Physically Based Shading

Erik Sintorn, 2016

What is Physically Based Shading?

- Somewhere around 2010, all Movie and Video Game studios started turning towards Physically Based Shading.
- Previously, programmers and artists did “whatever looked good”

Why suddenly important?

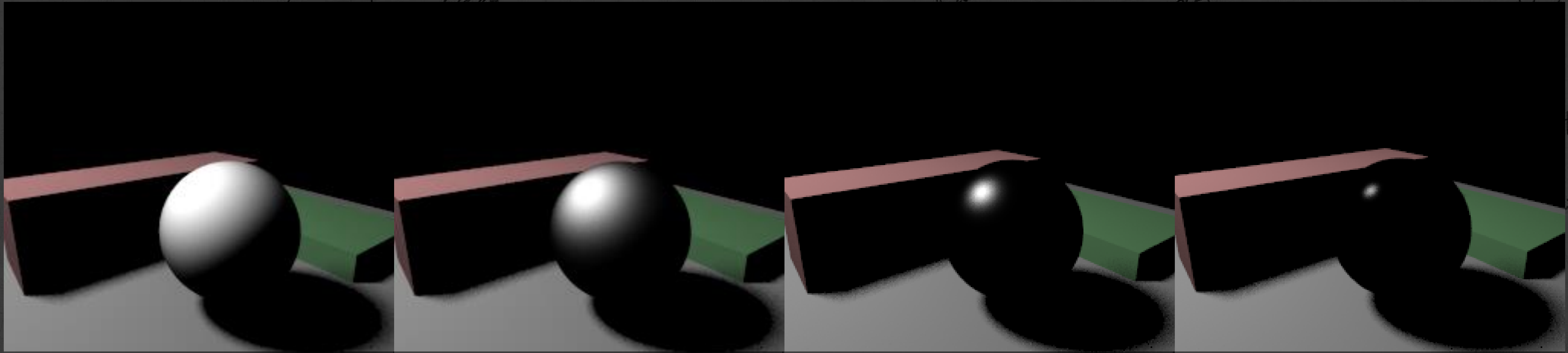
Photorealistic graphics are a reasonable goal these days

Battlefield 1942 (2002)

BATTLEFIELD 1 Battlefield 1 (2016)

Why suddenly important?

Getting the maths right from the start saves a *lot* of work down the line.



Shininess = 2 | Shininess = 10 | Shininess = 100 | Shininess = 1000

$$\boxed{\text{brdf} = dot(\boldsymbol{n}, \boldsymbol{h})^{shininess}}$$

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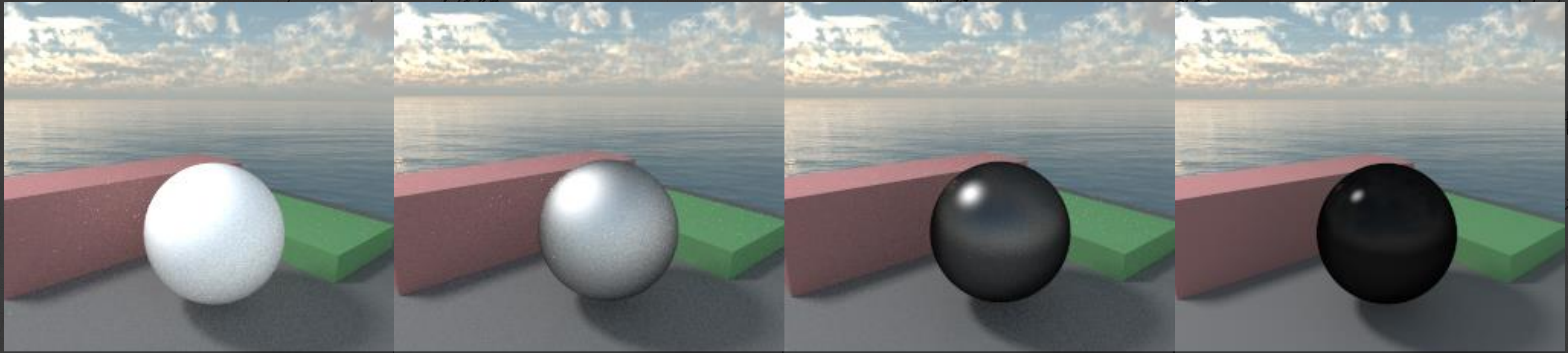

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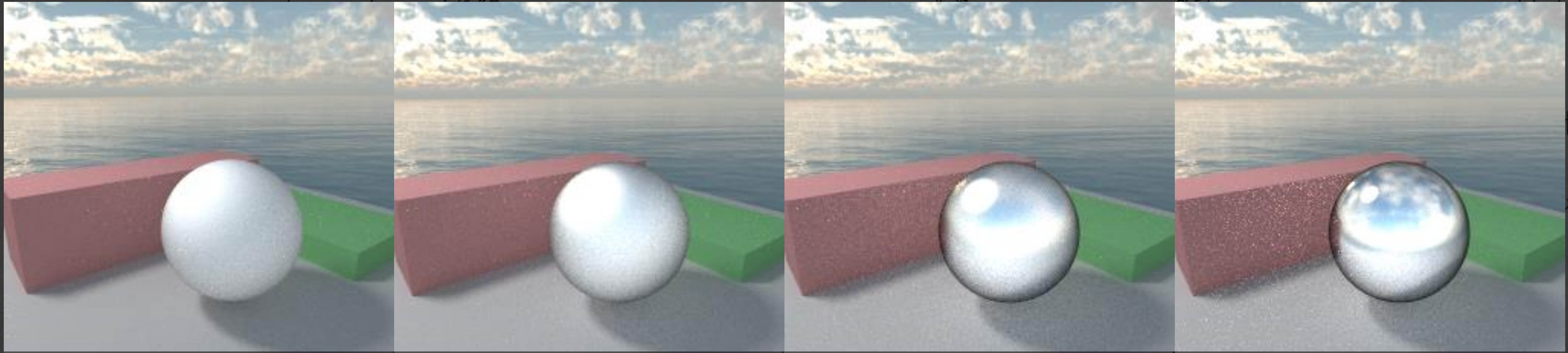


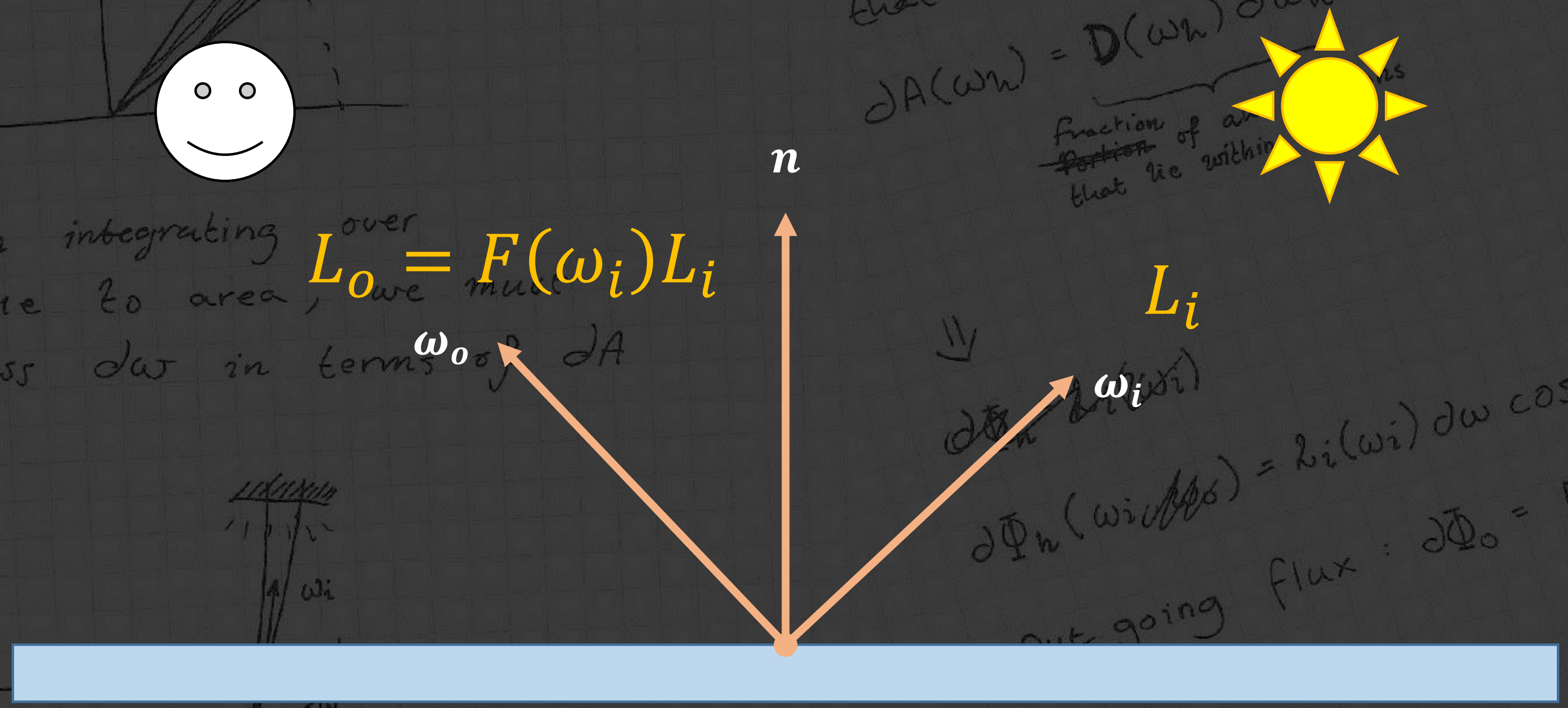
Shininess = 2 | Shininess = 10 | Shininess = 100 | Shininess = 1000

$$\text{brdf} = \frac{shininess+2}{2\pi}\ dot(\boldsymbol{n},\boldsymbol{h})^{shininess}$$

Okay, so how do we do it *correctly* then?

Optically smooth materials

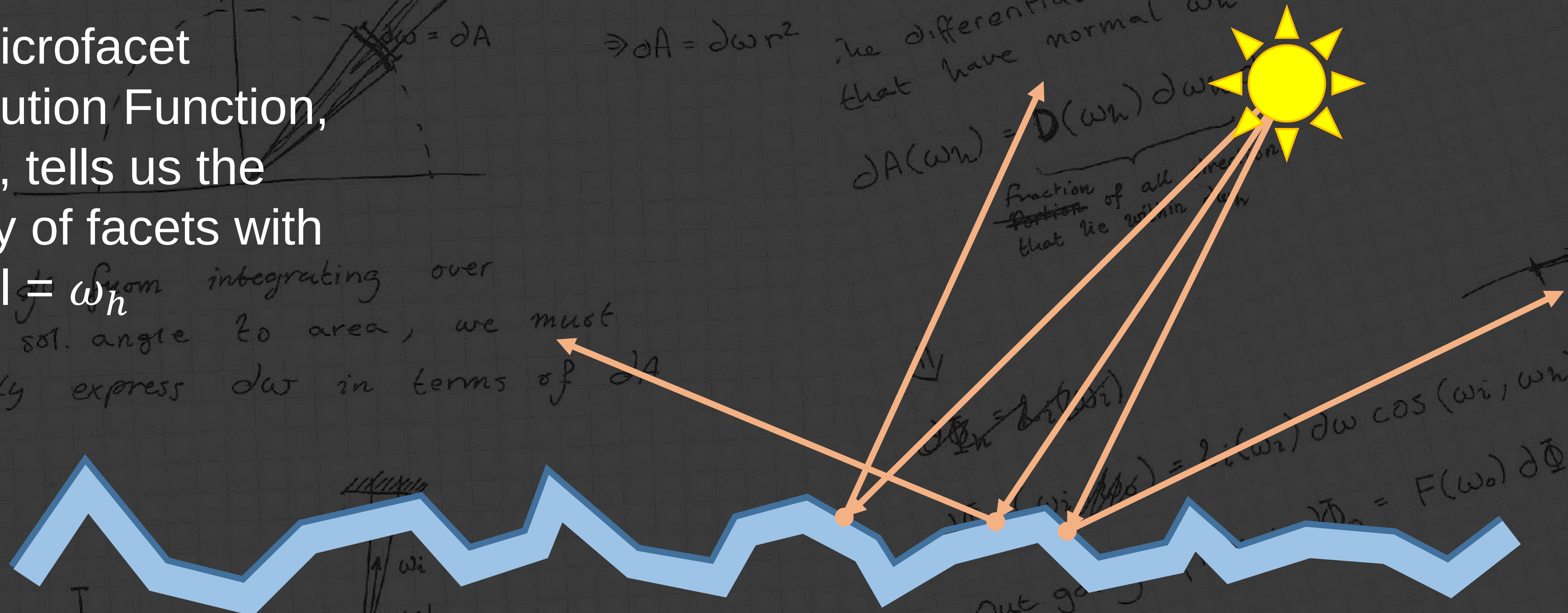
$$L_o = F(\omega_i)L_i$$



Okay, so how do we do it *correctly* then?

Microfacet Theory (Torrance and Sparrow, 1967):

The Microfacet Distribution Function, $D(\omega_h)$, tells us the density of facets with normal = ω_h



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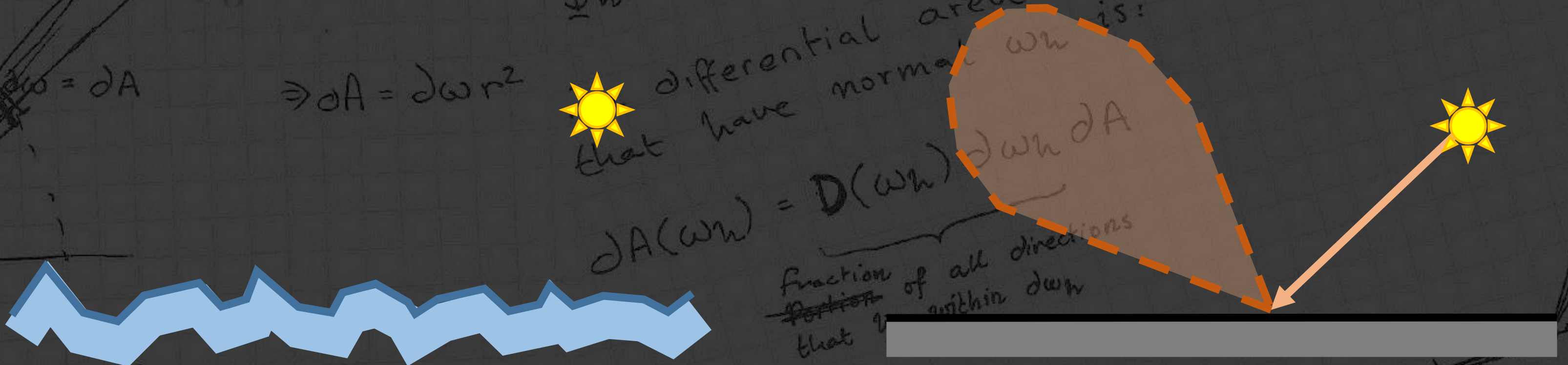
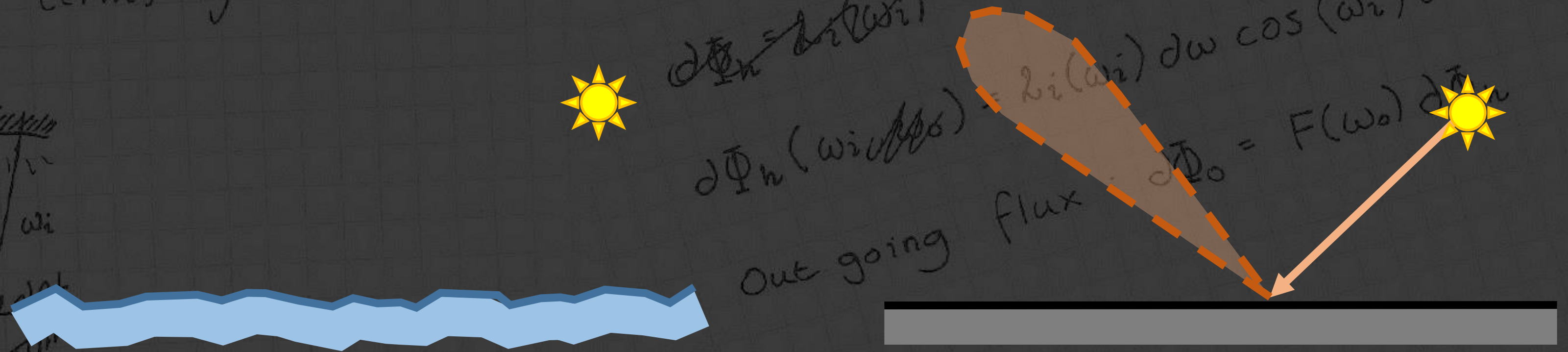




Microfacet Theory (Torrance and Sparrow, 1967):

Microfacet BRDF:

Microfacet distribution function

Fresnel

$$\text{brdf} = \frac{D(\omega_h)F(\omega_i)}{|n \cdot \omega_o||n \cdot \omega_i|}$$

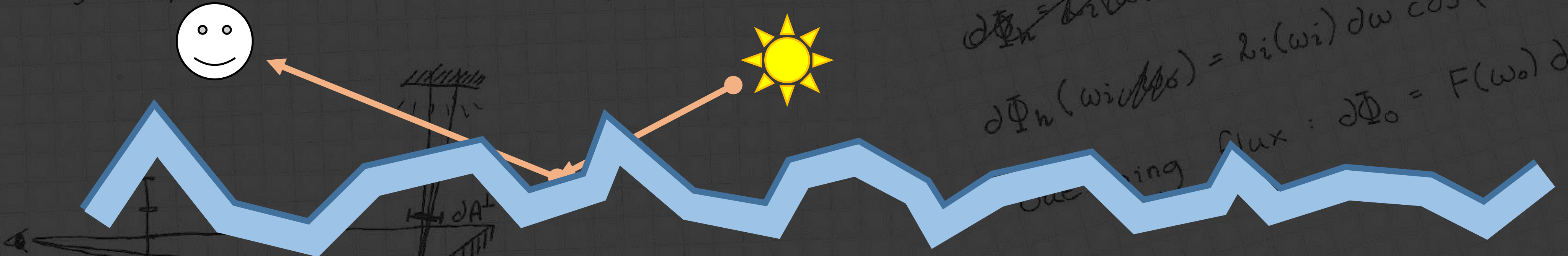
Microfacet Theory (Torrance and Sparrow, 1967):

Shadowing/Masking function

Microfacet distribution function

Fresnel

$$\text{brdf} = \frac{G(\omega_i,\omega_o)D(\omega_h)F(\omega_i)}{|n\cdot\omega_o||n\cdot\omega_i|}$$



Microfacet Theory (Torrance and Sparrow, 1967):

$$\text{brdf} = \frac{G(\omega_i,\omega_o)D(\omega_h)F(\omega_i)}{|n\cdot\omega_o||n\cdot\omega_i|}$$

How about, $\mathrm{D}(\omega_h) = dot(\boldsymbol{n},\boldsymbol{h})^{shininess}$

Hmmm…. math math math math…. No:

$$\mathrm{D}(\omega_h) = \frac{shininess + 2}{2\pi}\, dot(\boldsymbol{n},\boldsymbol{h})^{shininess}$$

Microfacet Theory (Torrance and Sparrow, 1967):

$$\text{brdf} = \frac{G(\omega_i,\omega_o)D(\omega_h)F(\omega_i)}{|n\cdot\omega_o||n\cdot\omega_i|}$$

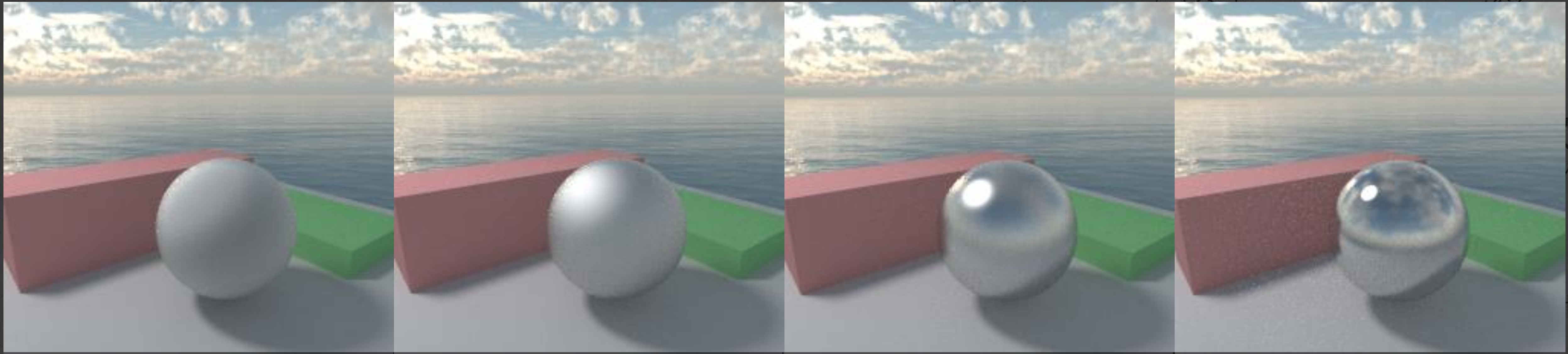
$$\mathrm{F}(\omega_i) \approx R_0 + (1 - R_0)\big(1 - (n\cdot\omega_i)\big)^5$$

Microfacet Theory (Torrance and Sparrow, 1967):

$$\text{brdf} = \frac{G(\omega_i,\omega_o)D(\omega_h)F(\omega_i)}{|n\cdot\omega_o||n\cdot\omega_i|}$$

$$\mathrm{G}(\omega_i,\omega_o) = \min\left(1.0, \min\left(2\frac{(n\cdot\omega_h)(n\cdot\omega_o)}{\omega_o\cdot\omega_h}, 2\frac{(n\cdot\omega_h)(n\cdot\omega_i)}{\omega_o\cdot\omega_h}\right)\right)$$

Microfacet Theory (Torrance and Sparrow, 1967):



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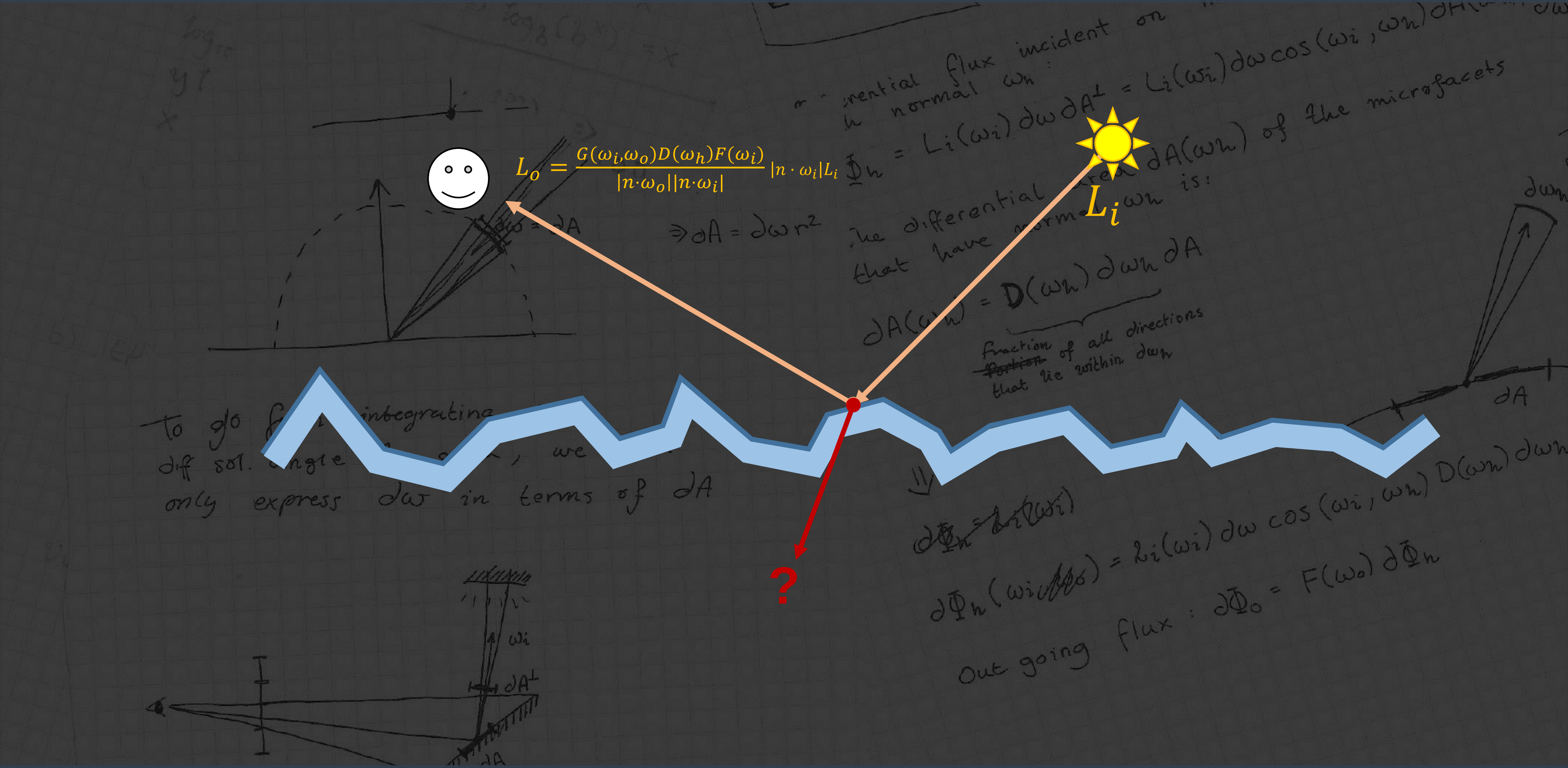
$$\text{brdf} = \frac{G(\omega_i,\omega_o)D(\omega_h)F(\omega_i)}{|n\cdot\omega_o||n\cdot\omega_i|}$$

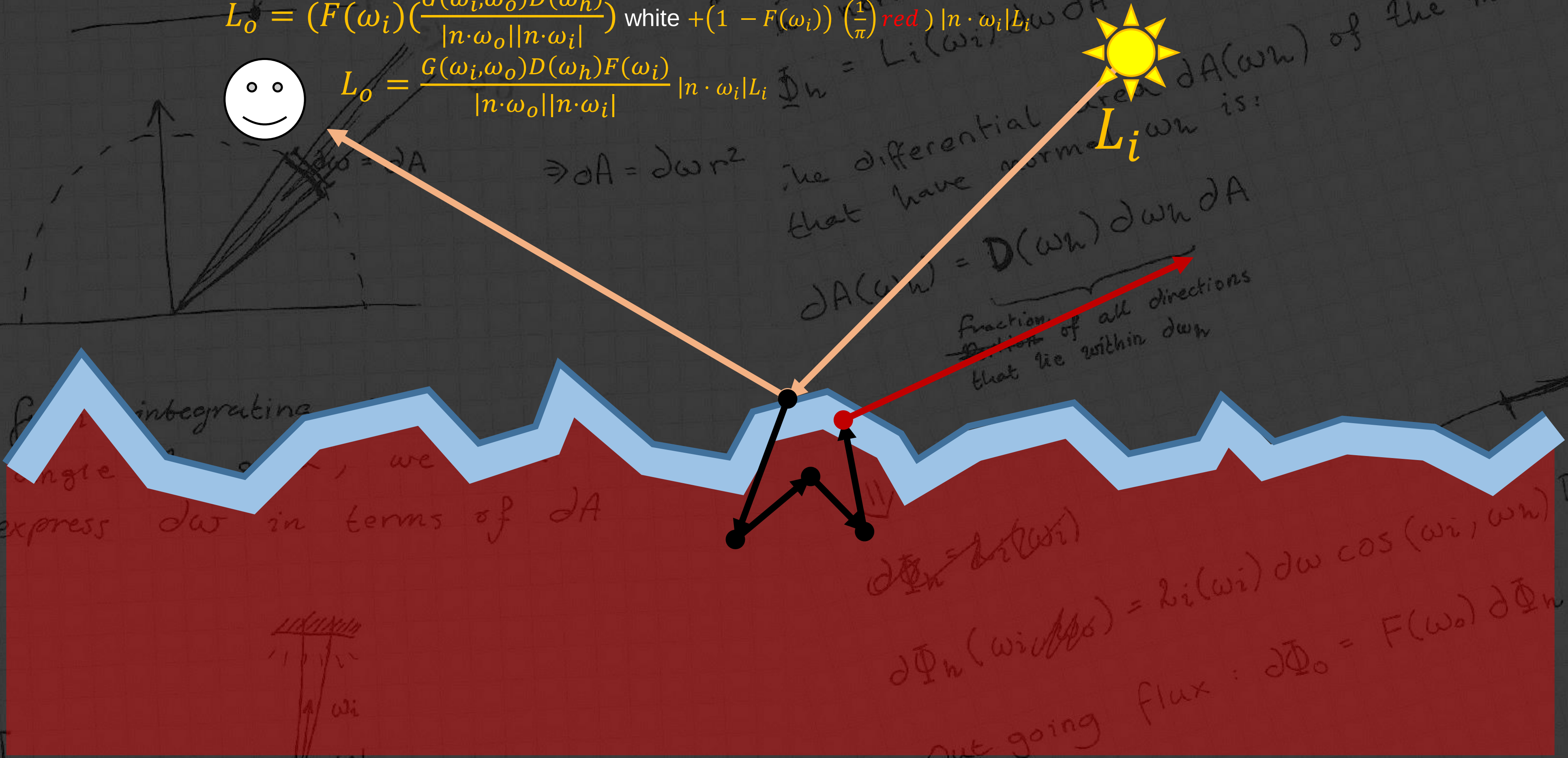
Material Model



Material Model

$$L_o = \left(F(\omega_i)\left(\frac{G(\omega_i,\omega_o)D(\omega_h)}{|n\cdot\omega_o||n\cdot\omega_i|}\right) \text{ white } + (1 - F(\omega_i))\left(\frac{1}{\pi}\right) \textit{red}\right) |n\cdot\omega_i| L_i$$

$$L_o = \frac{G(\omega_i,\omega_o)D(\omega_h)F(\omega_i)}{|n\cdot\omega_o||n\cdot\omega_i|} |n\cdot\omega_i| L_i$$



Material Model

Will be a “color” for metals!

$$L_o = \frac{G(\omega_i,\omega_o)D(\omega_h)F(\omega_i)}{|n\cdot\omega_o||n\cdot\omega_i|}|n \cdot \omega_i|L_i$$