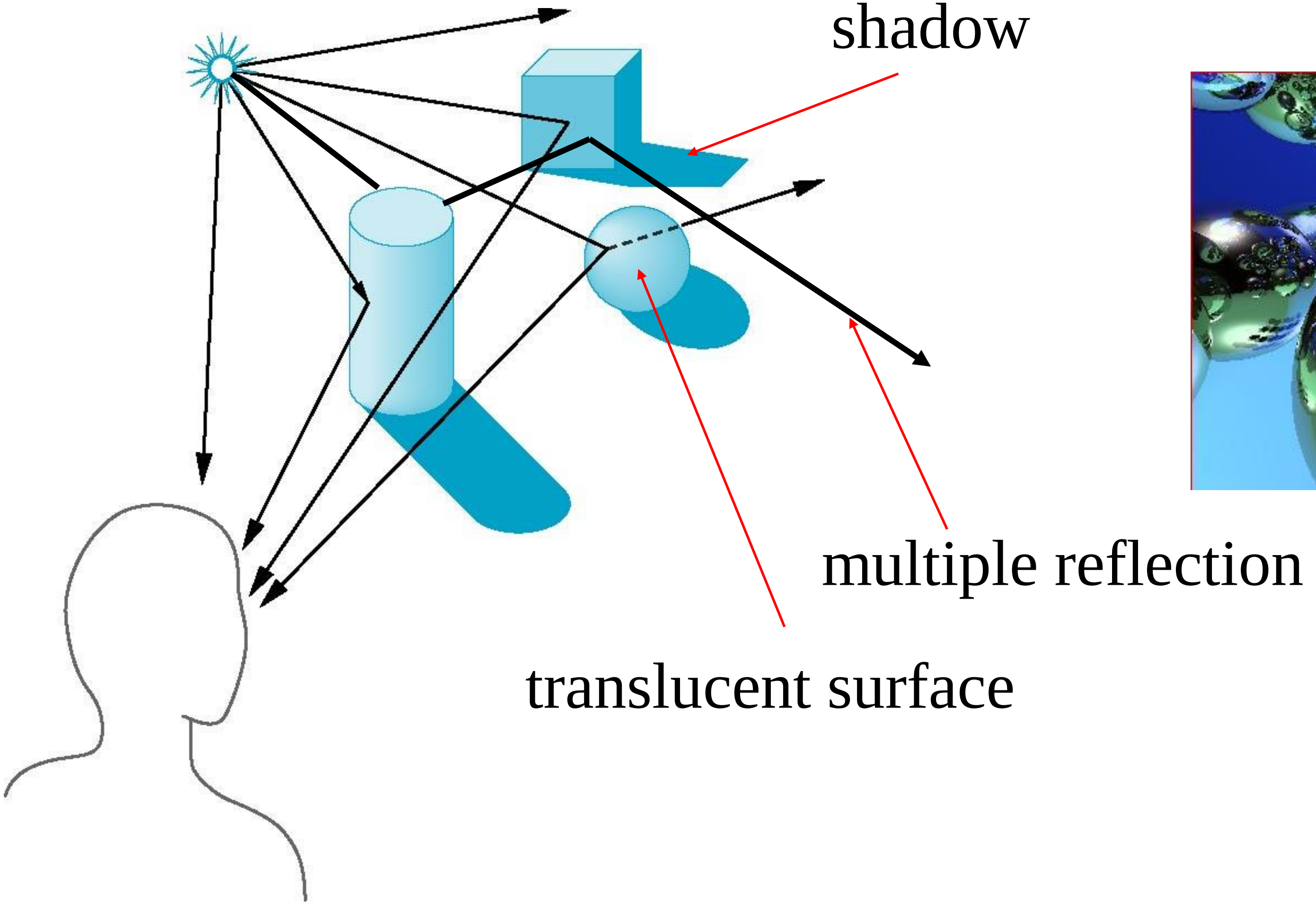
Lighting

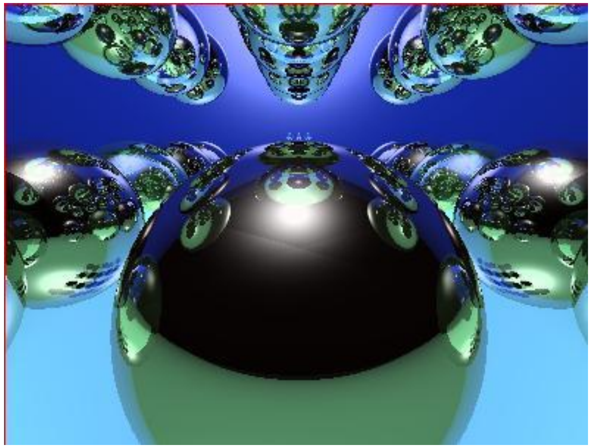


Lighting

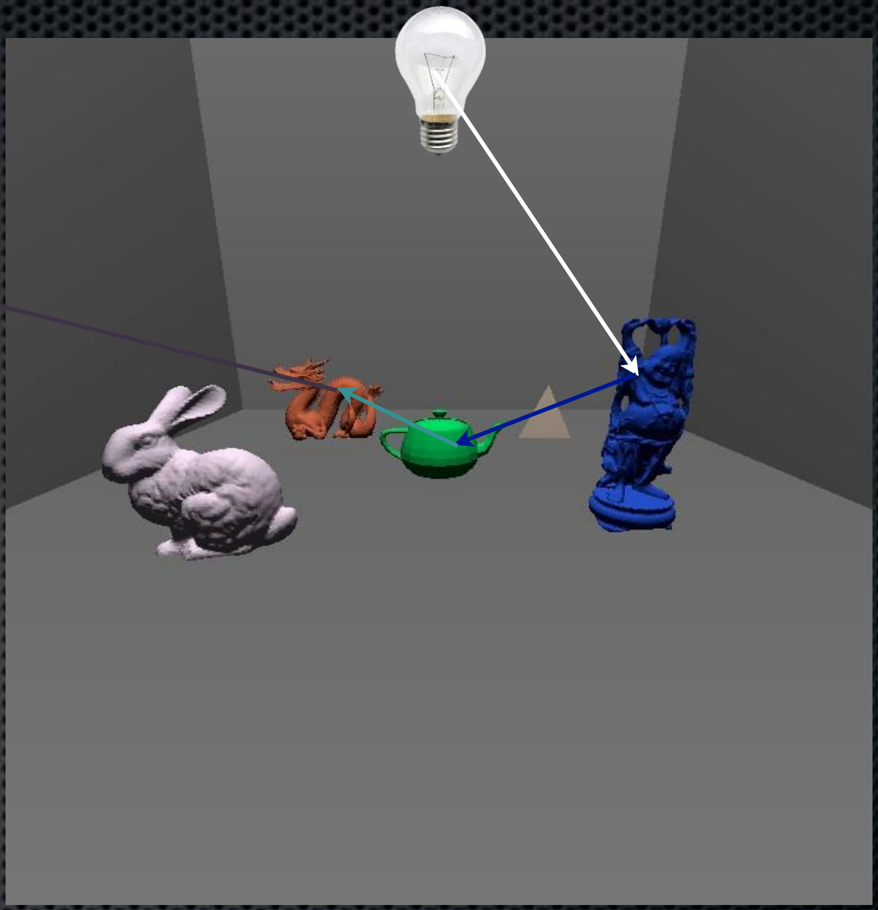


Global Illumination (Lighting) Model



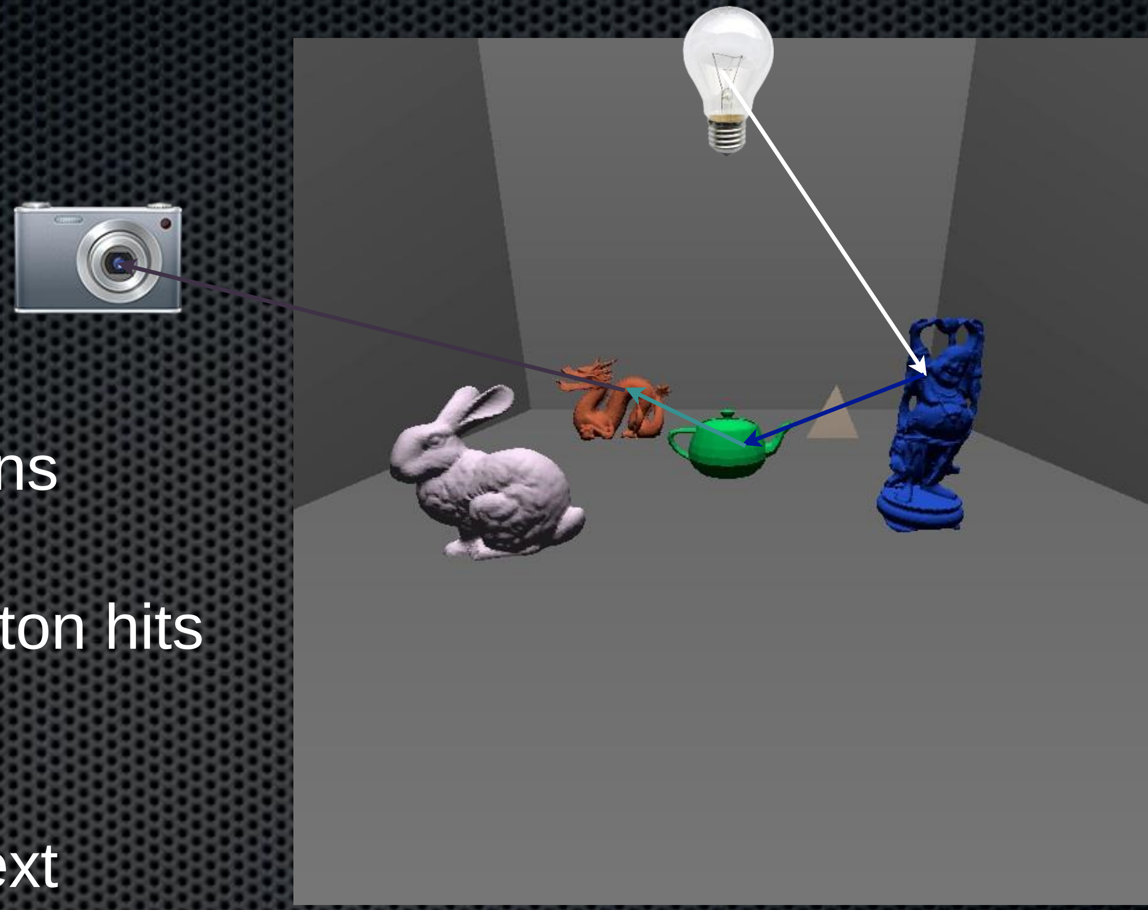


Lighting



For each light in scene
- Emit 1,000,000,000 photons
- For each photon
  - Find what geometry photon hits
  - Color photon
  - Scatter photon
  - Find what photon hits next
  - ...
  - Pray photon hits camera CCD
  - Light pixel that CCD micro-square represents

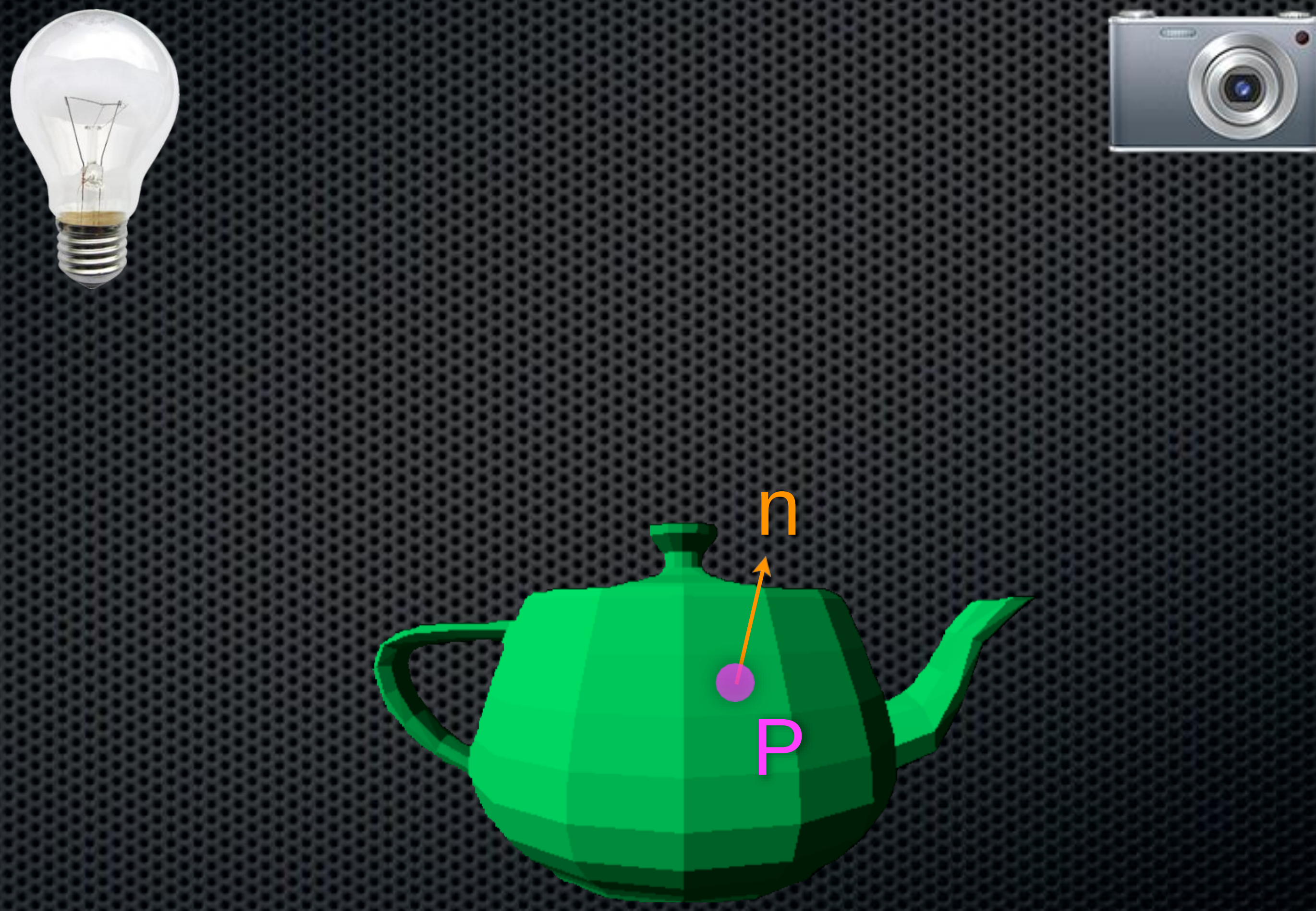
Lighting



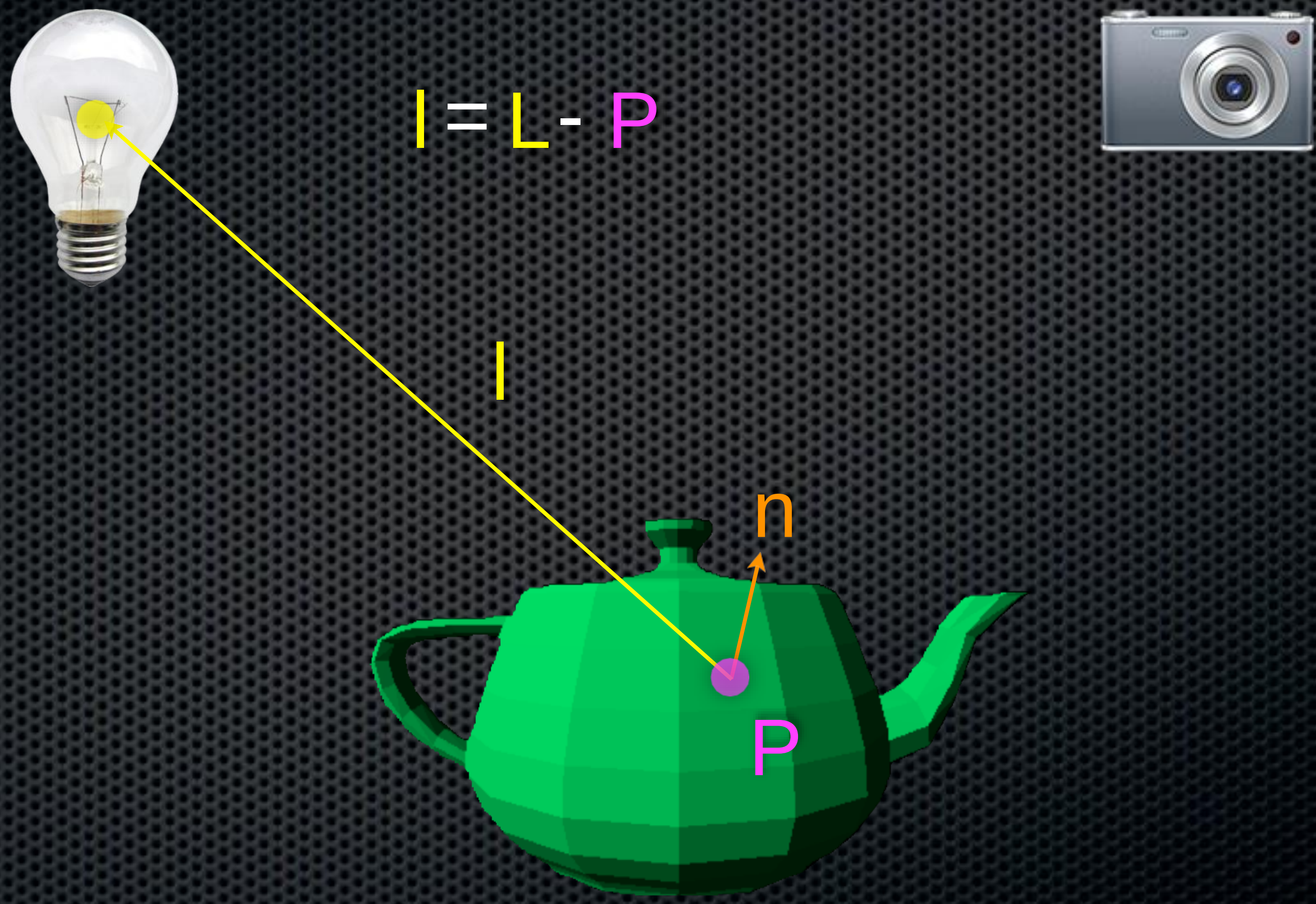
For each light in scene
- Emit 1.0 … photons
- For e…
  - F… oton hits
  - C…
  - S…
  - F… next
  - ...
  - Pray ph… camera CCD
  - Light pixel that CCD micro-square represents

Local Lighting

Local Lighting

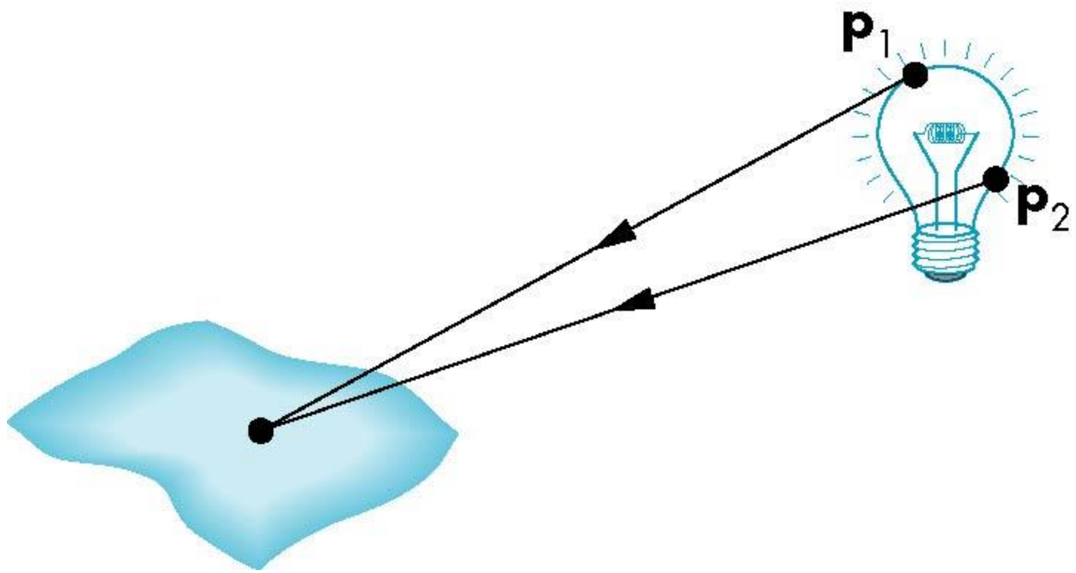


Local Lighting

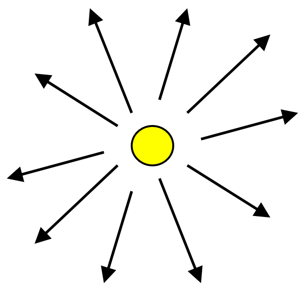


Light Sources

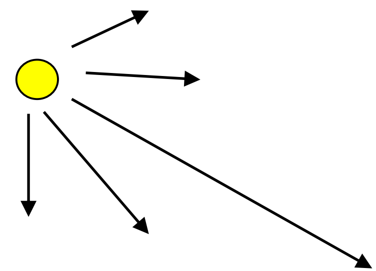
- General light sources are difficult to model (e.g. light bulb)
- Why? We must compute effect of light coming from all points on light source



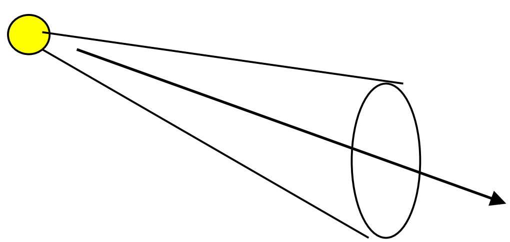
Light Sources Abstractions



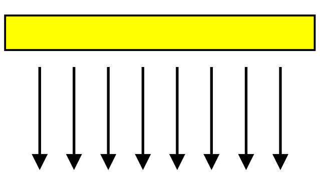
Point light



Directional light

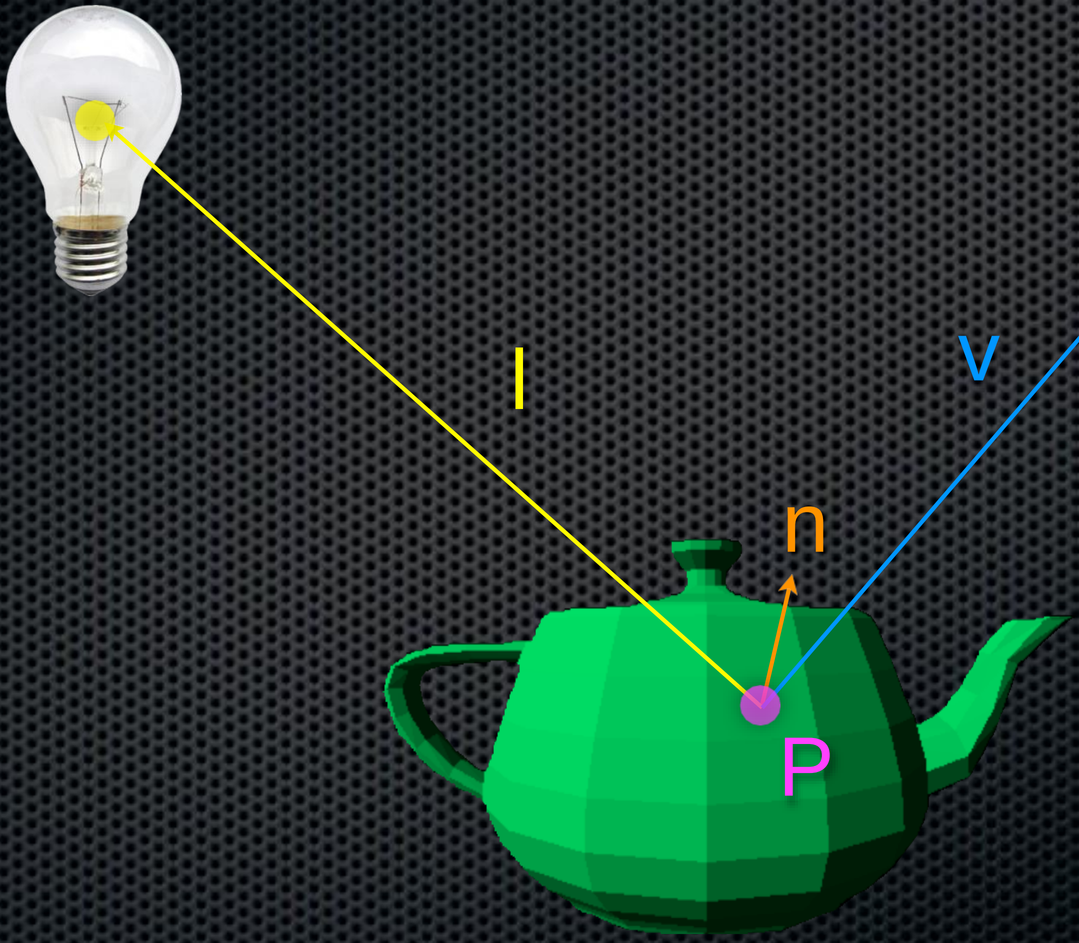


Spot light



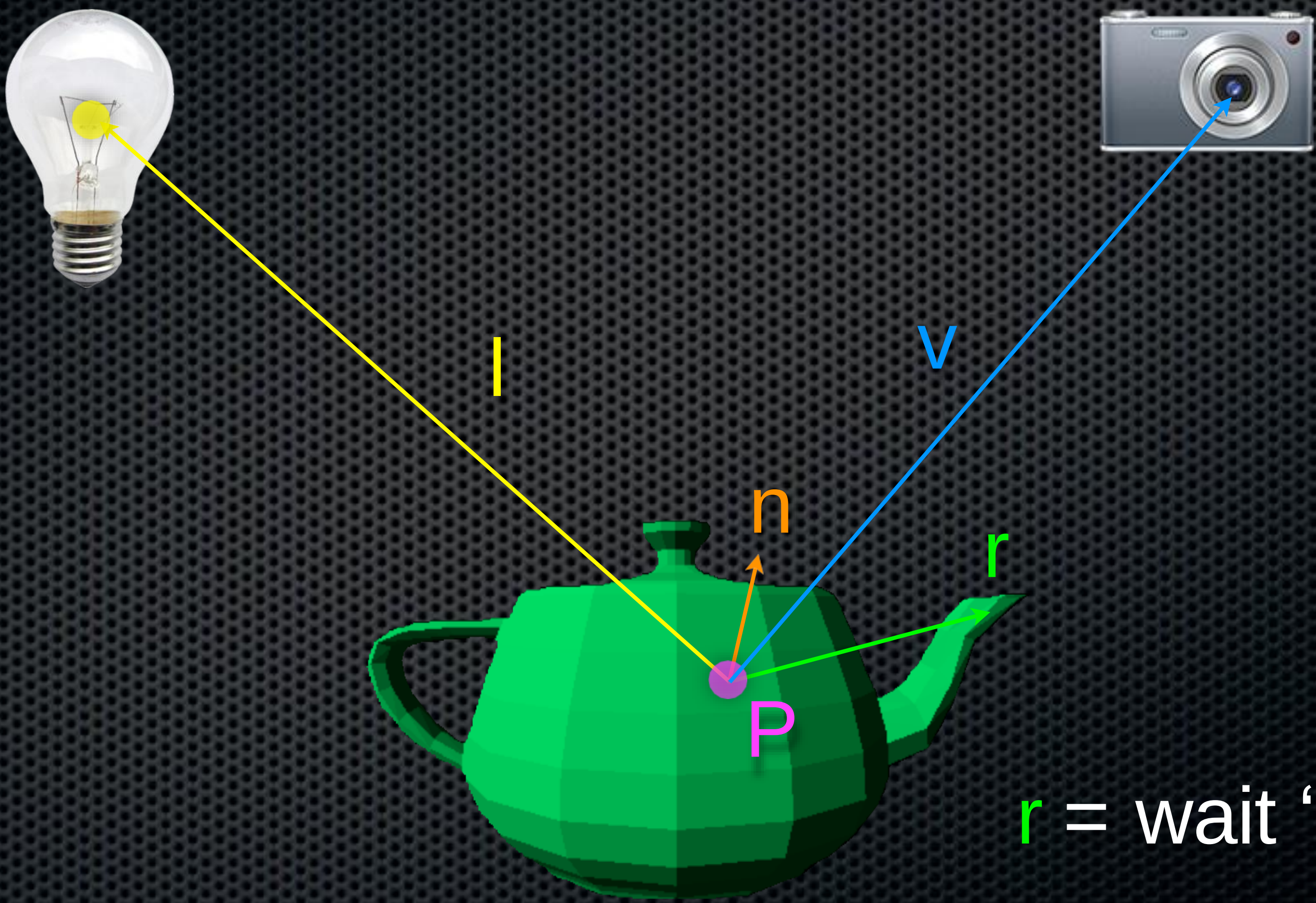
Area light

Local Lighting



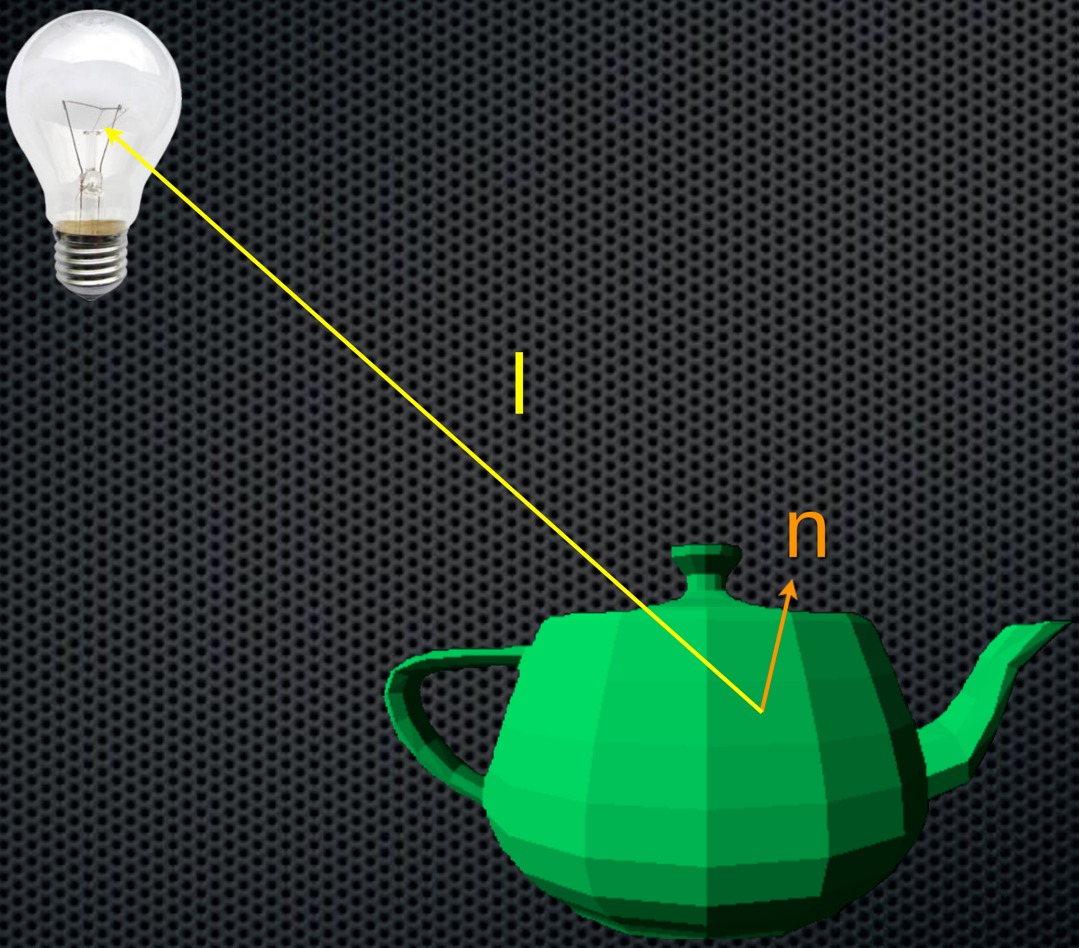
$v = V - P$

Local Lighting

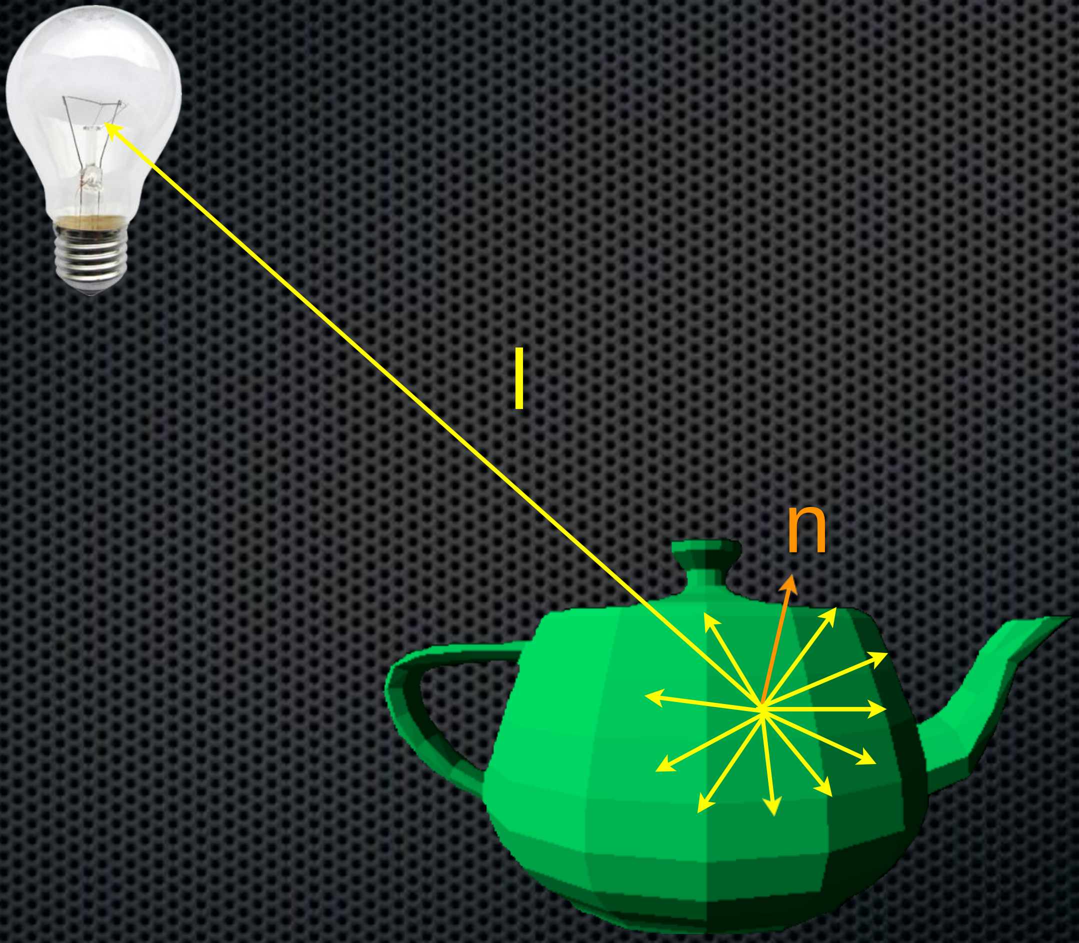


r = wait 'til later

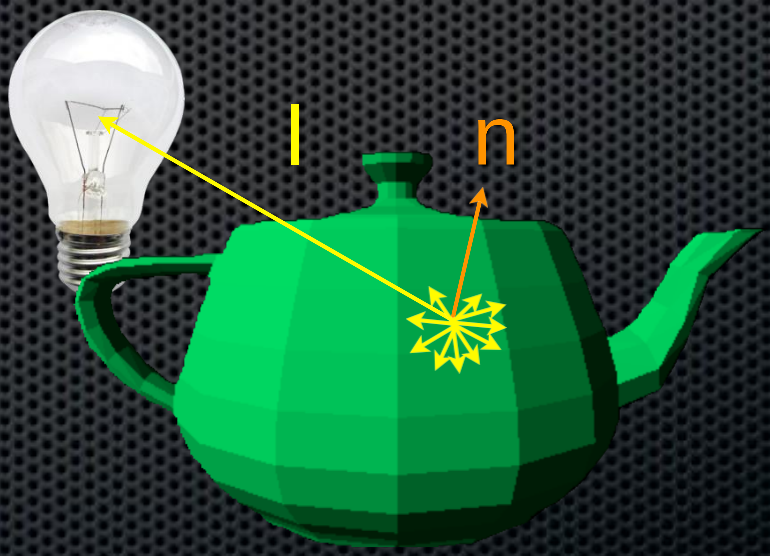
Local Lighting



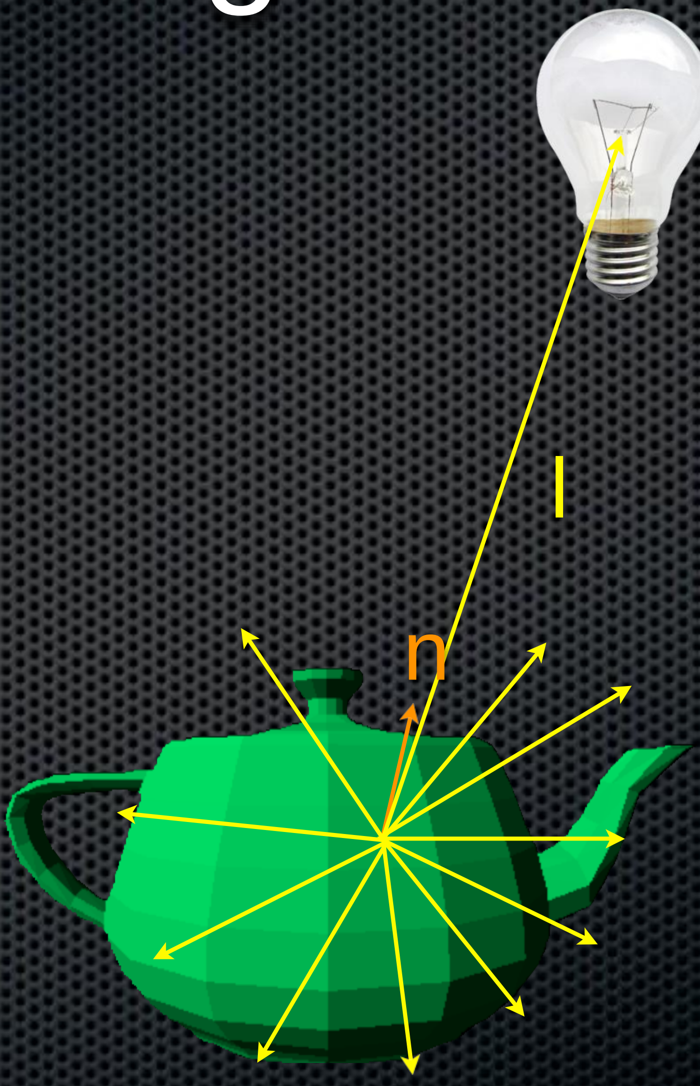
Local Lighting



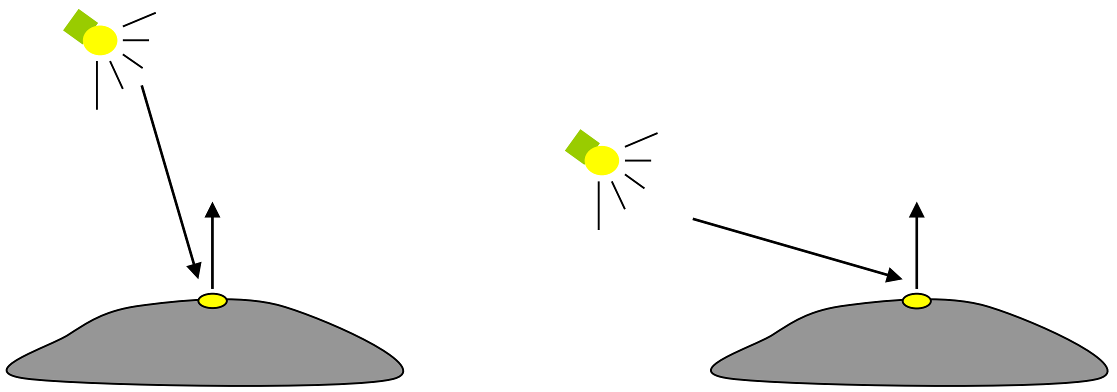
Local Lighting



Local Lighting



Diffuse Light Calculation



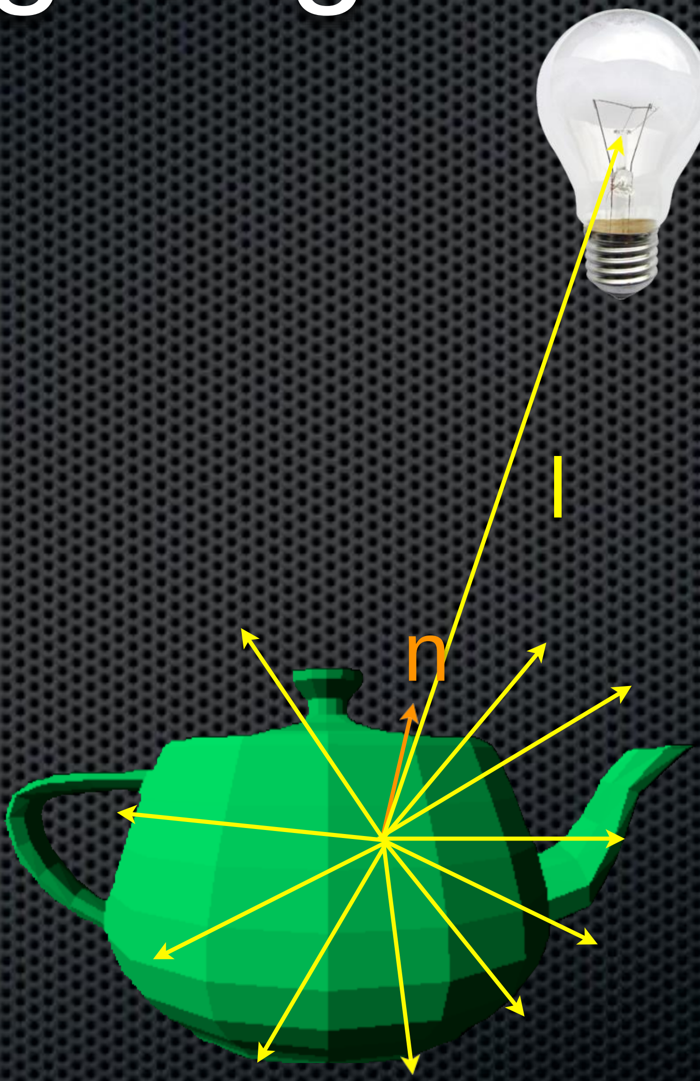
Receive more light

Receive less light

Diffuse Lighting

$$I_d = L_d k_d \, \hat{l} \cdot \hat{n}$$

$$0 < I < 1$$



L_d = light intensity

k_d = material diffuse coefficient

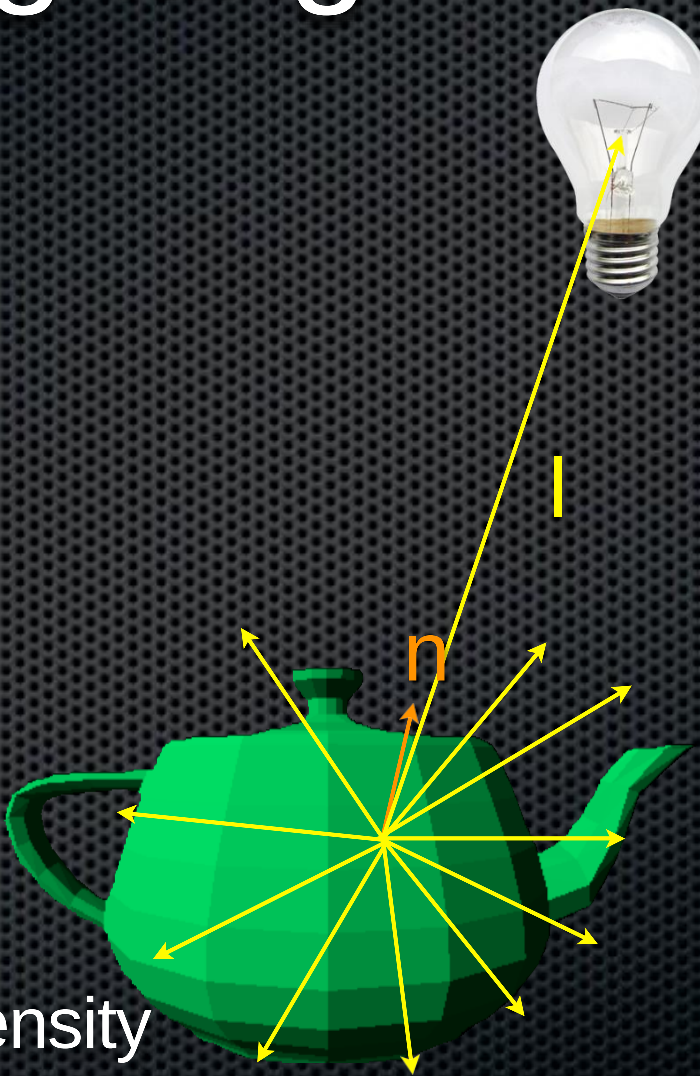
Diffuse Lighting

$$I_{dr} = L_{dr} k_{dr}\, \hat{l} \cdot \hat{n}$$

$$I_{dg} = L_{dg} k_{dg}\, \hat{l} \cdot \hat{n}$$

$$I_{db} = L_{db} k_{db}\, \hat{l} \cdot \hat{n}$$

$$0 < I_{dx} < 1$$



L_{dx} = light channel intensity

k_{dx} = material diffuse coefficient for channel

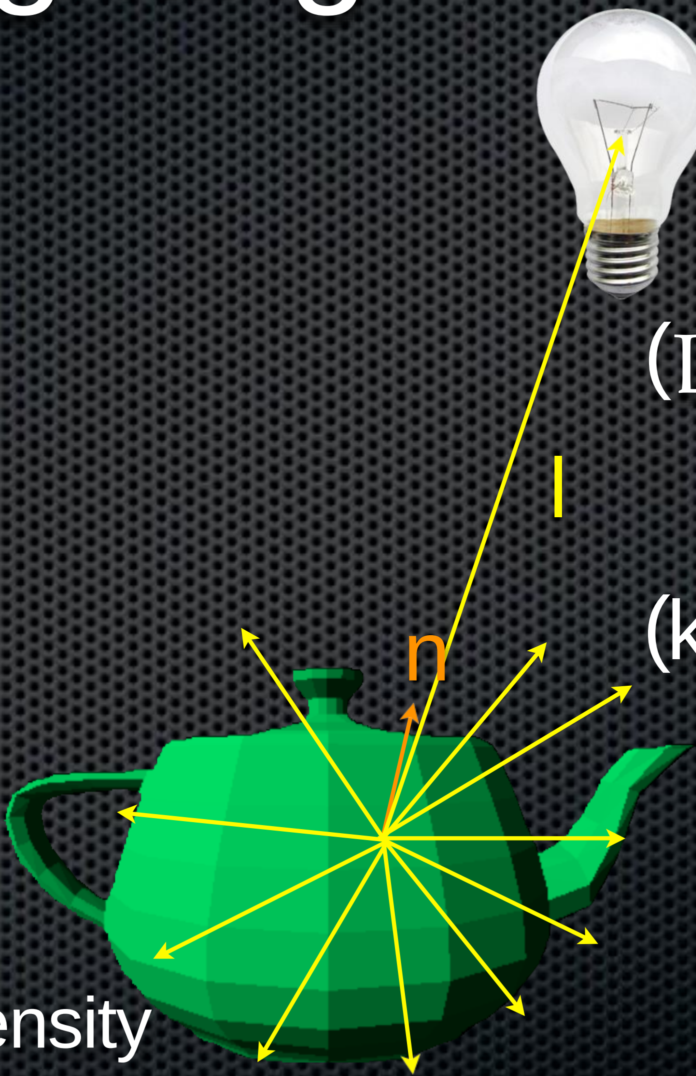
Diffuse Lighting

$I_{dr} = L_{dr} k_{dr}\, \hat{l} \cdot \hat{n}$

$I_{dg} = L_{dg} k_{dg}\, \hat{l} \cdot \hat{n}$

$I_{db} = L_{db} k_{db}\, \hat{l} \cdot \hat{n}$

$0 < I_{dx} < 1$



(L_{dr}, L_{dg}, L_{db})

= light color

(k_{dr}, k_{dg}, k_{db})

= material color

L_{dx} = light channel intensity

k_{dx} = material diffuse coefficient for channel

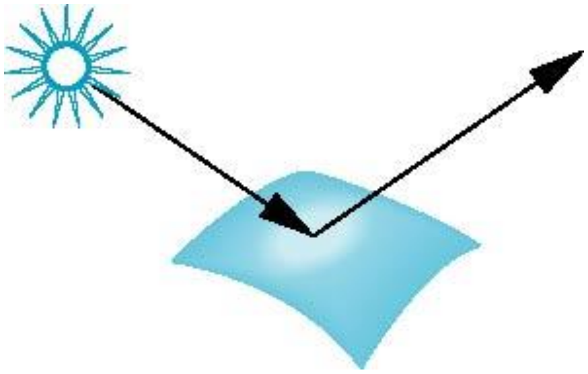
Diffuse Lighting Example

Specular light example

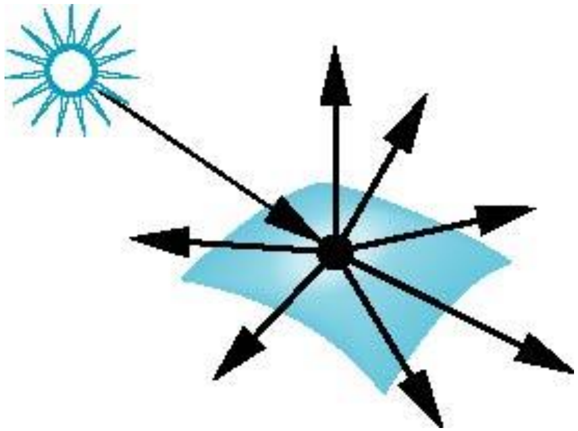
Specular?
Bright spot on object

Surface Roughness

- **Smooth surfaces:** more reflected light concentrated in mirror direction
- **Rough surfaces:** reflects light in all directions

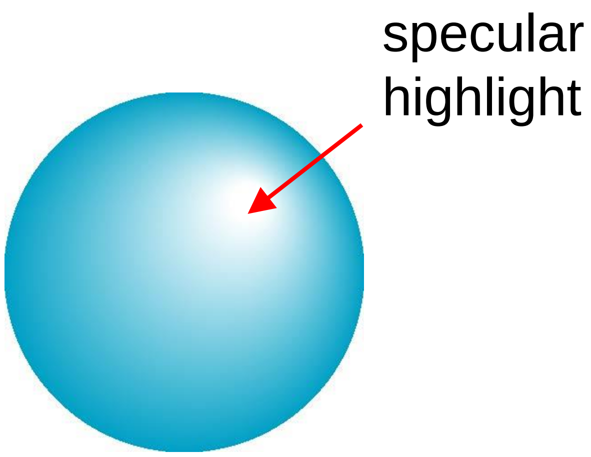


smooth surface

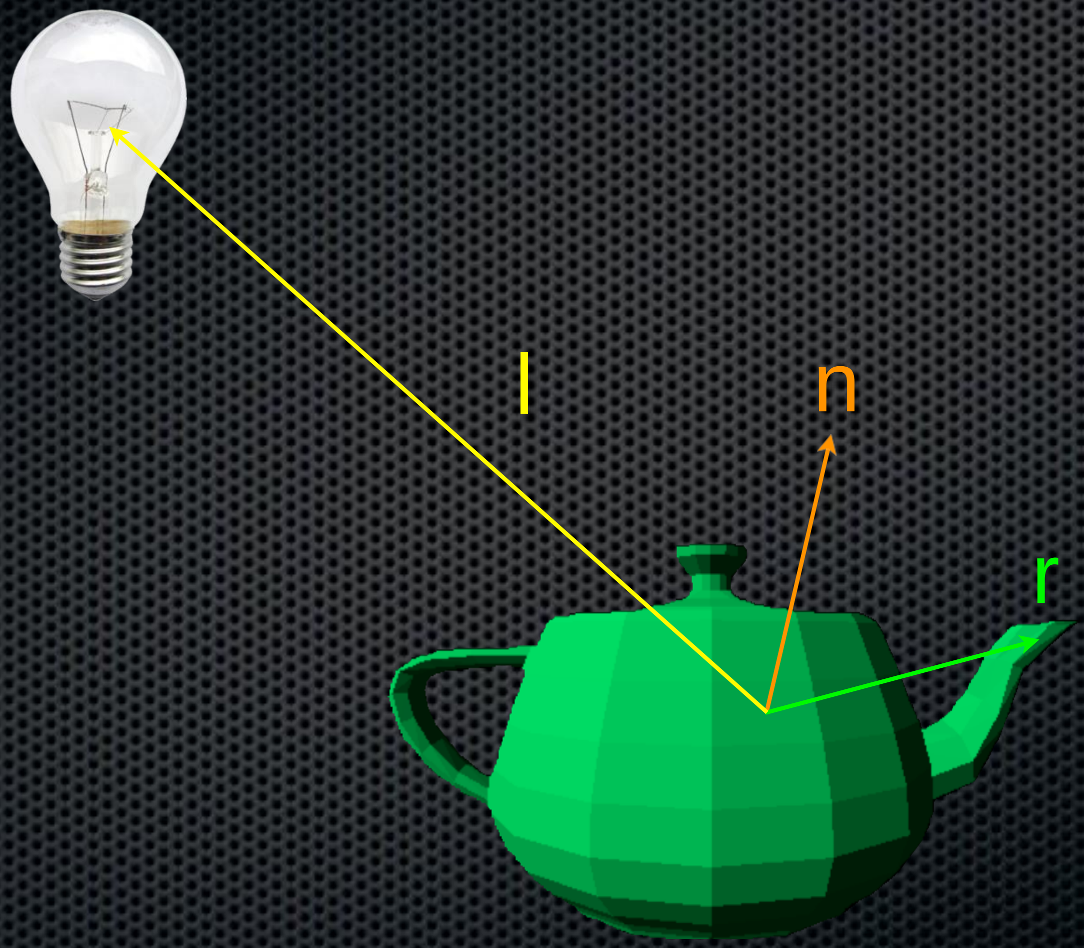


rough surface

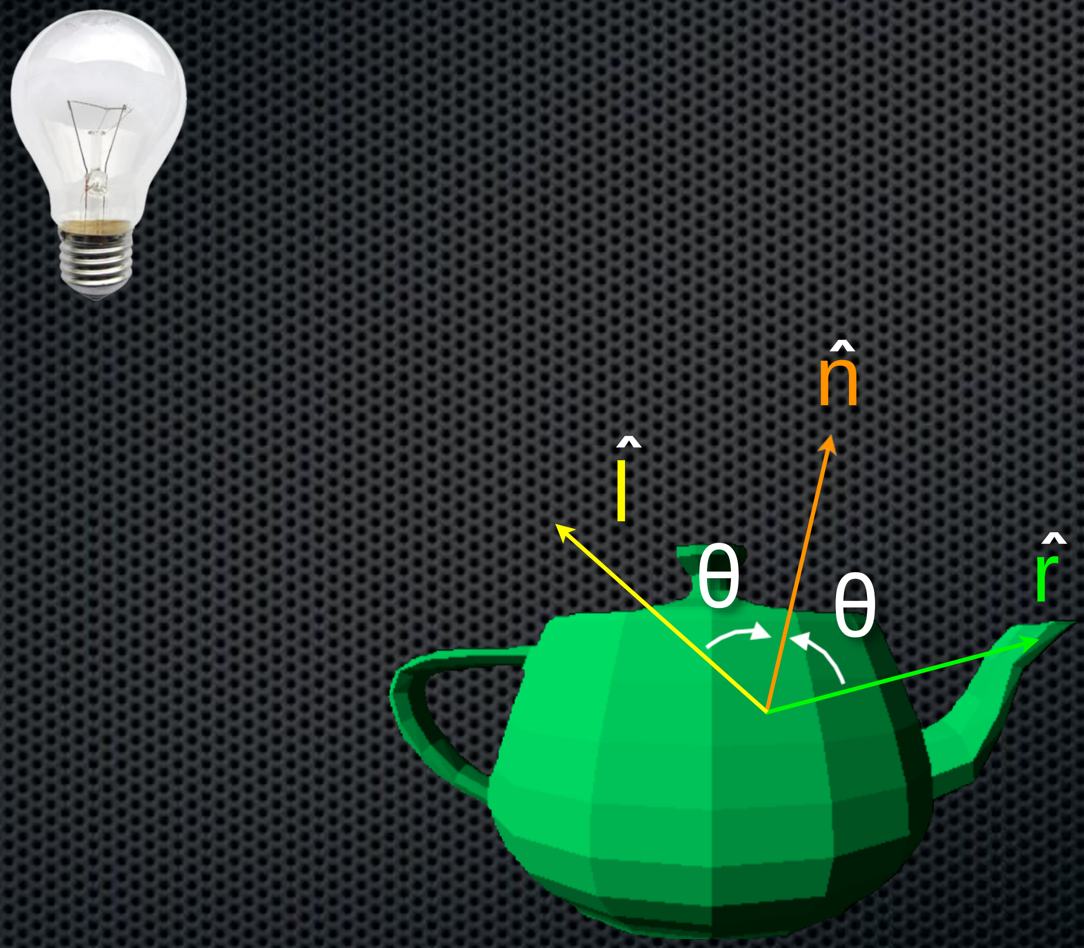
Specular Highlights



Specular Lighting



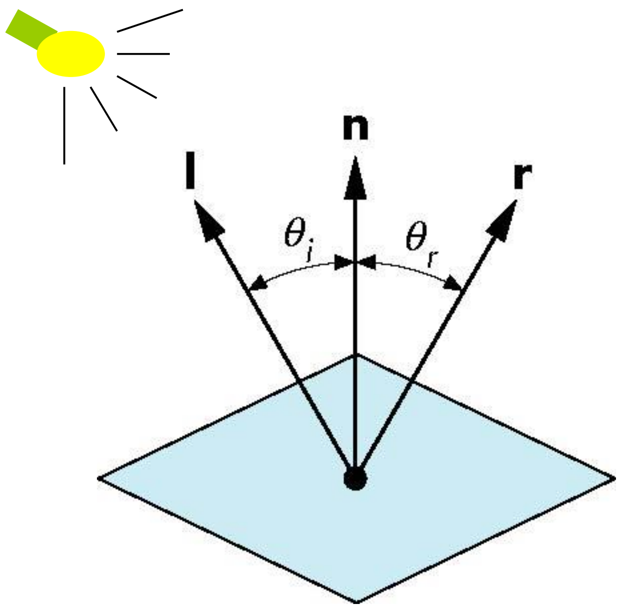
Specular Lighting



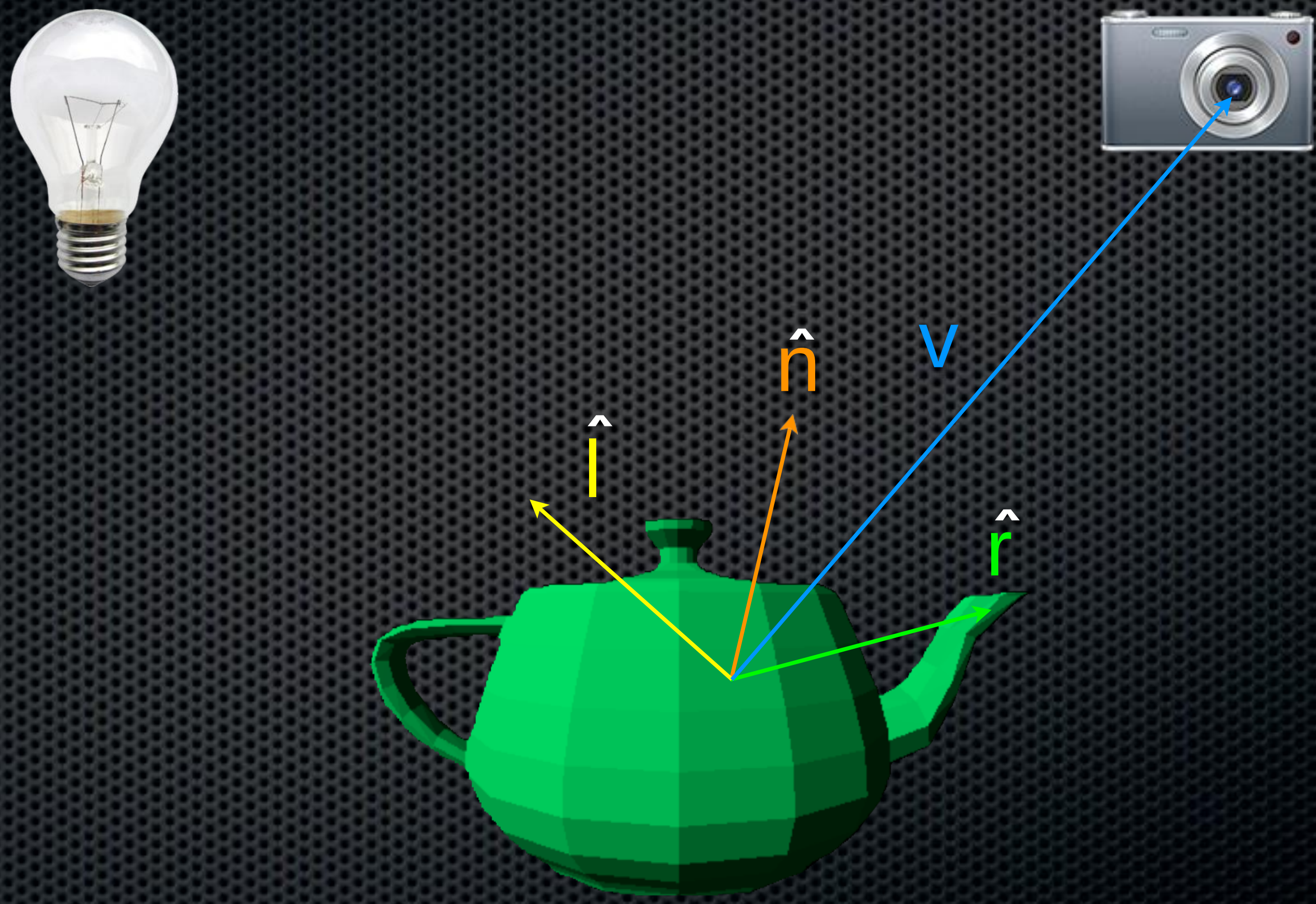
Mirror Direction?

- Angle of reflection = angle of incidence

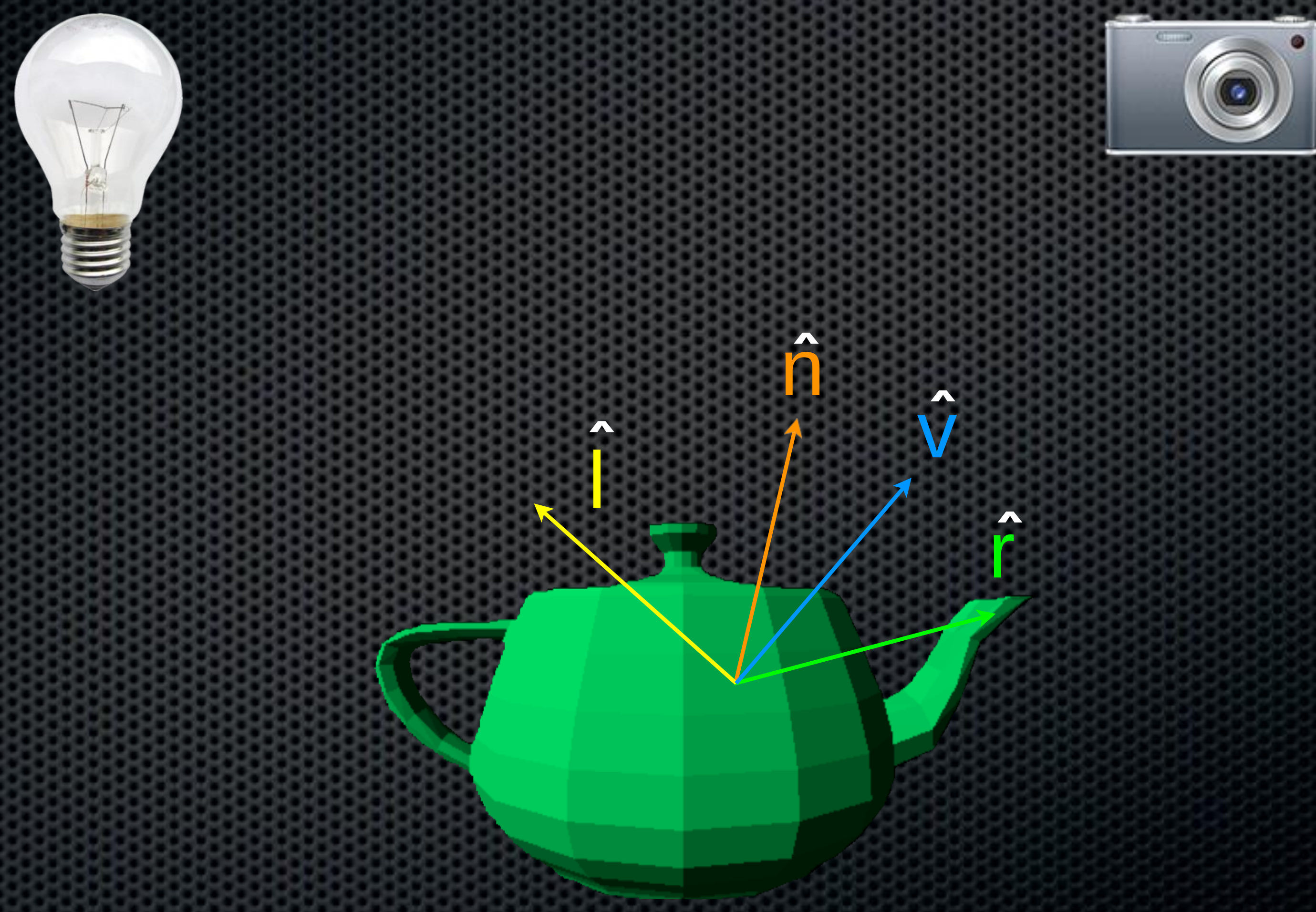
$$\mathbf{r} = (2\,(\mathbf{l} \cdot \mathbf{n})\,\mathbf{n}) - \mathbf{l}$$



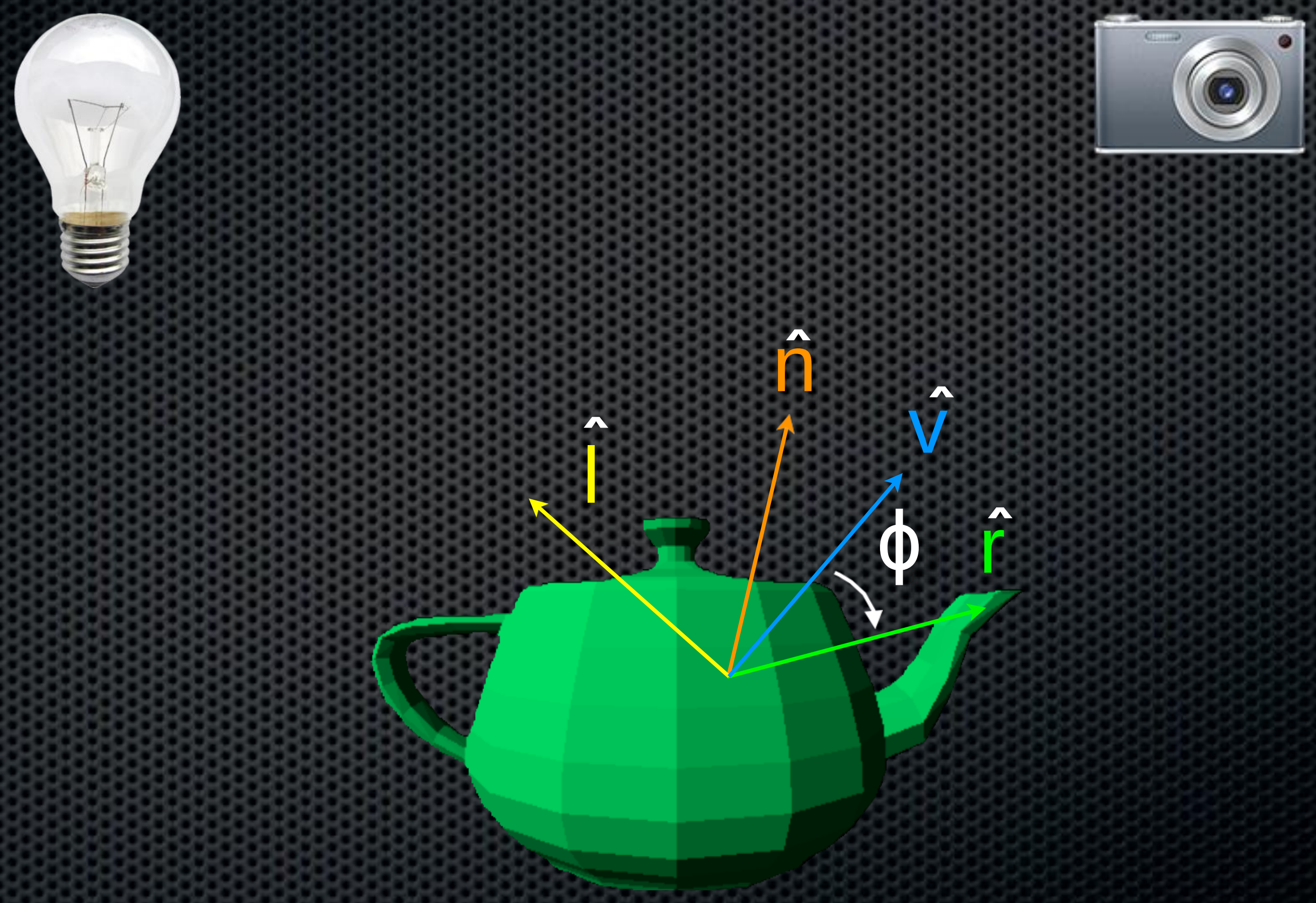
Specular Lighting



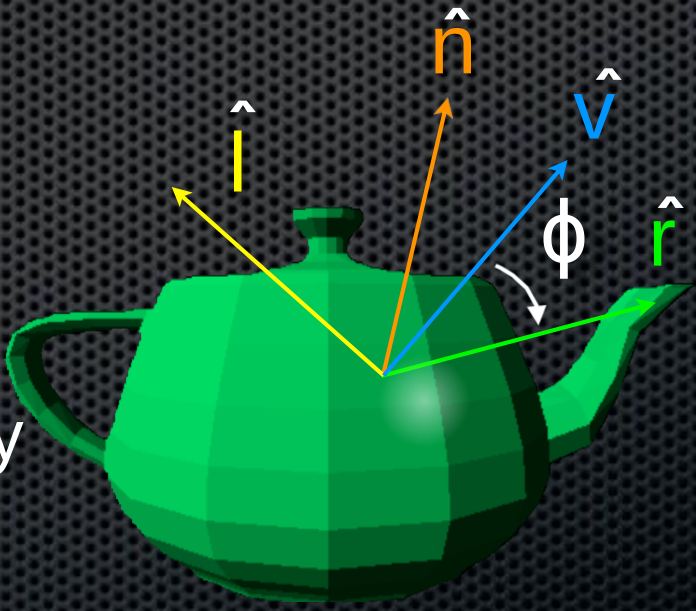
Specular Lighting



Specular Lighting



Specular Lighting



$$I_s \simeq L_s k_s (\hat{v} \cdot \hat{r})^{\alpha}$$

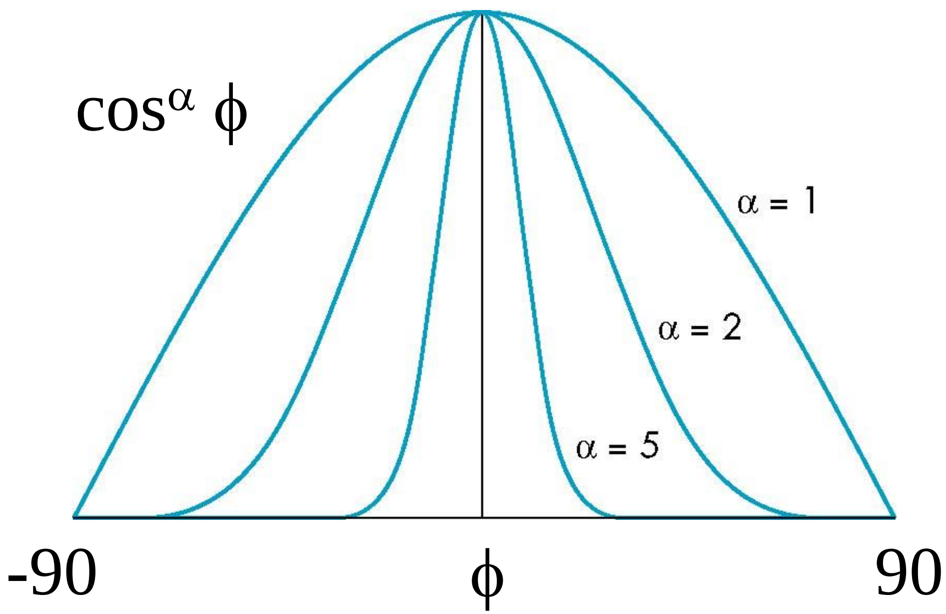
L_s = specular intensity

α = shininess

k_s = material specular coefficient

The Shininess Coefficient, α

- α controls falloff sharpness
- High α = sharper falloff = small, bright highlight
- Low α = slow falloff = large, dull highlight
  - α between 100 and 200 = metals
  - α between 5 and 10 = plastic look



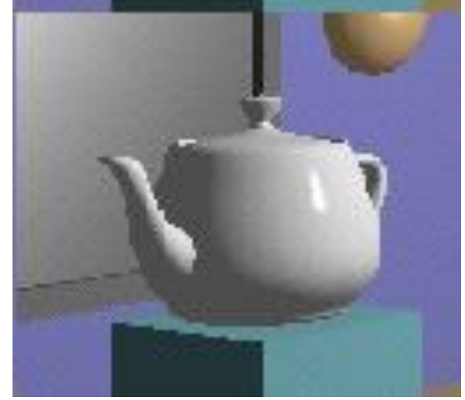
Specular light: Effect of ‘α’

α = 10

α = 30

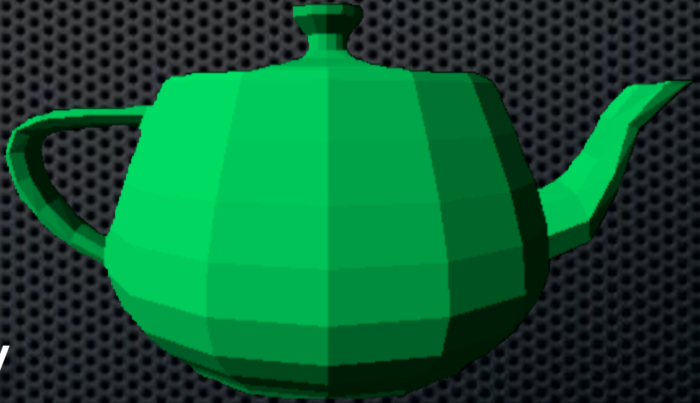
α = 90

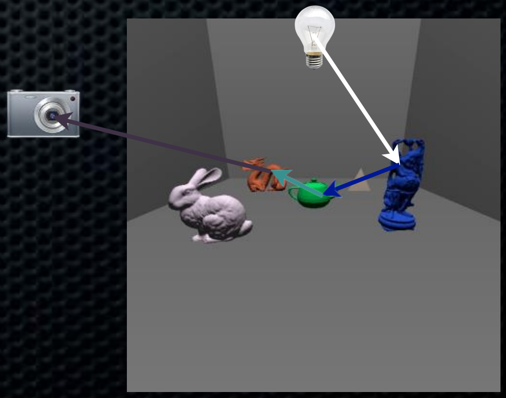
α = 270



Ambient Lighting

$I_a = L_a k_a$





L_a = ambient intensity

k_a = material ambient coefficient

Ambient Light Example

Ambient: background light, scattered by environment

Coefficients for Real Materials

Material	Ambient Kar, Kag,kab	Diffuse Kdr, Kdg,kdb	Specular Ksr, Ksg,ksb	Exponent, α
Black plastic	0.0 0.0 0.0	0.01 0.01 0.01	0.5 0.5 0.5	32
Brass	0.329412 0.223529 0.027451	0.780392 0.568627 0.113725	0.992157 0.941176 0.807843	27.8974
Polished Silver	0.23125 0.23125 0.23125	0.2775 0.2775 0.2775	0.773911 0.773911 0.773911	89.6

Figure 8.17, Hill, courtesy of McReynolds and Blythe

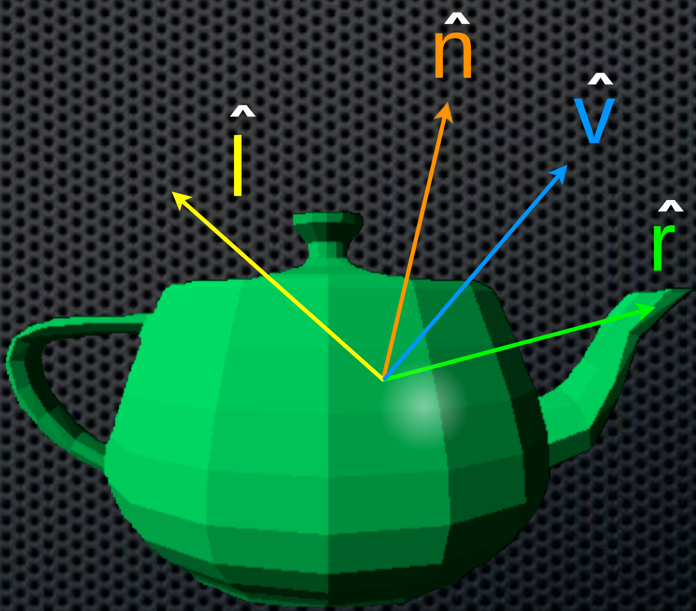
Phong Lighting Model

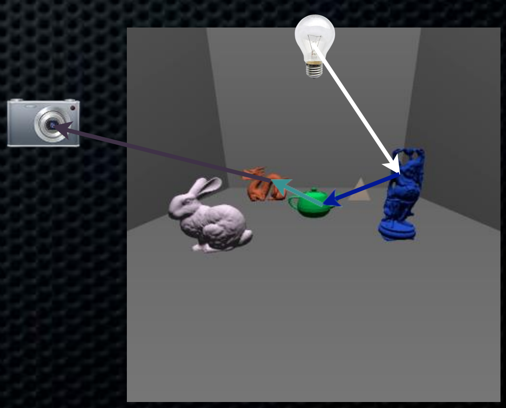
$$I = I_a + I_d + I_s$$

I_a = ambient intensity

I_d = diffuse intensity

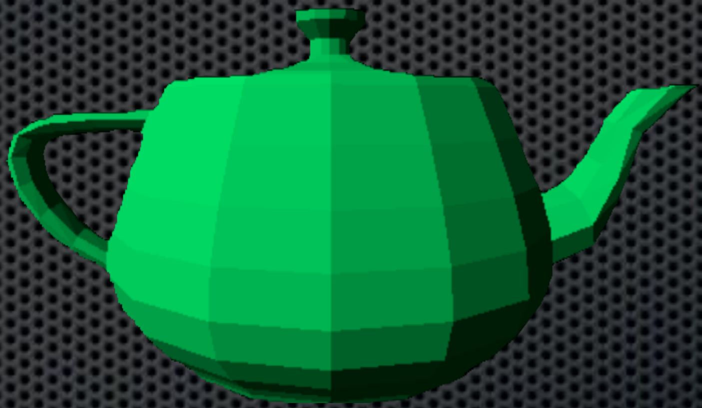
I_s = specular intensity





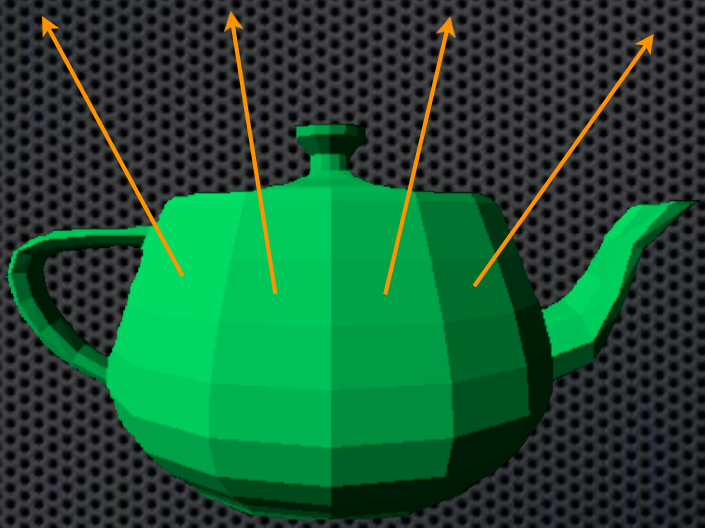
Interpolation

Where to apply the lighting model?



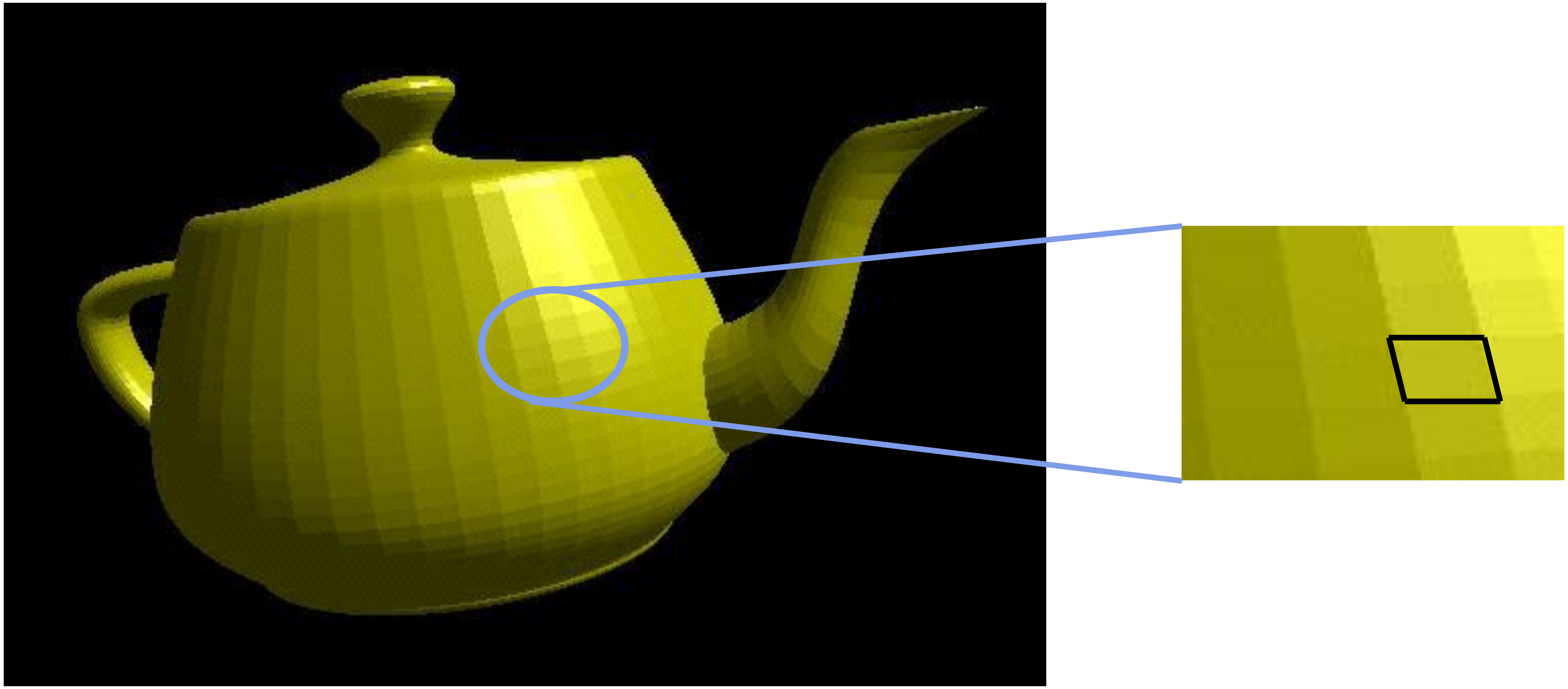
Flat Interpolation

Where to apply the lighting model?



Normals supplied per face
Lighting calculated for face
Color constant across face

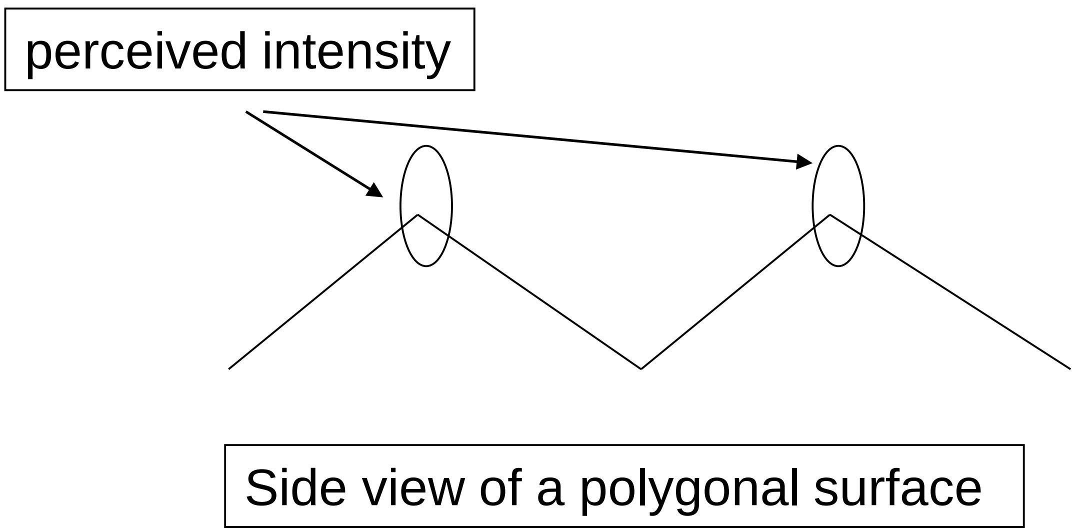
Flat Shading

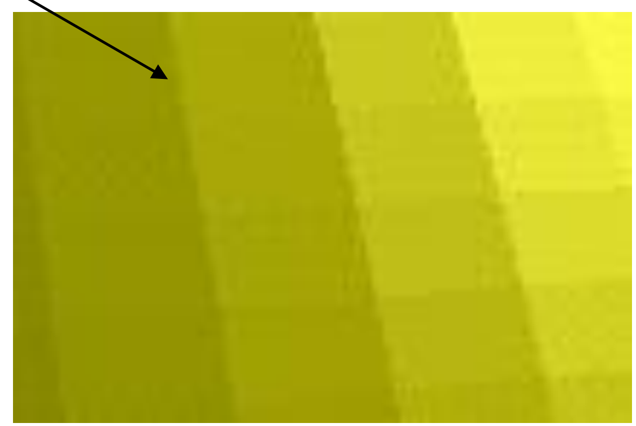



×5
×7
×31

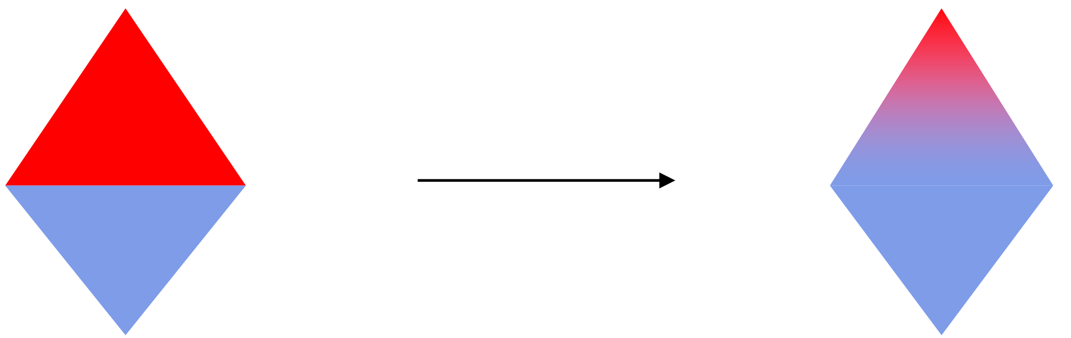
Mach Band Effect

- Human eyes amplify discontinuity at the boundary





Smooth shading

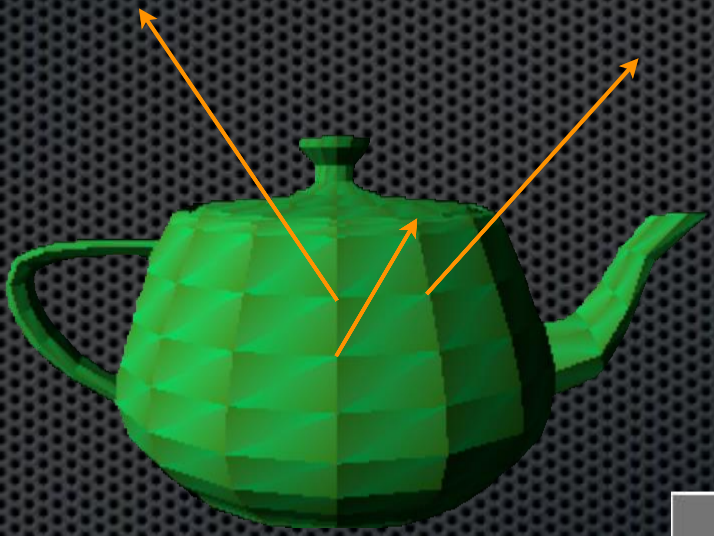


Flat shading

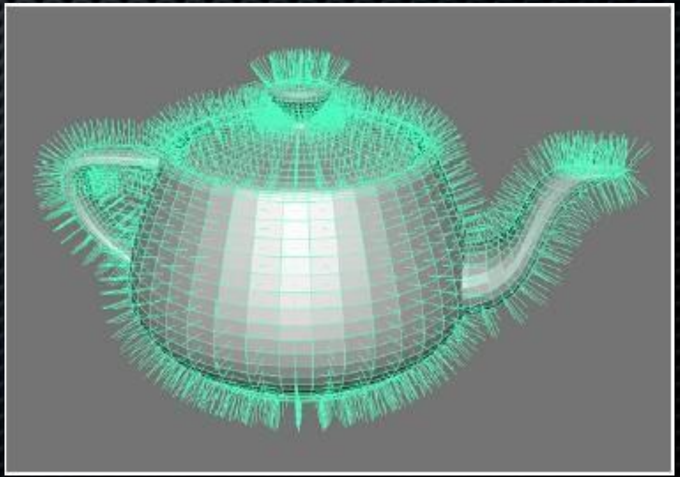
Smooth shading

Gouraud Interpolation

Where to apply the lighting model?



Henri Gouraud



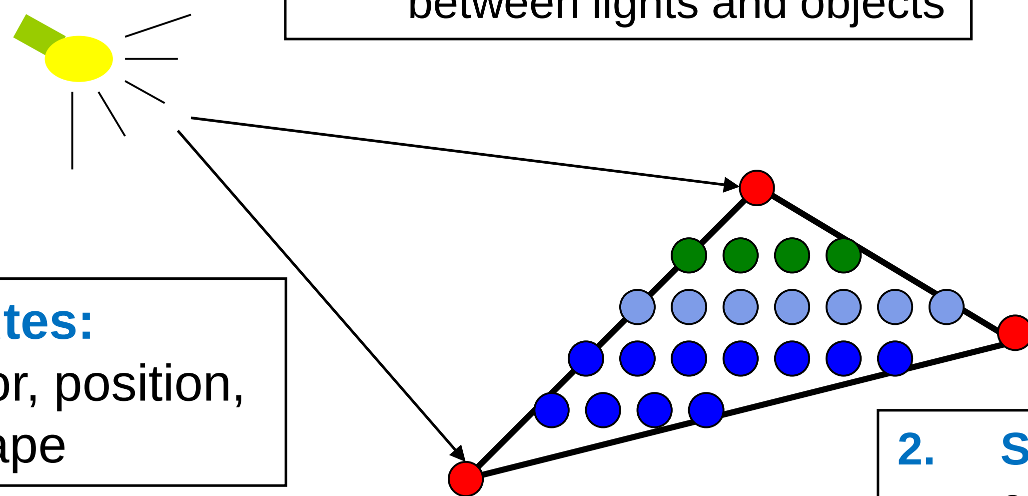
Normals supplied per vertex

Lighting calculated at vertex

Color interpolated across face

Lighting?

3. **Interaction**
   between lights and objects

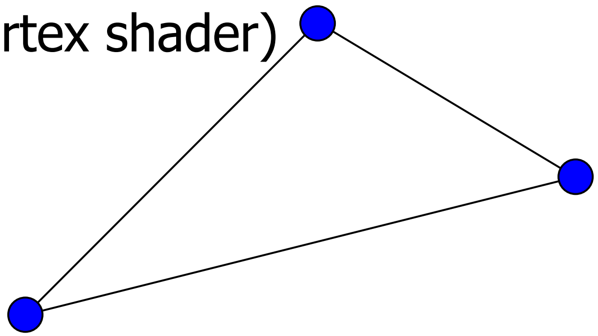


1. **Light attributes:**
   intensity, color, position, direction, shape

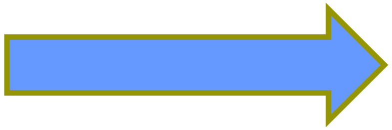
2. **Surface attributes**
   color, reflectivity, transparency, etc

Shading?

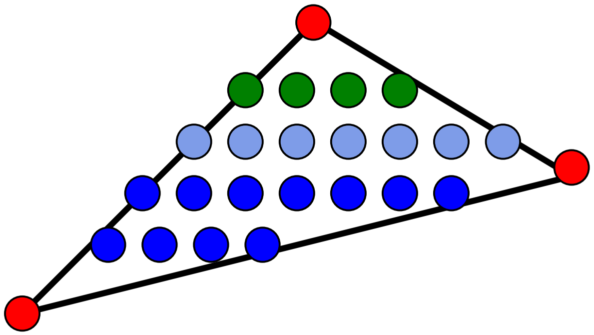
Lighting
(calc at vertices
in vertex shader)



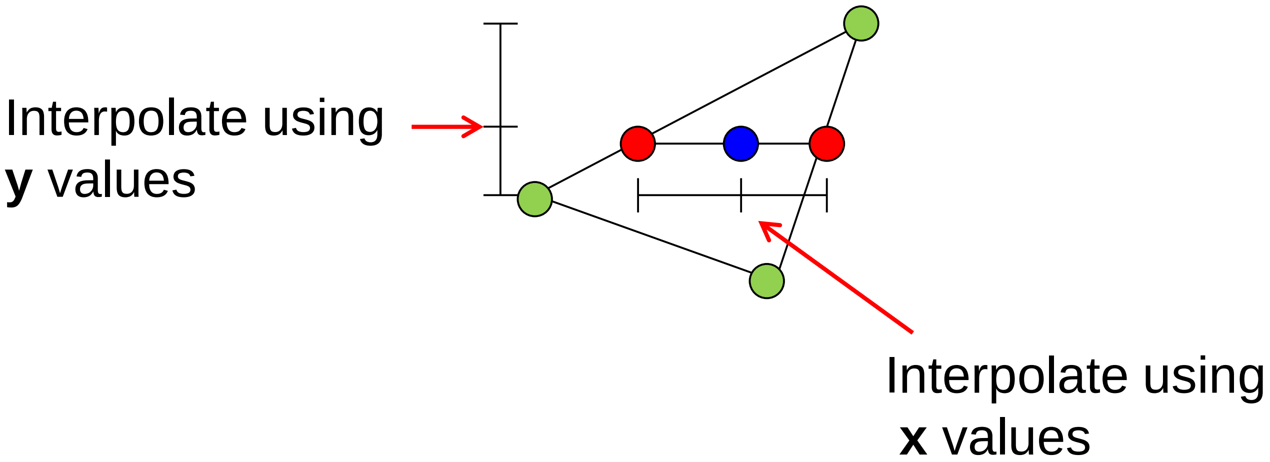
Rasterization
Find pixels belonging
to each object



Shading
(done in hardware
during rasterization)

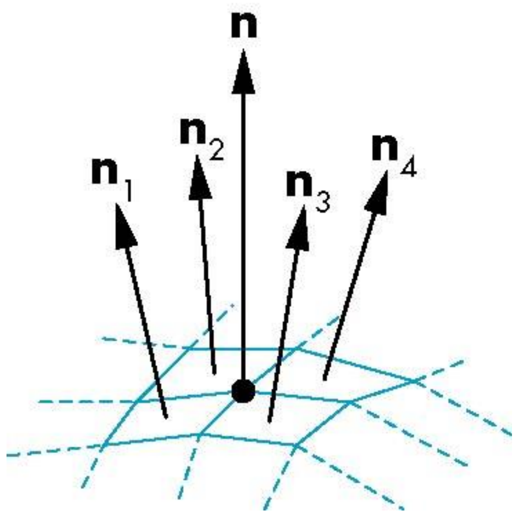


Gouraud Shading

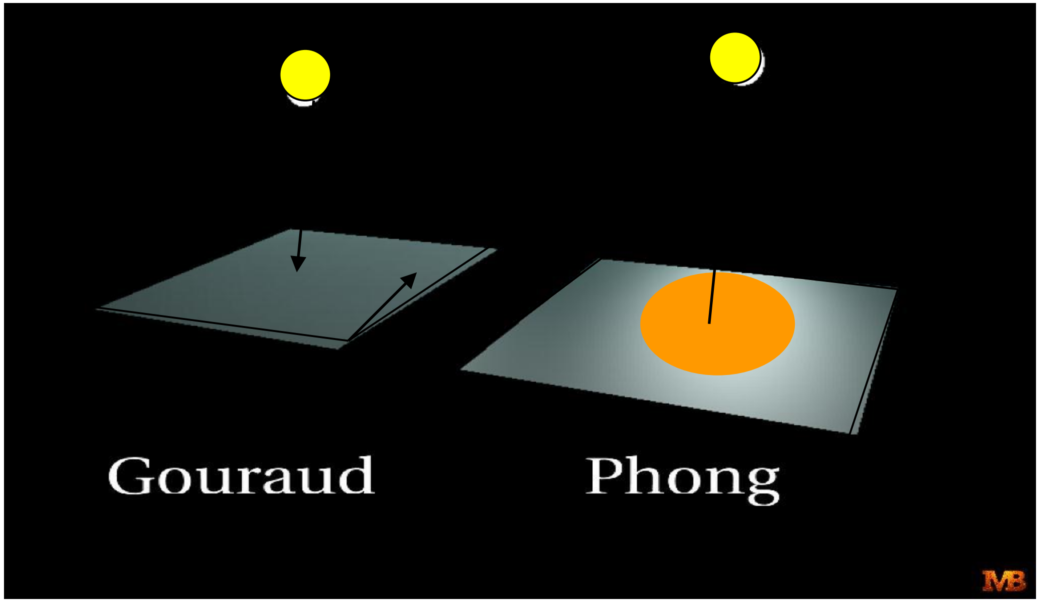


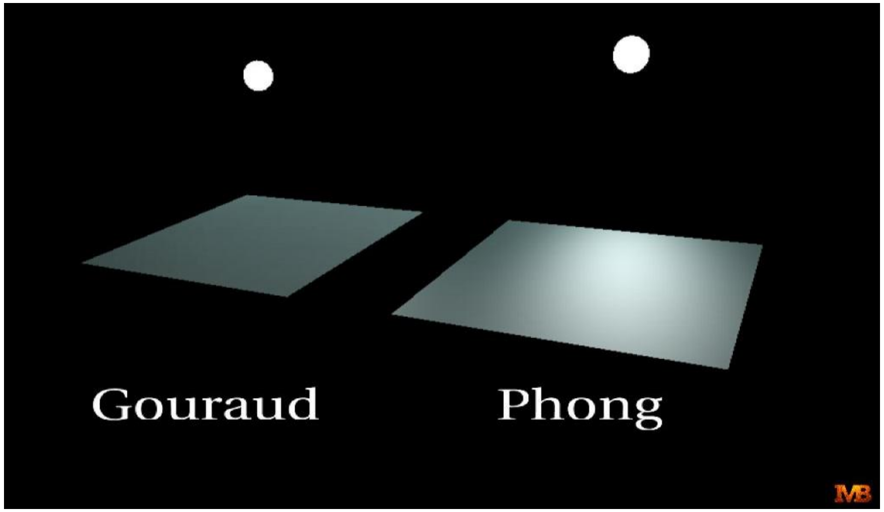
Calculating Normals for Meshes

$$\mathbf{n} = (\mathbf{n}_1+\mathbf{n}_2+\mathbf{n}_3+\mathbf{n}_4)/\ |\mathbf{n}_1+\mathbf{n}_2+\mathbf{n}_3+\mathbf{n}_4|$$



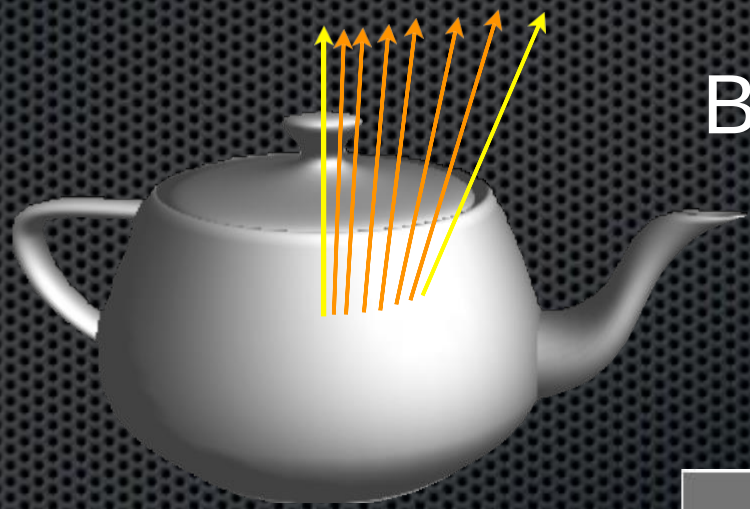
Gouraud Shading Problem



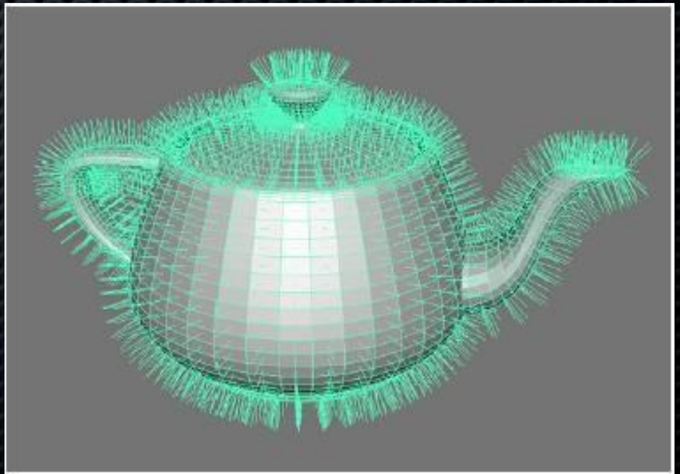


Phong Interpolation

Where to apply the lighting model?



Bui Tuong Phong



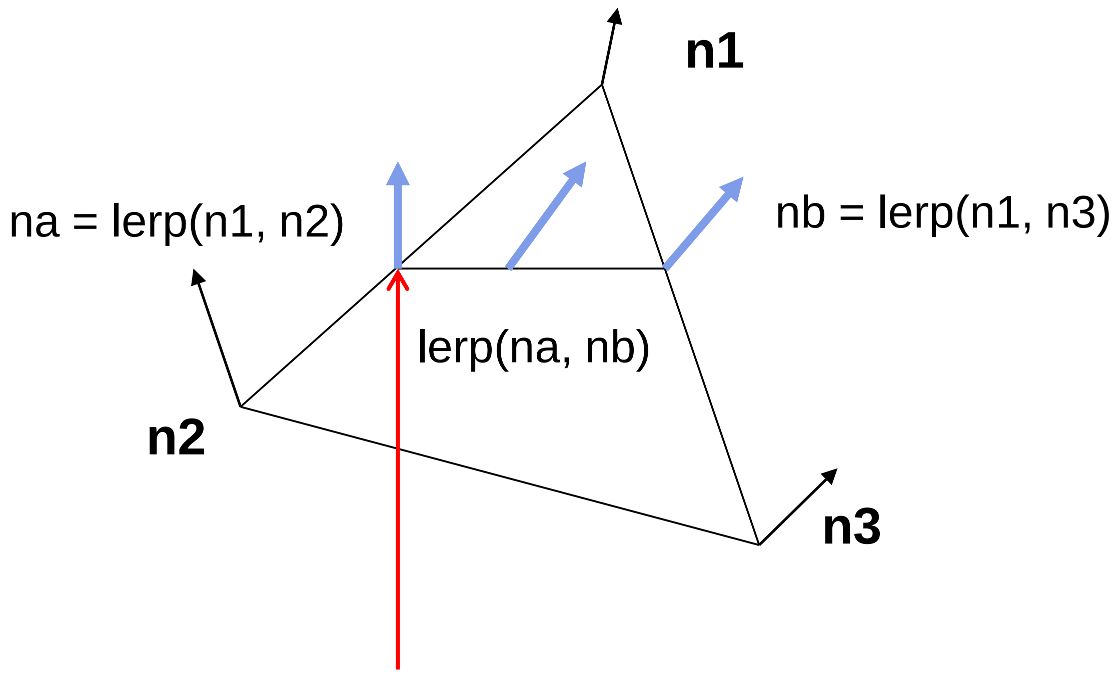
Normals supplied per vertex

Normals interpolated across face

Color & lighting calculated per pixel

Phong Shading (Per Fragment)

- Normal interpolation (also interpolate l,v)



At each pixel, need to interpolate
Normals (n) and vectors v and l

Toon (or Cel) Shading

- Non-Photorealistic (NPR) effect
- Shade in bands of color