Lighting/Illumination/Reflection Model

BRAC UNIVERSITY
Inspiring Excellence

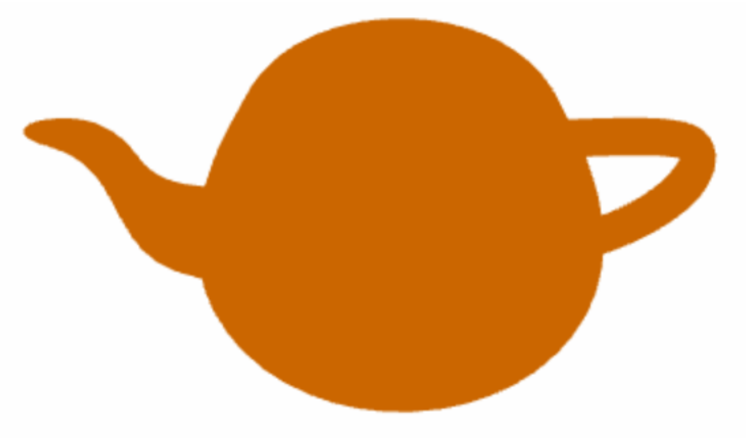
BY NC SA

Some of the contents used in this lecture belong to…

- Dr Jon Shiach, Manchester Metropoliton University, "Direct Lighting Model", https://www.youtube.com/watch?v=7CdS8oOJtVA
- Mr. Jacobson, University of Toronto, "WebGL Phong Shading", http://www.cs.toronto.edu/~jacobson/phong-demo/
- RapidCompact, "Simplifying a 3D Mesh", https://rapidcompact.com/doc/cli/latest/Simplify/index.html

BRAC UNIVERSITY
Inspiring Excellence

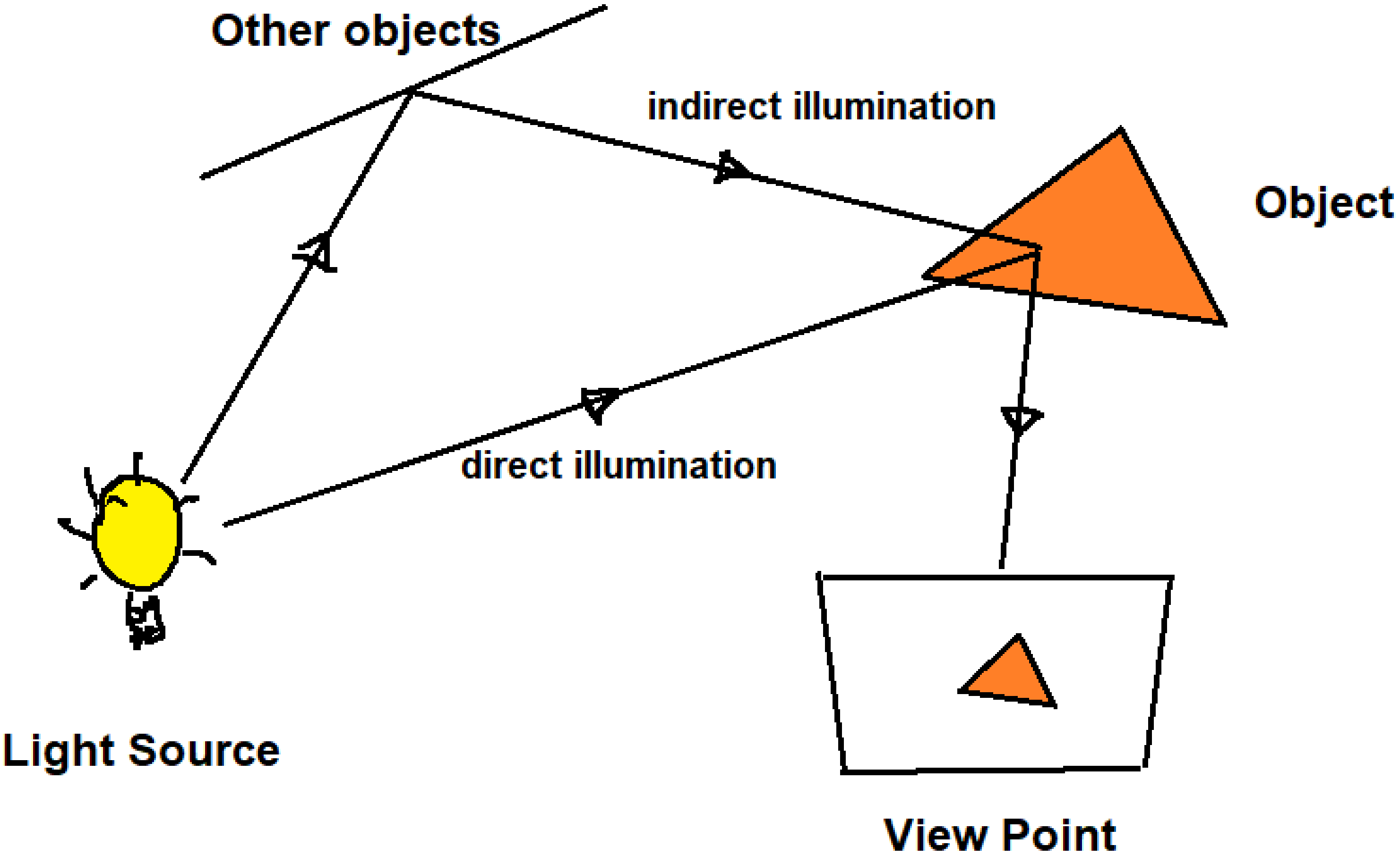
Effects of Lighting



Pixel colours only

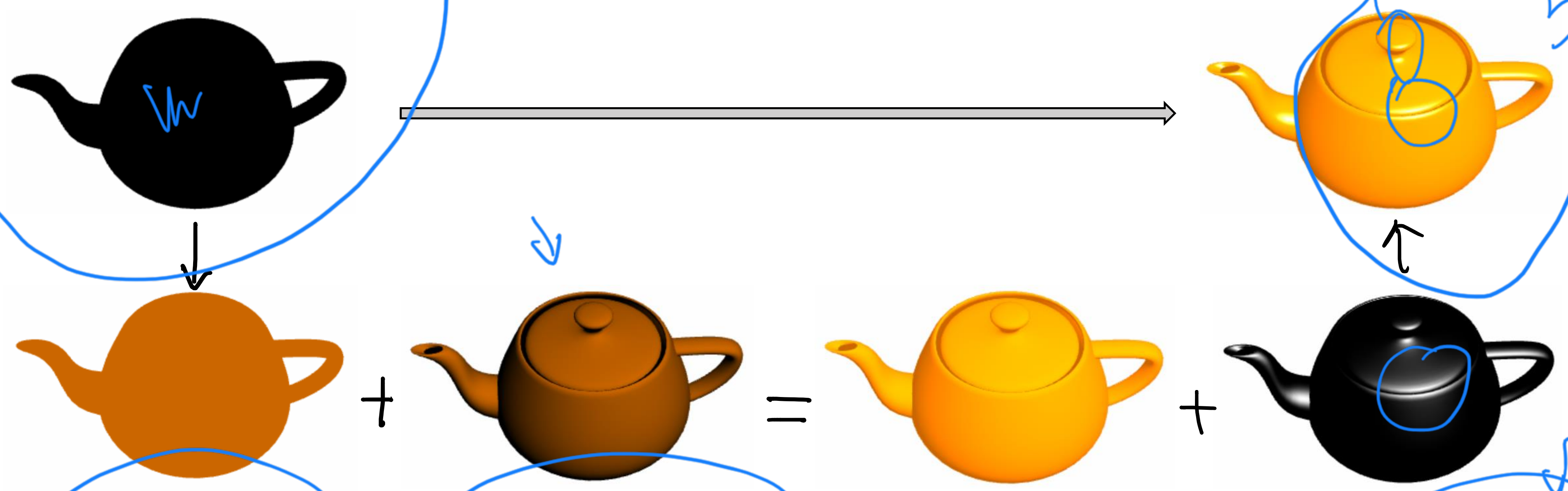
Pixel colours and lighting

Illumination



BRAC UNIVERSITY
Inspiring Excellence

Phong's Reflection Model



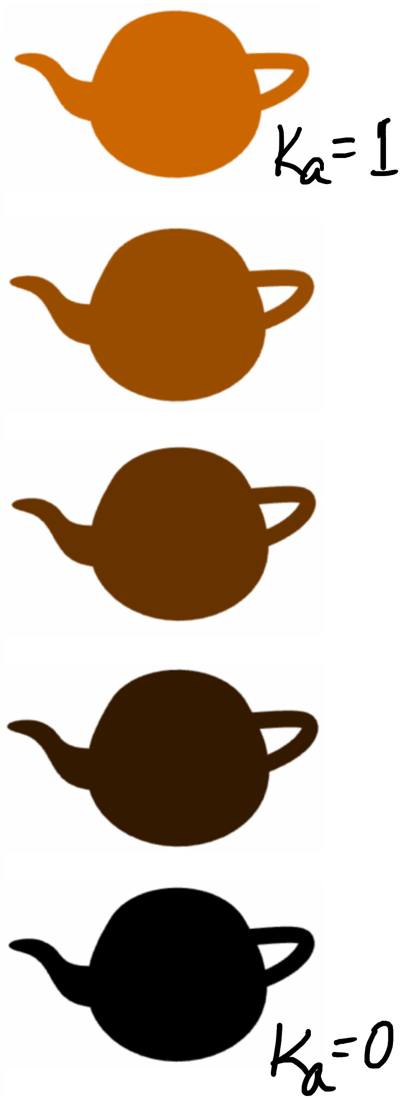
BRAC UNIVERSITY
Inspiring Excellence

Ambient Reflection

- **Ambient reflection** is the reflection of light that does not come directly from a light source
- Even in a darkened room, we can make out the edges of objects – this is because of light bouncing off of objects
- Since Phong is a **direct** lighting model, we assume that ambient light falls equally on all objects, i.e.,

$$A = I_a k_a$$

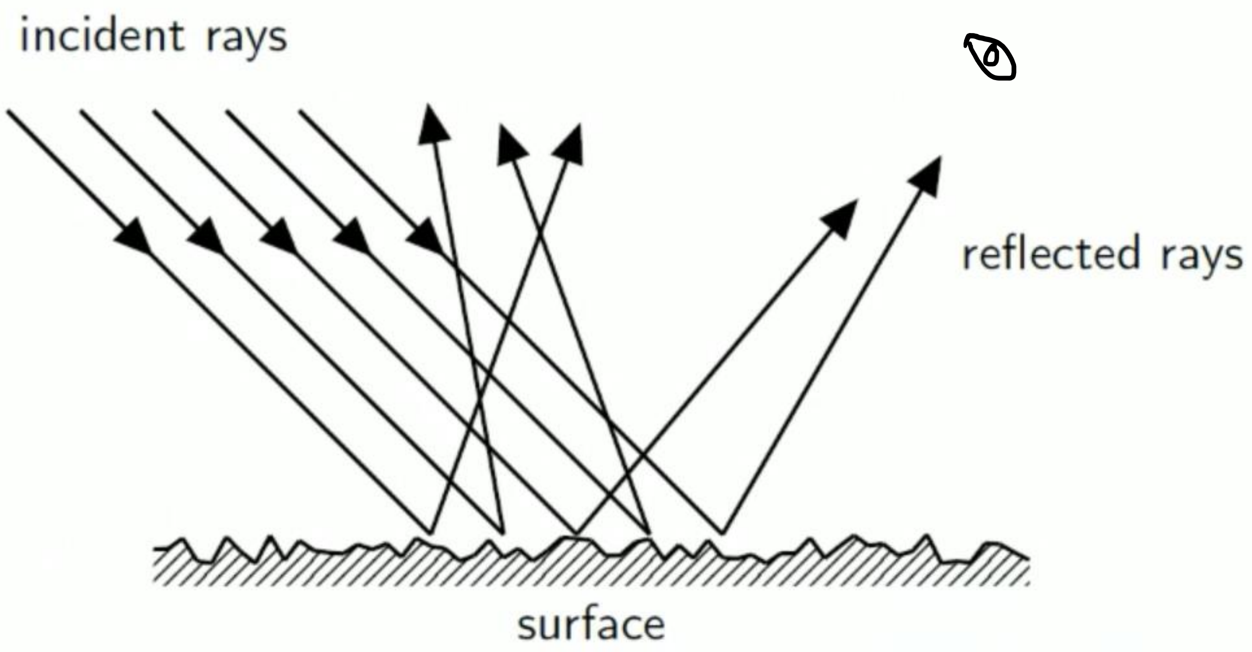
  where I_a is the intensity of the ambient light and $k_a \in [0, 1]$ is the **ambient coefficient**
- k_a is set to provide the right amount of ambient light for a scene, e.g., $k \to 1$ for bright scenes and $k \to 0$ for dark or nighttime scenes.



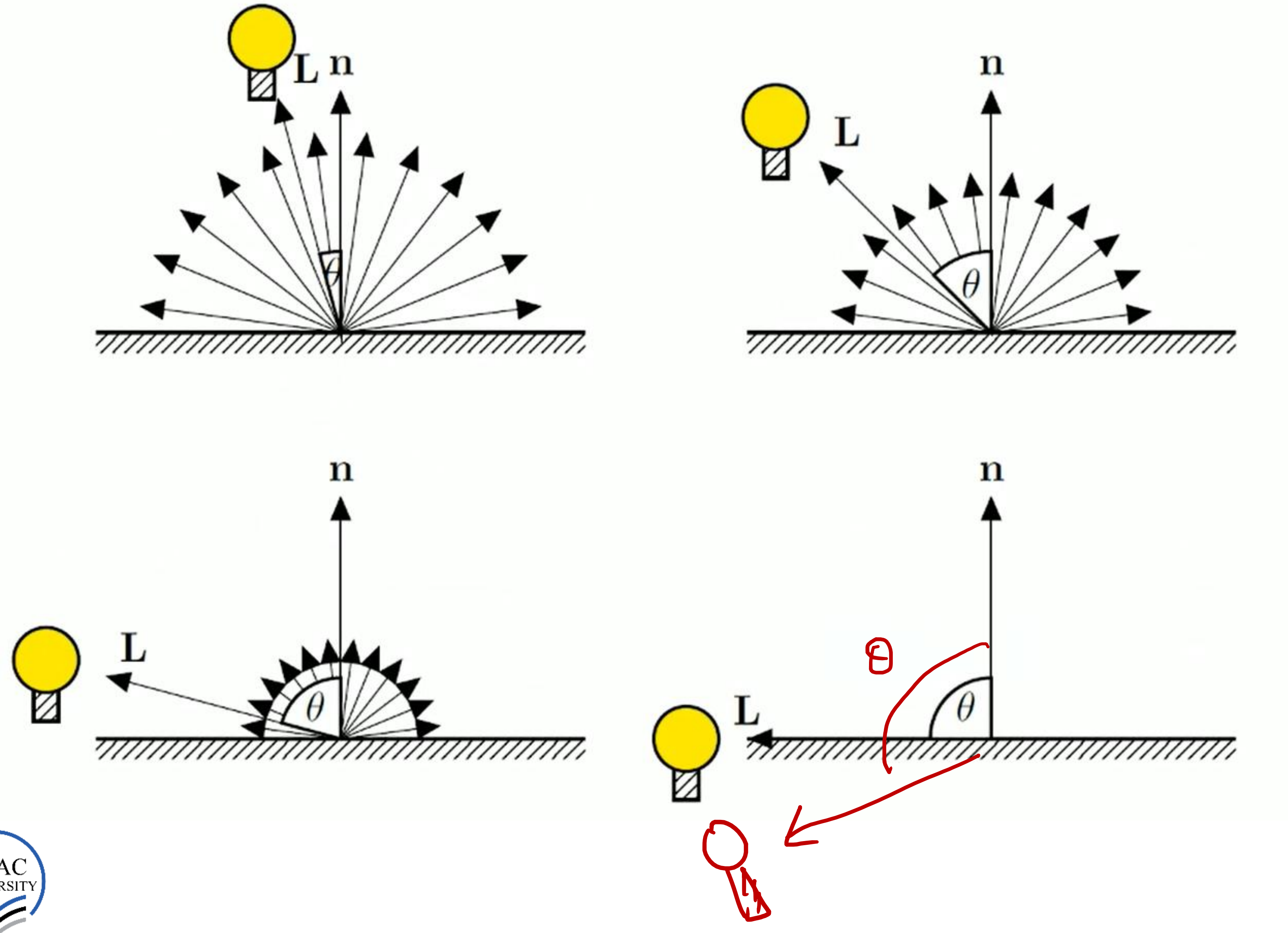
BRAC UNIVERSITY
Inspiring Excellence

Diffuse Reflection

- Parallel rays from light source
- Reflected rays are scattered
- Direction of reflection
- Some are visible, some are not



Diffuse Reflection – Phong's model



- Point light source
- Light reflected equally in all direction
- "Magnitude" of reflection depends on θ
- Direction of L reversed? → (–L)

BRAC UNIVERSITY
Inspiring Excellence

Diffuse Reflection – Phong's model

- Phong's diffuse reflection model depends upon the position of the light source relative to the surface

$$D = I_p k_d \max[\underline{\cos(\theta)}, 0]$$

where

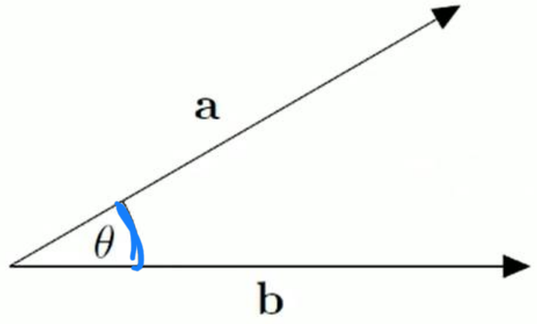
- I_p is the intensity of the point light source
- $k_d \in [0, 1]$ is the **diffuse coefficient**
- θ is the angle between the lighting vector and the surface normal

- The $\max[\cos(\theta), 0]$ is used so that no light is reflected if the light source is behind the surface

Diffuse Reflection – Phong's model

Dot product $\leftrightarrow$ cos(θ)

$a.b = |a||b|\cos\theta$



- The definition of the dot product is

$$\mathbf{a}\cdot\mathbf{b} = |\mathbf{a}||\mathbf{b}|\cos(\theta)$$

$a.b = \cos(\theta)$

- If $\mathbf{L}$ and $\mathbf{n}$ are unit vectors then

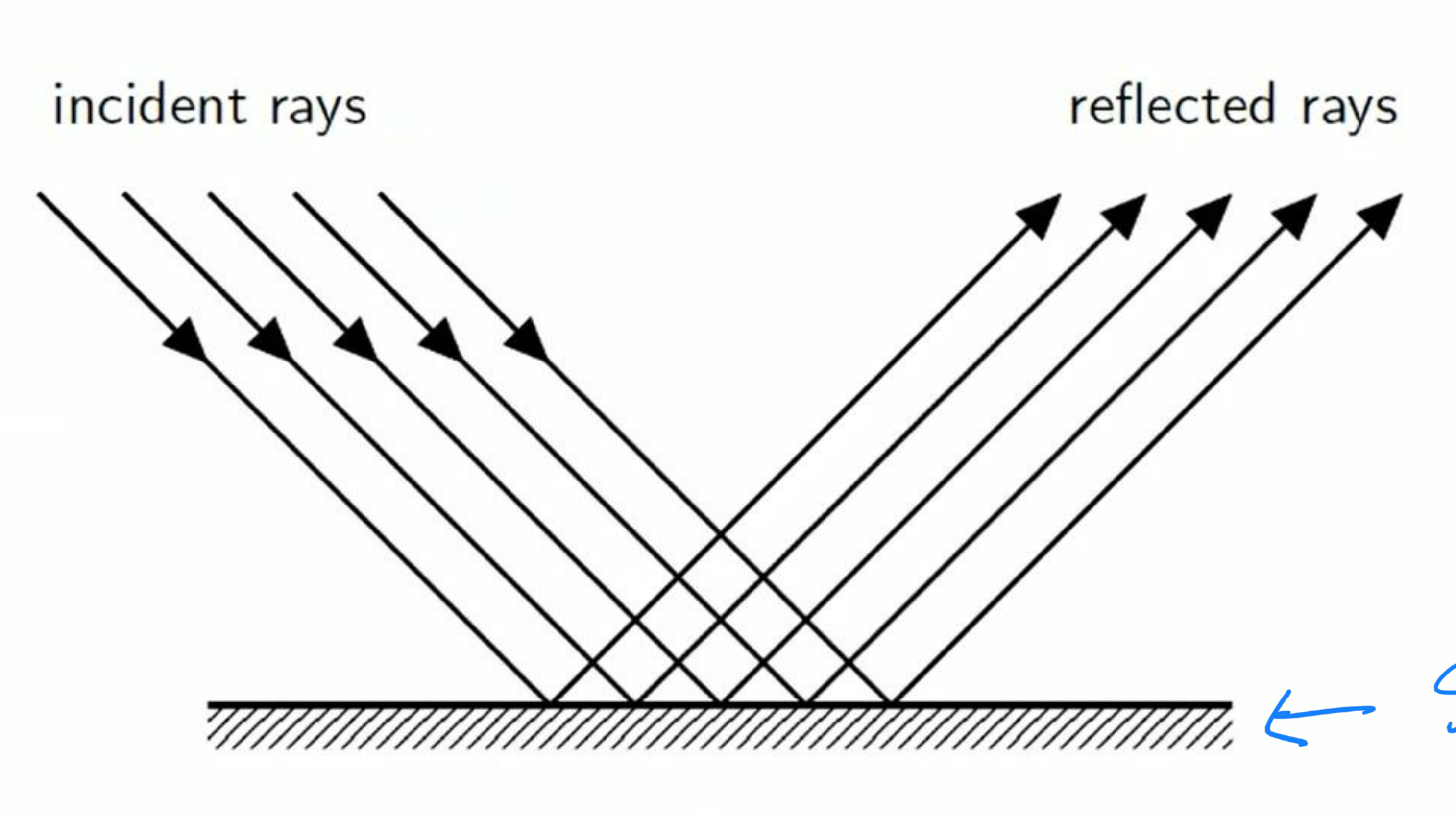
$$\mathbf{L}\cdot\mathbf{n} = \cos(\theta)$$

so we can replace the expensive cosine calculation by an easy dot product, i.e,

$$D = I_p k_d \max(\mathbf{L}\cdot\mathbf{n}, 0)$$

BRAC UNIVERSITY
Inspiring Excellence

Specular Reflection



Smooth surface.

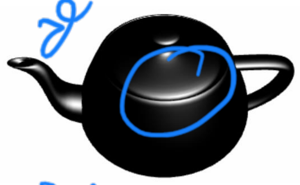
Specular Reflection

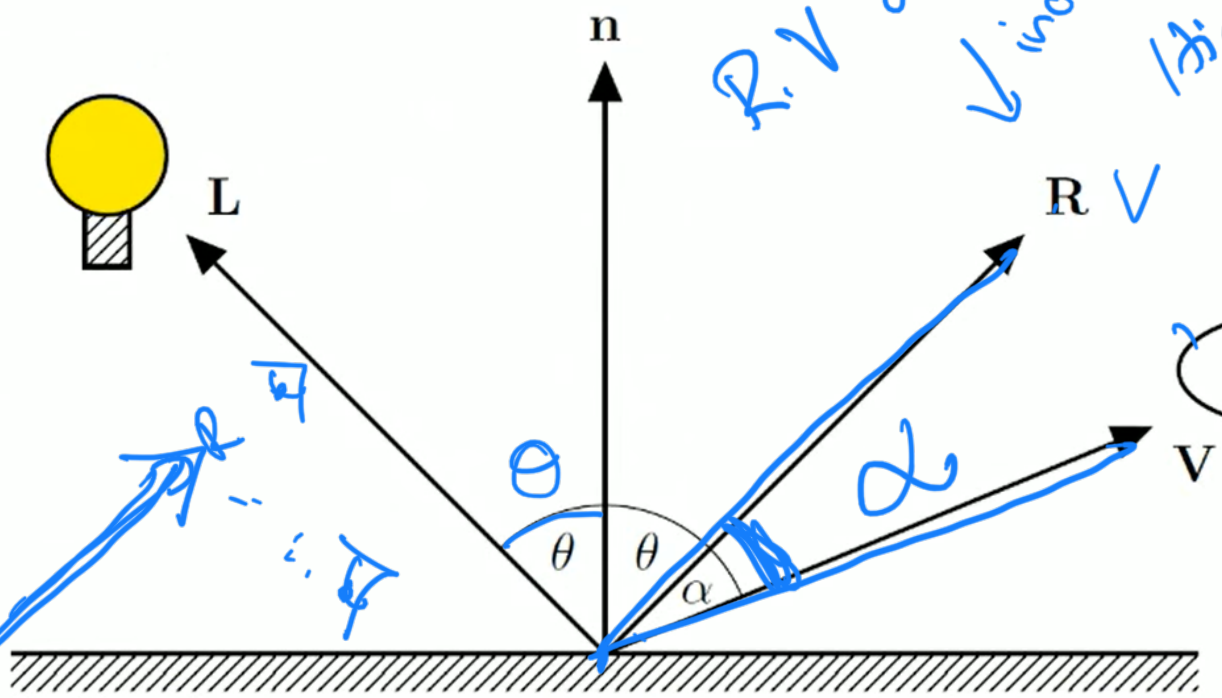
angle of i = angle of re

R.V angle θ ↓ increase

Same intensity ↓ decrease

High intensity.





R.R — V.P

θ

α

R V

weak intensity light.

Shiny

R

BRAC UNIVERSITY
Inspiring Excellence

Specular Reflection

- Phong's specular model is

Ip x 0 :-

0 ← shineni

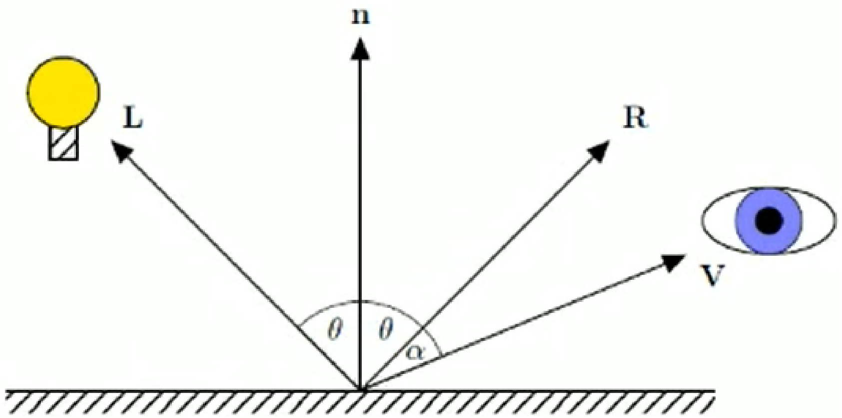
0 ← kom.

→ 1

$$S = I_p k_s \cos^n(\alpha)$$

Ip x 1 = Ip

where
  - $k_s \in [0, 1]$ is the **specular coefficient**
  - n is the **specular exponent** (shininess)
  - α is the angle between $\mathbf{R}$ and $\mathbf{V}$
- The $\cos^n(\alpha)$ term determines the amount of light that is reflected

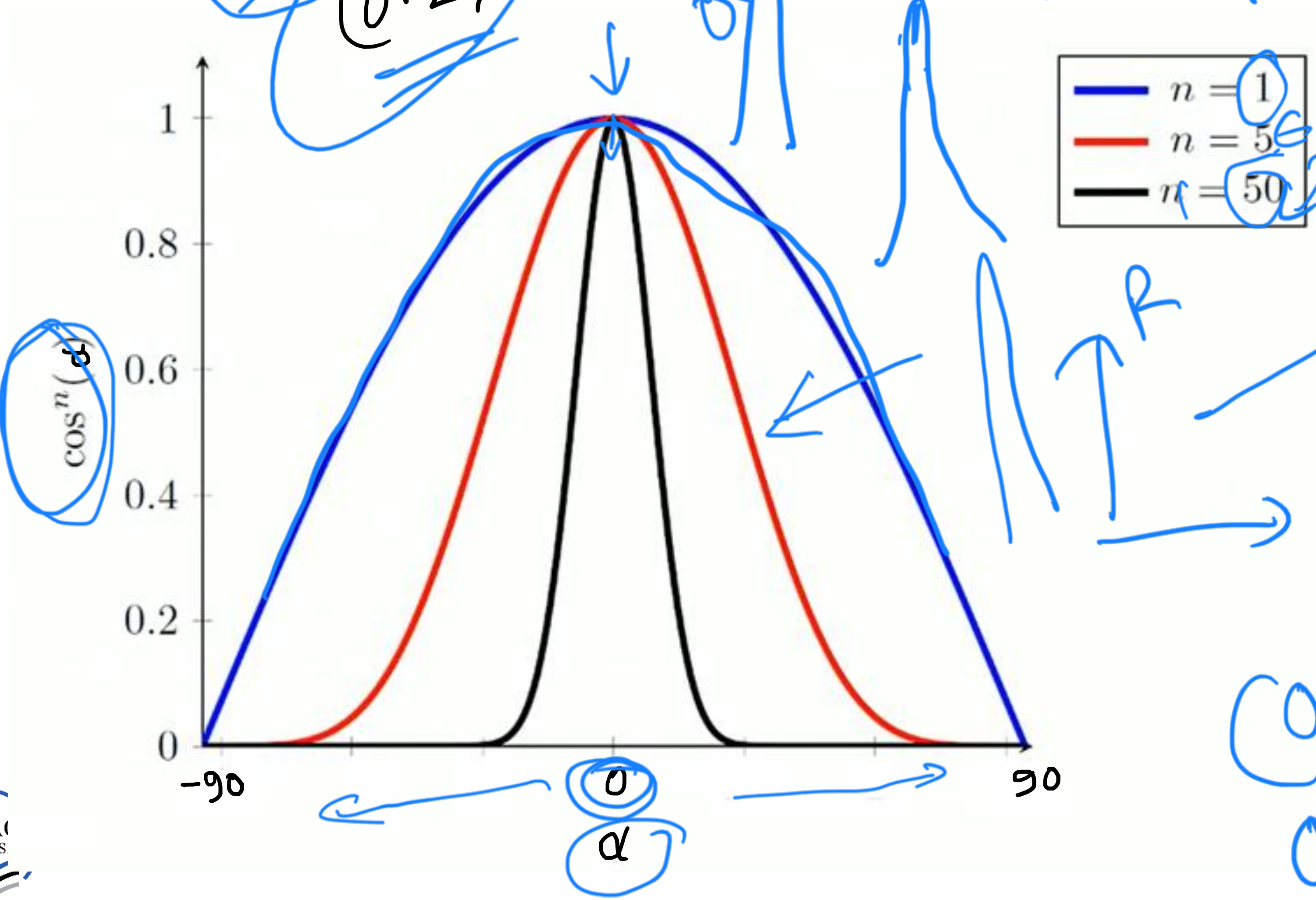


BRAC UNIVERSITY
Inspiring Excellence

Specular Reflection

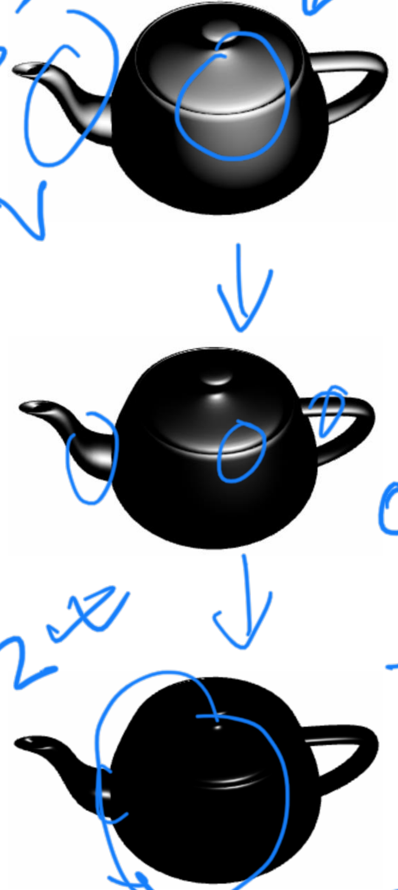
Shininess

$n=1$ $(0.2)^5$ 0.2 0.2^{50}



$n=1$ $\cos^1(\alpha)$ $\cos^{50}(\alpha)$

$\cos^5(\alpha)$



$2^1=2$

$2^5=32$

$0.2=\frac{1}{5}$

$\frac{1}{5\times5\times5\times5}$

$(0.2)^1 = 0.2$

$0.2^5 = 3.2\times10^{-4}$

.008 smaller

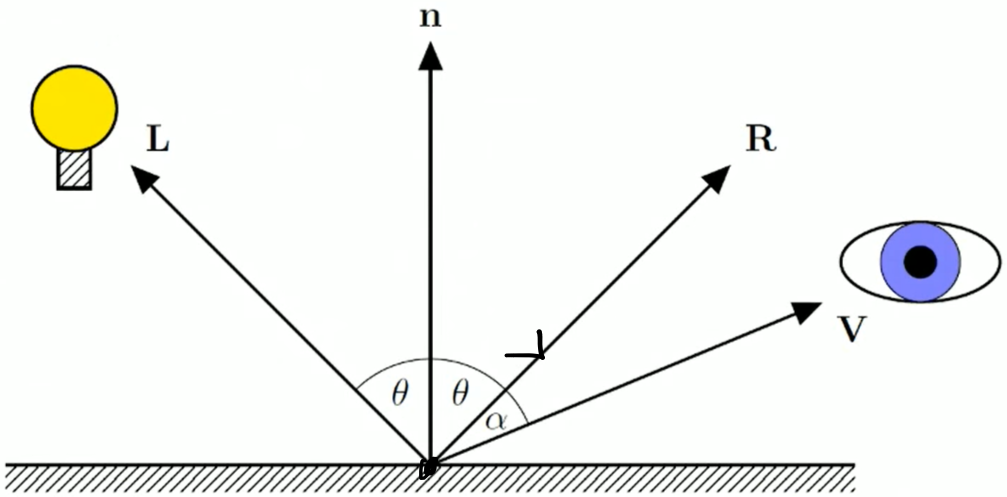
BRAC UNIVERS
Inspiring Excellence

Specular Reflection

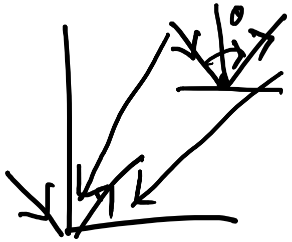
$$S = I_p k_s \cos^n(\alpha)$$

Calculate α, $\cos(\alpha)$

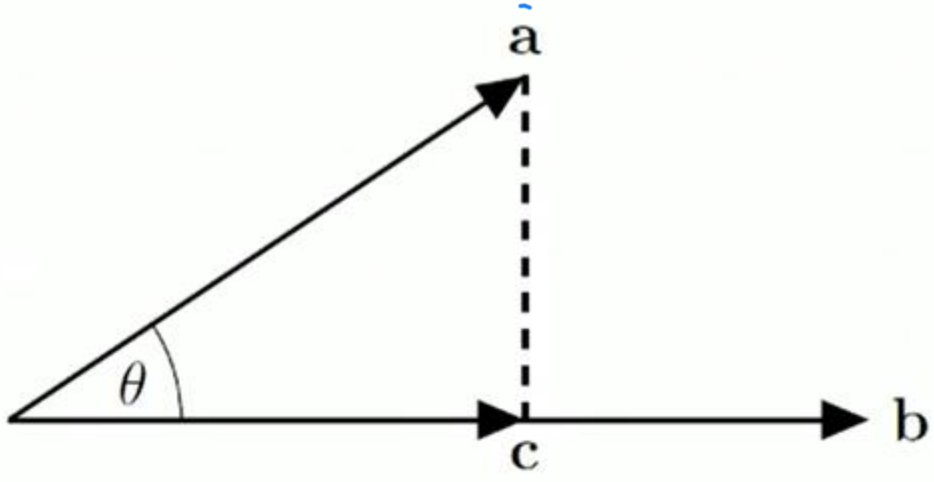
- $\cos(\alpha) = \underline{V.R}$ [unit vectors]



- R
  - ✓ Using Rotation
  - ✓ Projection of vector



Vector Projection



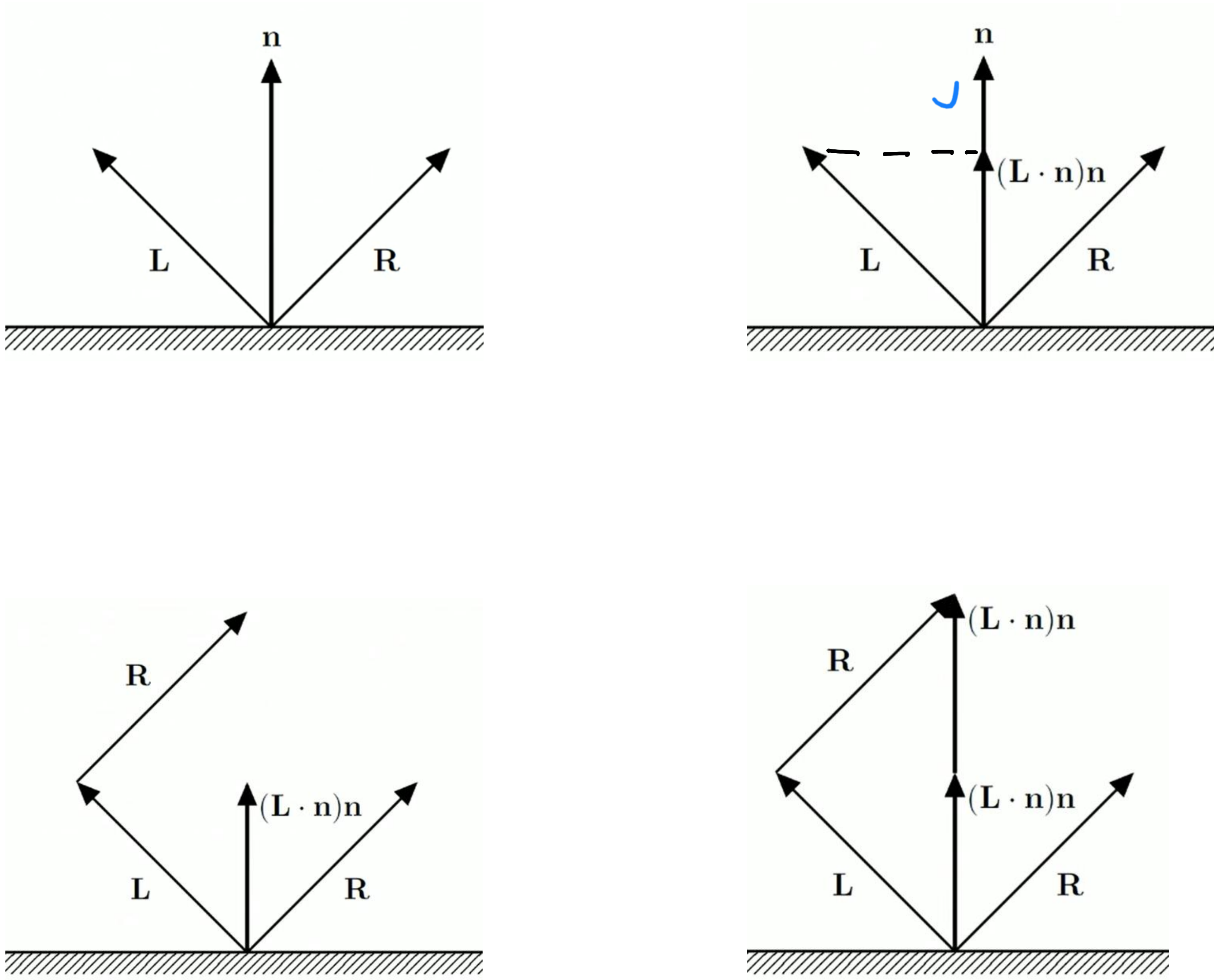
- Using the definition of a dot product

$$\mathbf{a}\cdot\mathbf{b} = |\mathbf{a}||\mathbf{b}|\cos(\theta) = |\mathbf{a}||\mathbf{b}|\frac{|\mathbf{c}|}{|\mathbf{a}|} = |\mathbf{b}||\mathbf{c}|$$

$$\therefore |\mathbf{c}| = \frac{\mathbf{a}\cdot\mathbf{b}}{|\mathbf{b}|}$$

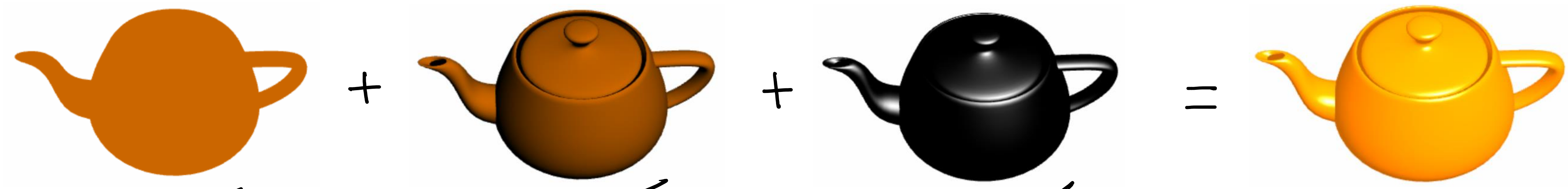
- If $\mathbf{b}$ is a unit vector then $|\mathbf{c}| = \mathbf{a}\cdot\mathbf{b}$ and

$$\mathbf{c} = (\mathbf{a}\cdot\mathbf{b})\mathbf{b}$$



$$\mathbf{L} + \mathbf{R} = 2(\mathbf{L} \cdot \mathbf{n})\mathbf{n}$$
$$\therefore \mathbf{R} = 2(\mathbf{L} \cdot \mathbf{n})\mathbf{n} - \mathbf{L}$$

Phong's Reflection Model

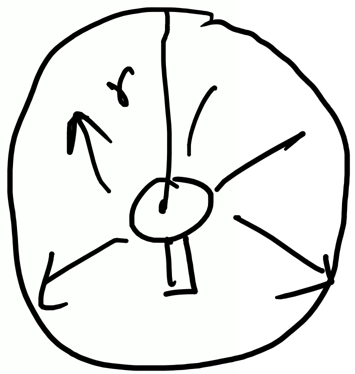


$$I = \underline{I_a K_a} + \underline{I_p K_d \max(L \cdot n, 0)} + \underline{I_p K_s (\max(V \cdot R, 0))^n}$$

Attenuation

- **Attenuation** is the loss of light energy over space
- In Phong's model attenuation is account for by the variable f_{att} and applied to diffuse and specular components
- Theoretically is should follow the inverse square law, i.e.,

$$f_{att} = \frac{1}{d^2}$$

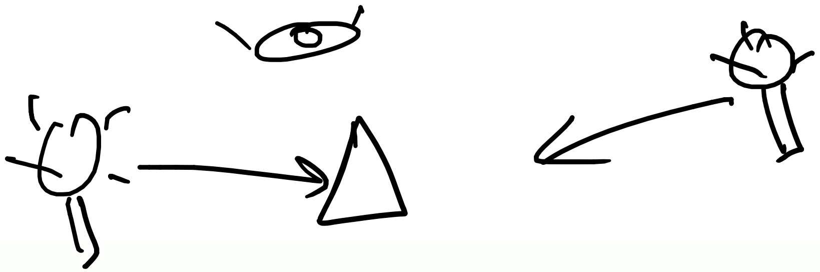


- In practice this removes too much light, Phong's model uses

$$f_{att} = \max\left[1 - \left(\frac{d}{r}\right)^2 , 0\right]$$

where r is the radius of the light source's sphere of influence

BRAC UNIVERSITY
Inspiring Excellence



- Combining ambient, diffuse, specular and attenuation models results in Phong's model of reflection

$$I = \underbrace{I_a K_a}_{\text{ambi}} + I_p f_{att} \left(\underbrace{K_d \max(L \cdot n, 0)}_{\text{Di}} + \underbrace{K_s \left(\max(V \cdot R, 0)\right)^n}_{\text{Spe}} \right)$$

- For multiple light sources, the diffuse and specular components are calculated for each light source and added together, i.e.,

$$I = I_a K_a + \sum_{i=1}^{m} I_{p_i} f_{att} \left(K_d \max(L_i \cdot n, 0) + K_s \left(\max(V \cdot R_i, 0)\right)^n \right)$$

Shading

whether an object, or some part of an object is obstructed by another object.

– Z buffer / Depth buffer

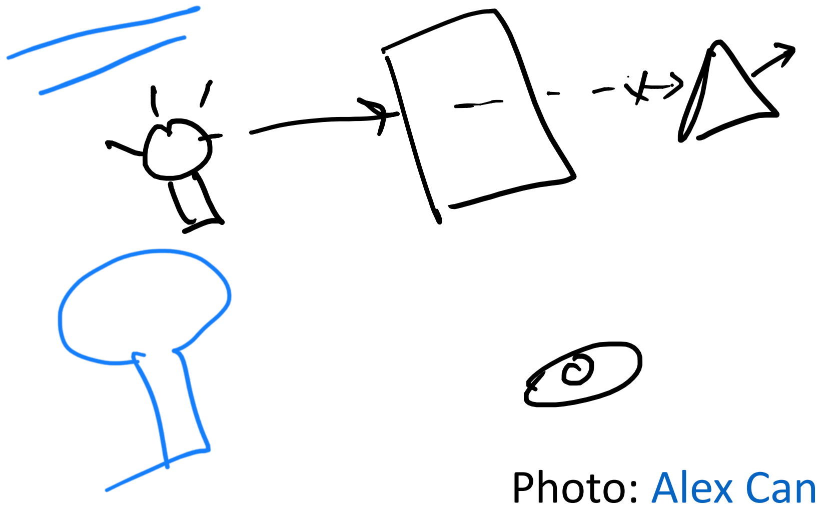


Photo: [Alex Canclini]()

BRAC UNIVERSITY
Inspiring Excellence