matfyz

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The Phong Shading Model

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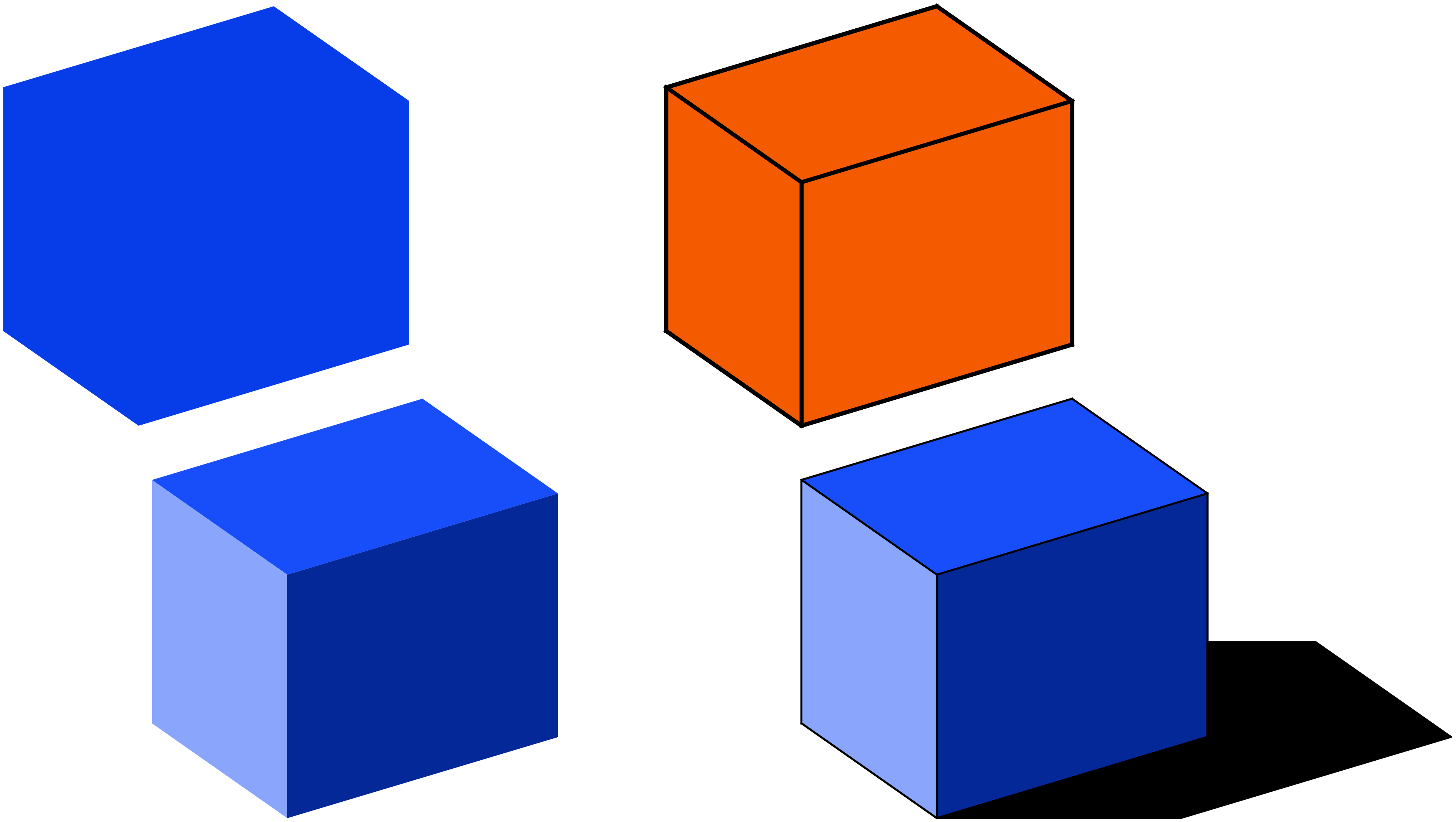
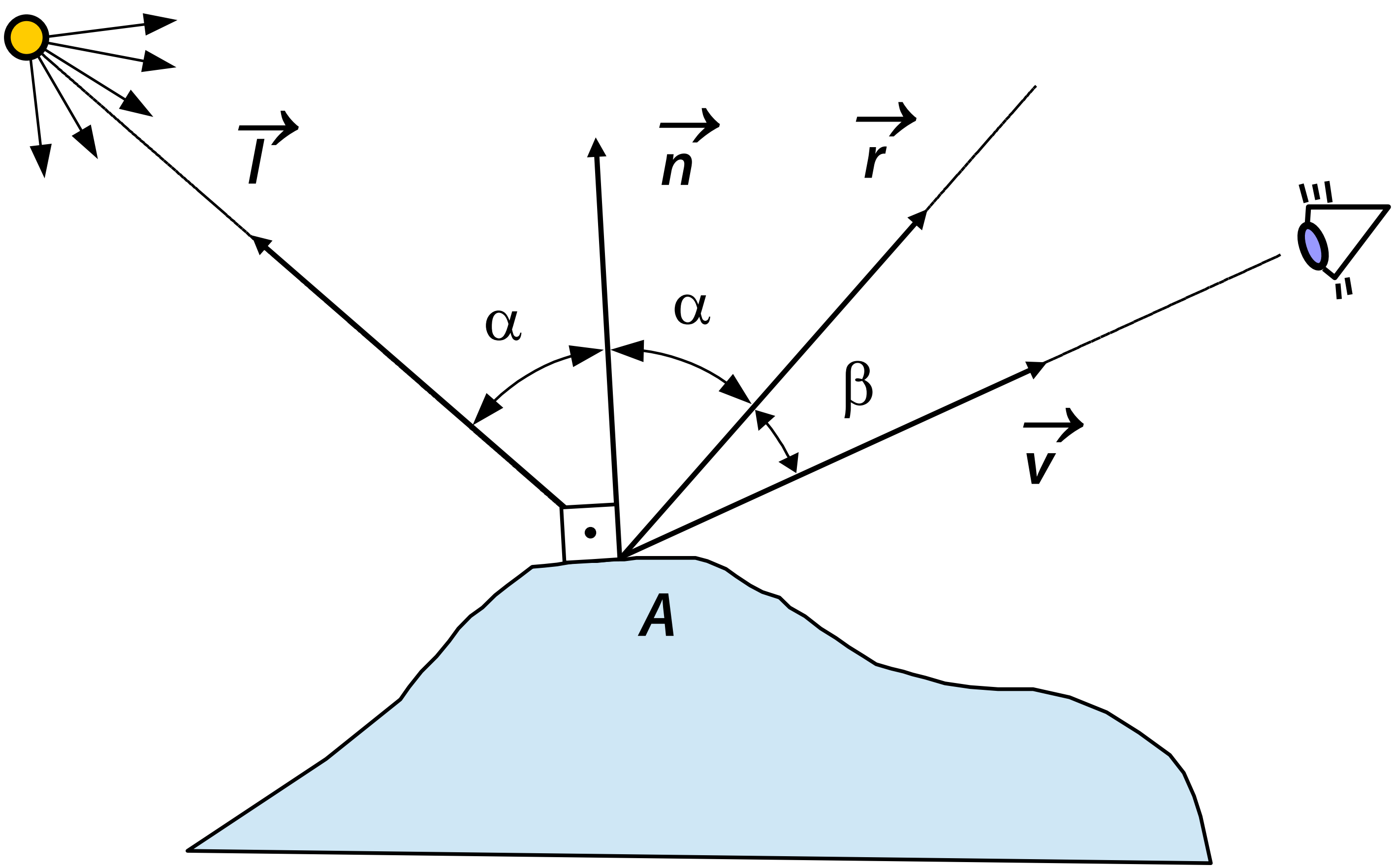
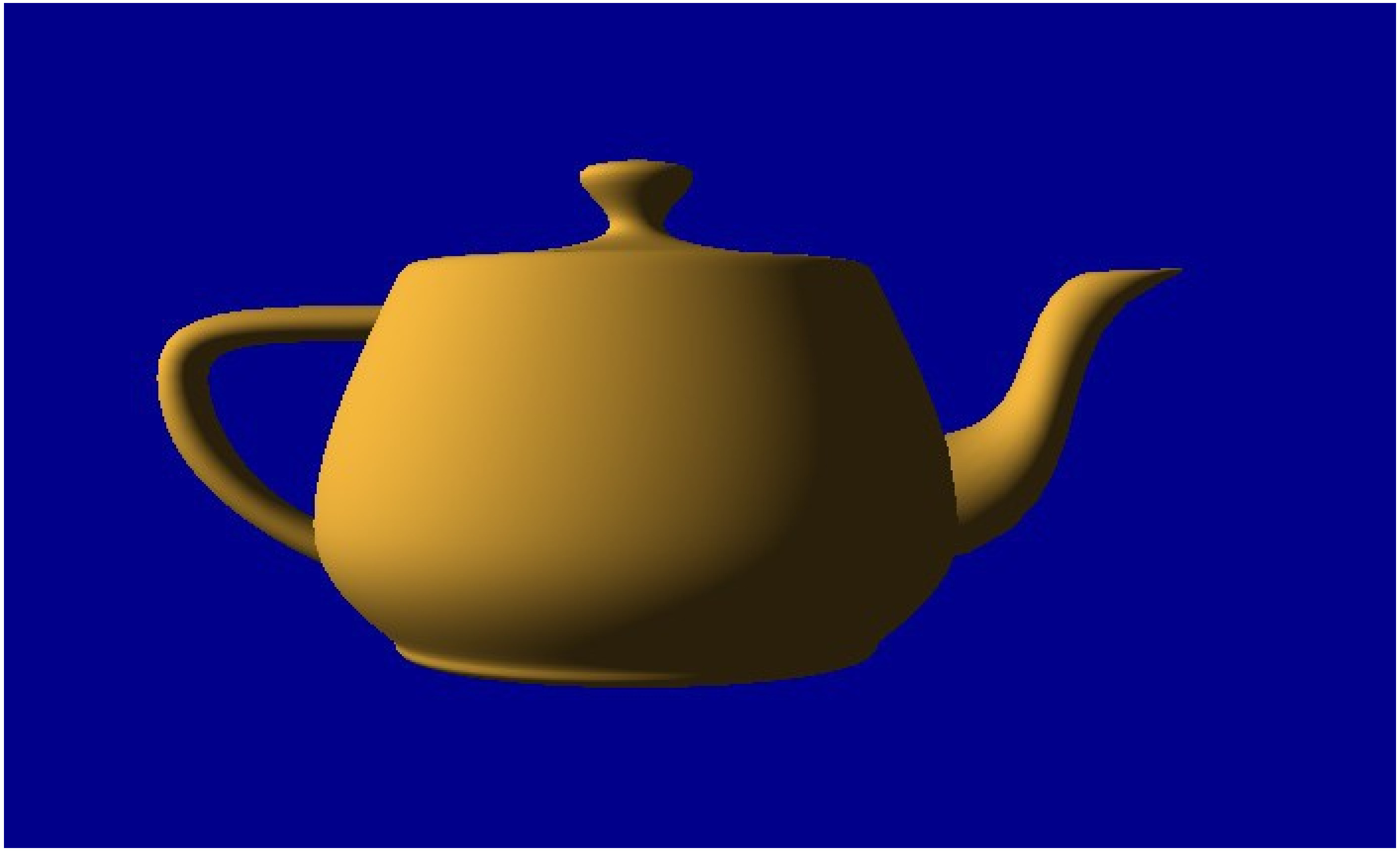
Shading and Shadows



Phong Reflectance Model



Diffuse and Ambient Light



Diffuse Component E_D

Describes an **ideally diffuse surface** (Lambert's cosine law)

$$\mathbf{E_D = I_i \cdot C_D \cdot k_D \cdot \cos}\ \alpha$$

- $\mathbf{I_i}$ … light source intensity
- $\mathbf{C_D}$ … diffuse color (RGB)
- $\mathbf{k_D}$ … diffuse coefficient (0.0 to 1.0)
- $\mathbf{\cos}\ \alpha = \mathbf{l \cdot n}$ … scalar product of light direction and surface normal

Ambient Light E_A

Globally constant lighting

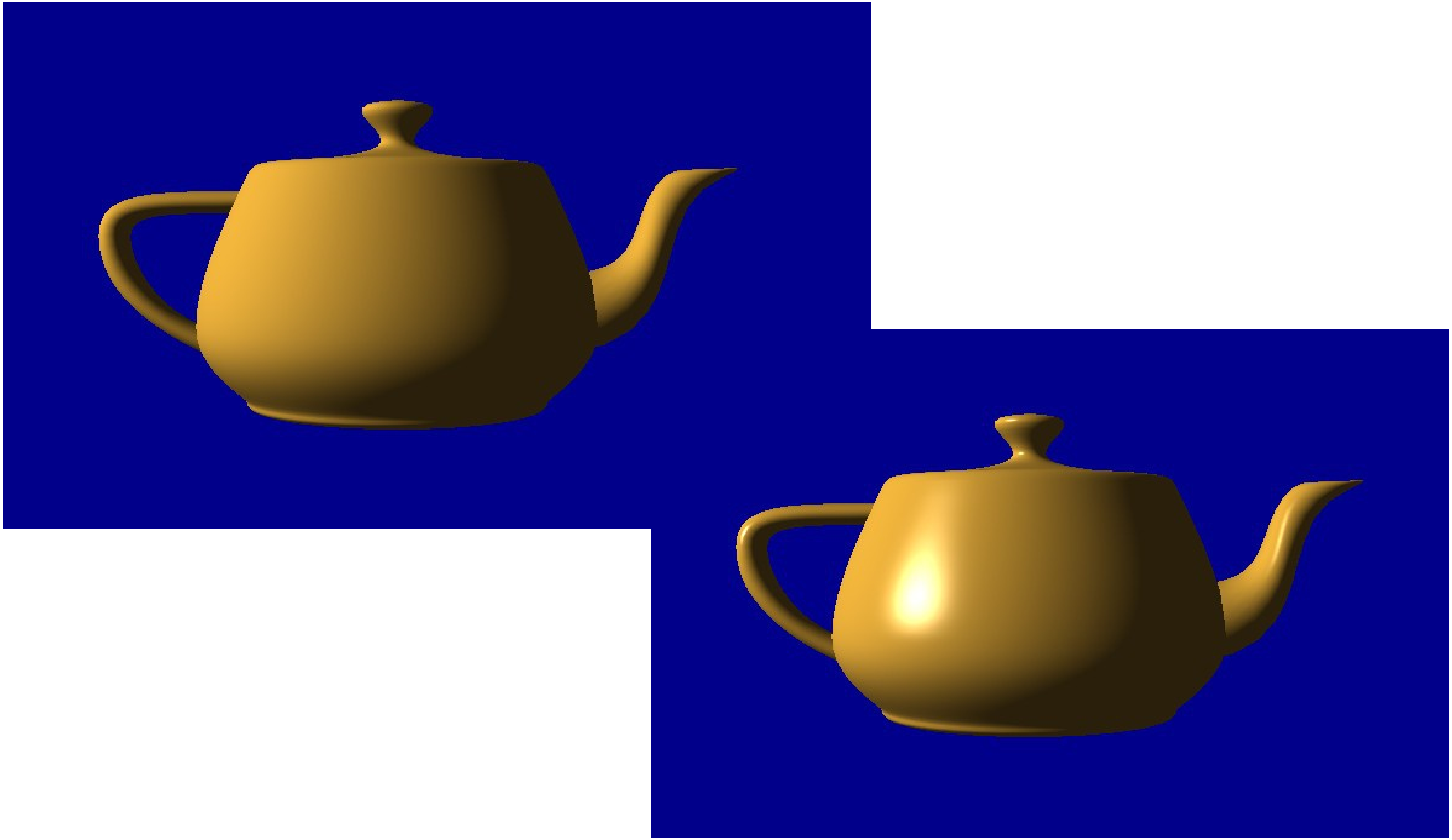
Approximates / replaces **indirect light**

$$E_A = C_D \cdot k_A$$

C_D … diffuse color (RGB)

k_A … ambient coefficient (0.0 to 1.0)

Specular Component



Specular Component E_s (Phong, 1975)

Simulates **highlights** on glossy surfaces

$$E_s = I_i \cdot C_s \cdot k_s \cdot \cos^h \beta$$

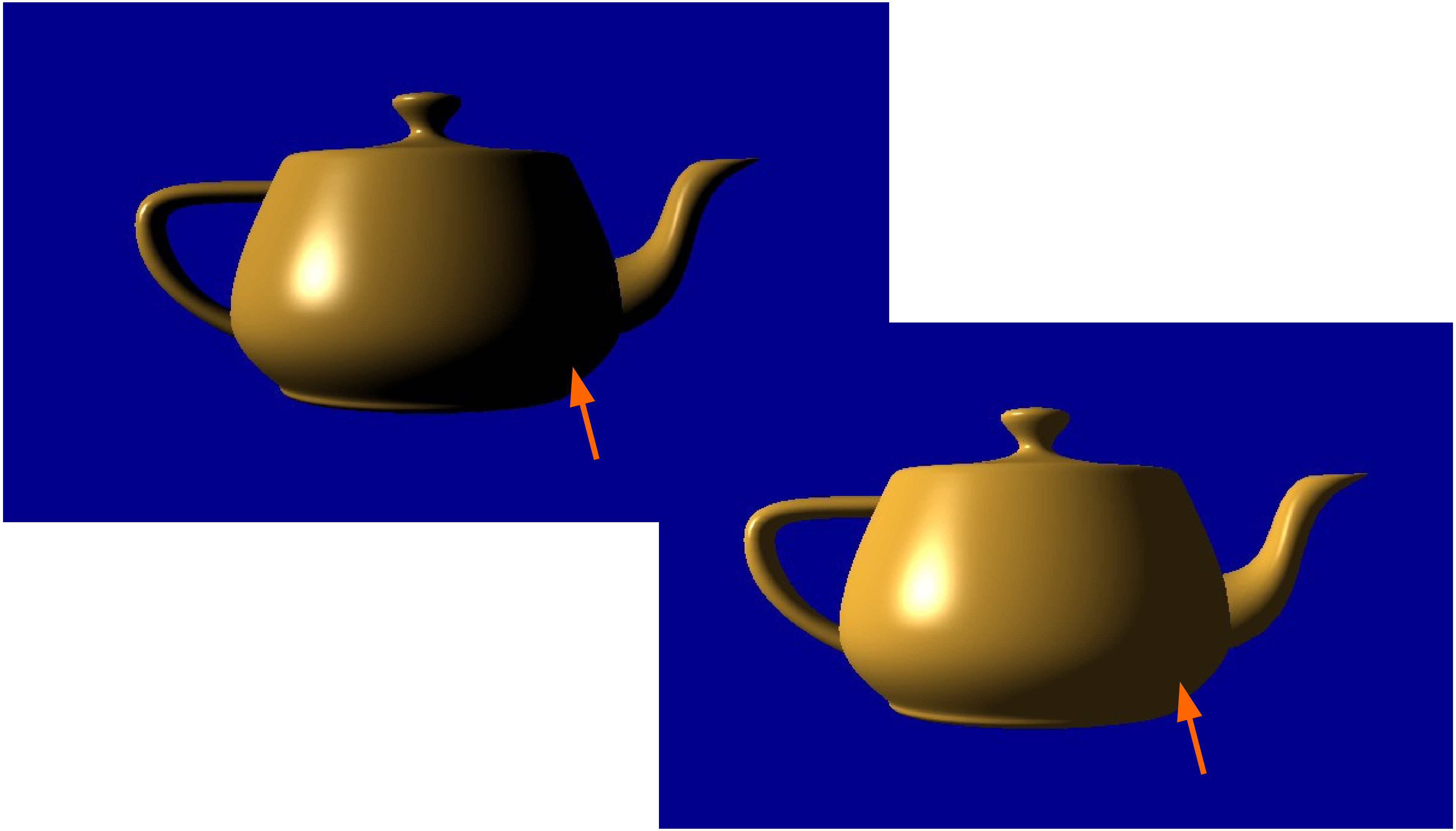
C_s … highlight color (RGB)

k_s … specular coefficient (0.0 to 1.0)

$\cos\beta = \vec{r} \cdot \vec{v}$ … dot product of unit vectors

h … highlight/specularity exponent (5 … 500)

Effect of the Ambient Light



Integrated Model (single light source)

$$E = E_A + E_D + E_S$$

Colors

$C_D = C$ … material color (RGB)

$C_S = C_L$ … light color (RGB)

Consistency

" $k_A + k_D + k_S = 1$ " (to avoid overflow)

- there's usually no need to be so strict
- for HDR it is enough to keep $k_D + k_S$ constant

Multiple Lights

$$E = E_A + \Sigma_i (E_D + E_S)$$

Implementation-wise, **Ambient Component E_A** can be considered as a contribution from a specific (omnidirectional and constant) source

Notes

1. Calculating the **reflection vector R** ($\vec{\mathbf{n}}$ and $\vec{\mathbf{l}}$ must be unit vectors)

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

2. Original formula of **Phong shading** for glossy surfaces had a **W(α)** function instead of constants $\mathbf{C_s} \cdot \mathbf{k_s}$

Reflections should be stronger (according to the Fresnel formula) at **large angles α** (and Phong was aware of it)

Compensation of Light Distance

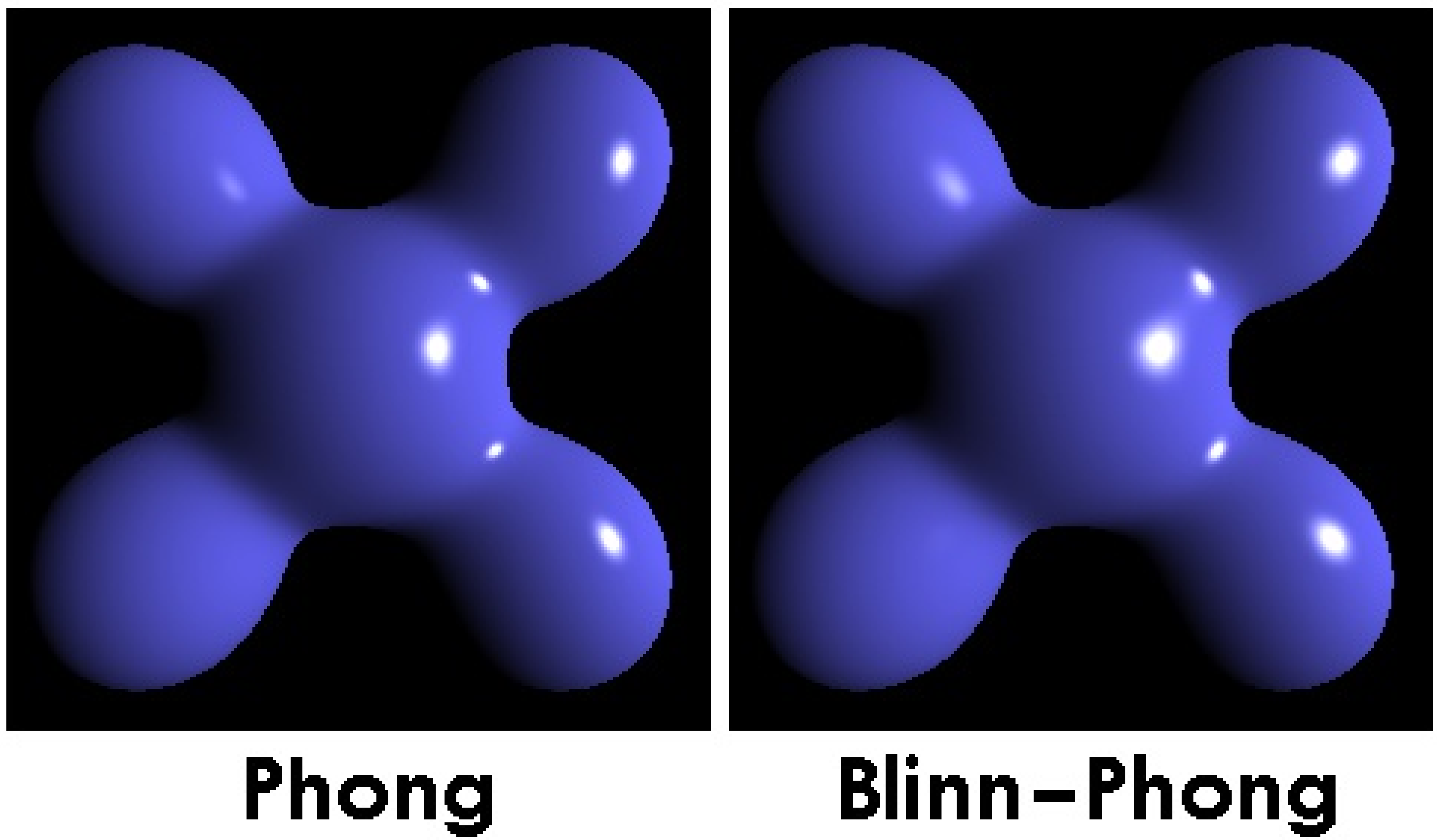
This should be … $\mathbf{1/d^2}$

– too large value range (monitors cannot display it)

Instead, use … $\mathbf{1/(c_0 + c_1 d + c_2 d^2)}$

$$\mathbf{E = E_A + \Sigma_i\, (E_D + E_S)/(c_0 + c_1 d_i + c_2 d_i^2)}$$

Blinn-Phong Model



Simplified Calculation (Blinn, 1977)

Light sources at infinity (directional light sources)

- in the entire scene, constant light vectors $\vec{\mathbf{l}}_i$

Parallel projection (observer at infinity)

- in the entire scene, the vector $\vec{\mathbf{v}}$ is constant

Simplification

If both previous conditions are met, we can use $(\vec{\mathbf{h}}_i \cdot \vec{\mathbf{n}})^{4h}$ instead of $(\vec{\mathbf{r}}_i \cdot \vec{\mathbf{v}})^h$

Half-way vector $\vec{\mathbf{h}}_i = (\vec{\mathbf{l}}_i + \vec{\mathbf{v}}) \,/\, |\vec{\mathbf{l}}_i + \vec{\mathbf{v}}|$

– $\vec{\mathbf{h}}_i$ is constant everywhere

Sometimes this simplification is called "**Blinn-Phong model**"

References

J. Foley, A. van Dam, S. Feiner, J. Hughes: ***Computer Graphics, Principles and Practice***, 721-734

Jiří Žára a kol.: ***Počítačová grafika, principy a algoritmy***, 343-346