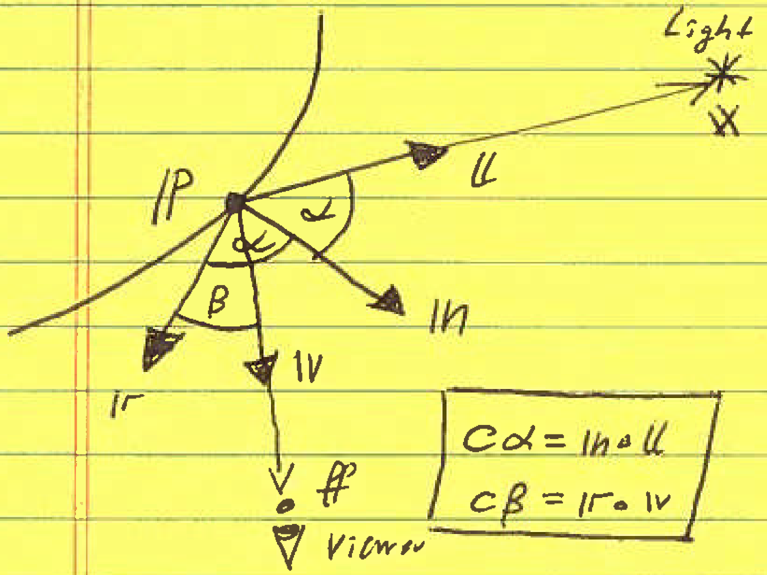
LEC 10

ILLUMINATION / LIGHTING

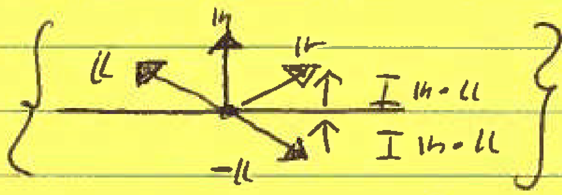
"PHONG LIGHTING" MODEL !



$$\boxed{\begin{aligned} c\alpha &= \mathbb{n}\cdot\mathbb{l} \\ c\beta &= \mathbb{r}\cdot\mathbb{v} \end{aligned}}$$

- Light vector $\mathbb{l} = \dfrac{* - \mathbb{p}}{\| \sim \|}$
- outward normal $\mathbb{n}$
- reflection vector $\mathbb{r}$,

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



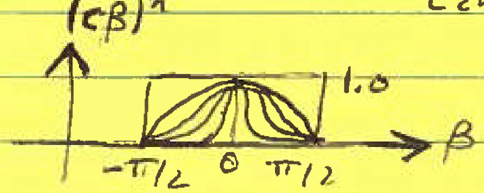
- Viewing vector $\mathbb{v} = \dfrac{\mathbb{f} - \mathbb{p}}{\| \sim \|}$

$$I(\mathbb{p}) = k_a I_a + \frac{I_L}{\|\mathbb{f}-\mathbb{p}\| + C}\Big(k_d \underbrace{c\alpha}_{\mathbb{n}\cdot\mathbb{l}} + k_s (\underbrace{c\beta}_{\mathbb{r}\cdot\mathbb{v}})^n\Big)$$

$$= k_a \cdots + k_d \cdots + k_s \cdots = \text{AMB} + \text{DIFF} + \text{SPEC.}$$

PHONG

- k_a, k_d, k_s : amb. / diff / spec. color coefficients, $\in [0,1]$
- I_a, I_L : amb. / light intensities, $\in [0,1]$
- $n \in \{1,2,3,\dots\}$: Phong constant (influencing size of "highlights")



$n \gg 1 \Rightarrow$ small-size highlights

BUT: COLOR models $\Rightarrow$ RGB colors:

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} = \text{black} \; ; \; \begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 255 \\ 255 \\ 255 \end{pmatrix} = \text{white}$$

...

$\Rightarrow$ USE PHONG MODEL FOR R-/G-/B-CHANNEL:

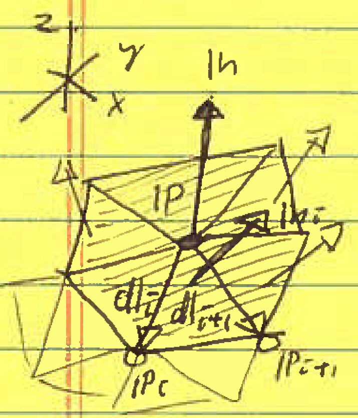
$$\boxed{\mathbb{I}(\mathbb{p}) = \begin{pmatrix} I^R \\ I^G \\ I^B \end{pmatrix}(\mathbb{p}) = \begin{pmatrix} k_a^R \\ k_a^G \\ k_a^B \end{pmatrix} I_a + \frac{I_L}{\|\mathbb{f} - \mathbb{p}\| + C} \cdot \left(\begin{pmatrix} k_d^R \\ k_d^G \\ k_d^B \end{pmatrix} \cos\alpha + \begin{pmatrix} k_s^R \\ k_s^G \\ k_s^B \end{pmatrix} (\cos\beta)^n \right)}$$

APPLIED IN WORLD SPACE

PHONG

- GRAPHICS MODELS: Meshes, Grids, Triangulations, ...

$\Rightarrow$ Apply PHONG to mesh vertices:



"Platelet of $\mathbb{p}$"

$\underline{\underline{d_i}} = \mathbb{p}_i - \mathbb{p}$; $\underline{\underline{\mathbb{n}_i}} = d_i \times d_{i+1}$

OR $\mathbb{n}_i^{norm} = \dfrac{d_i \times d_{i+1}}{\| \sim \|}$

Two ways to estimate normal $\underline{\underline{\mathbb{n}}}$:

① $\mathbb{n}_i^{norm} = \dfrac{d_i \times d_{i+1}}{\| \sim \|}$

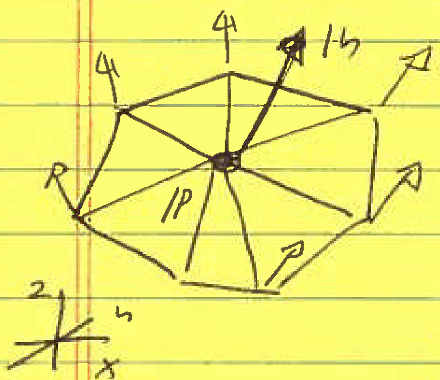
$$\underline{\underline{\mathbb{n}}} = \frac{\frac{1}{N} \sum \mathbb{n}_i^{norm}}{\| \frac{1}{N} \sum \mathbb{n}_i^{norm} \|}$$

OR ② $\mathbb{n}_i = d_i \times d_{i+1}$

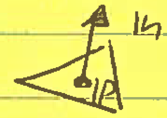
$$\underline{\underline{\mathbb{n}}} = \frac{\frac{1}{N} \sum \mathbb{n}_i}{\| \frac{1}{N} \sum \mathbb{n}_i \|}$$

"area-weighted" normal estimation

⇒ Surface = Set of points $\mathbb{P}$ and (normalized) outward normal vectors $\mathbb{n}$



⇒ apply RGB-based PHONG model to all points $\mathbb{P}$

{ ALTERNATIVE: 
Compute $\underline{\underline{1}}$ constant color per $\triangle$; use center of $\triangle$ as $\mathbb{P}$, use $\triangle$'s normal as surface normal vector }

⇒ OUTPUT: (I^R, I^G, I^B) triples for each point $\mathbb{P}$

⇒ NORMALIZATION STEP:

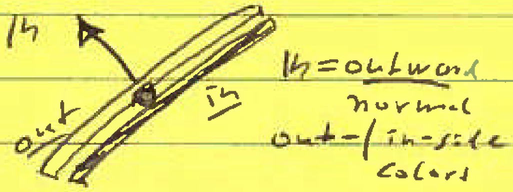
- find $\max I = \max\{I^R, I^G, I^B\}$
  /* max of ALL I^R, I^G, I^B values */
- normalize all values:
  $I^R = I^R/\max, \ldots, I^B = I^B/\max$

⇒ all I^R, I^G, I^B values $\in [0,1]$.

⇒ MAP TO RGB INTEGERS (0..255):

$$I^R_{INT} = \underline{rd}(255 \cdot I^R), \ldots, I^B_{INT} = \underline{rd}(255 \cdot I^B)$$

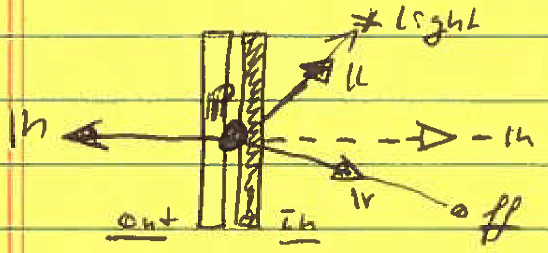
- SPECIAL CASES



① LIGHT SOURCE AND VIEWER ON SAME SIDE

⇒ USE OUTSIDE OR INSIDE COLOR ?

- $\mathbf{n}$ is $\mathbf{p}$'s OUTWARD normal



$\mathbf{n} \cdot \mathbf{l} \begin{cases} > 0 \Rightarrow \text{OUTSIDE} \\ < 0 \Rightarrow \text{INSIDE} \end{cases}$

(or: $\mathbf{n} \cdot \mathbf{v}$)

⇒ based on sign of $\mathbf{n} \cdot \mathbf{l}$, use OUT- or IN-SIDE color ($= \mathbf{k}_d^{out}$ or $\mathbf{k}_d^{in}$)

② LIGHT SOURCE AND VIEWER ON DIFFERENT SIDES

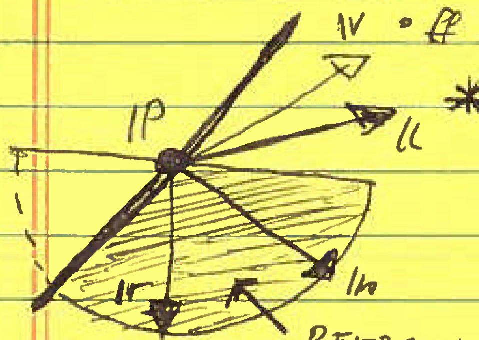
$(\mathbf{n} \cdot \mathbf{l} > 0 \wedge \mathbf{n} \cdot \mathbf{v} > 0)$
$\vee (\mathbf{n} \cdot \mathbf{l} < 0 \wedge \mathbf{n} \cdot \mathbf{v} < 0)$

⇒ light source and viewer on SAME side;

otherwise on DIFFERENT sides

⇒ light, viewer on diff. sides: $\boxed{\mathbf{I}(\mathbf{p}) = \mathbf{k}_a \cdot I_a}$

③ "RESTRICTION" OF HIGHLIGHTS (VIEWER, LIGHT ON SAME SIDE)



⇐ CANNOT SEE HIGHLIGHT HERE!

RESTRICT HIGHLIGHTS TO THIS "REGION"

$\boxed{\mathbf{r} \cdot \mathbf{v} < 0 \Rightarrow \text{NO HIGHLIGHT}}$

$\Rightarrow \mathbf{I}(\mathbf{p}) = \mathbf{k}_a I_a + \mathbf{k}_d \cdots$

$= \text{AMB} + \text{DIFF}$