Light

Shading

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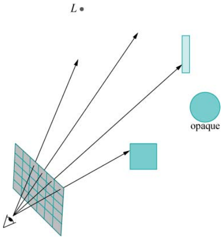

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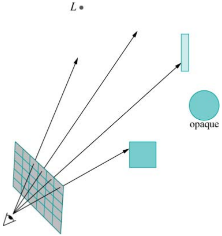

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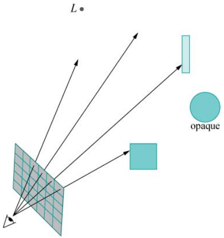

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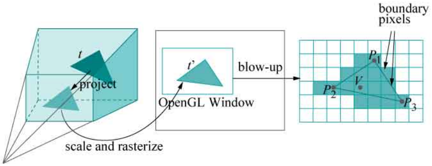
Recall:

- Rendering is triangle-driven (`foreach triangle: render`).
- Triangles are simply (triples of) vertices until rasterization phase, where pixels of the triangle are found from pixels of the vertices.



So the actual rays are determined in the rasterization phase.

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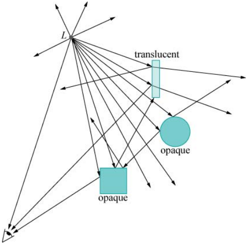

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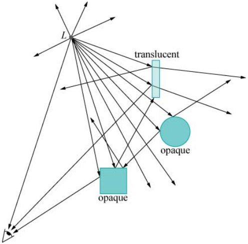

Photons are

- Emitted from ligth sources.
- Reflected, absorbed, re-emitted, transmitted when hitting objects.

Modeling Light

Highly complex physical proces. Zillions of photons.

Can only be modeled to a certain degree mathematically (ongoing research expands on the available models).

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(Figure by Jason Jacobs)

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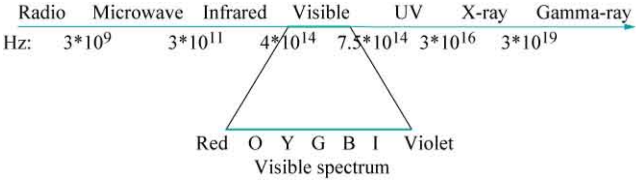
More advanced models: use programmable GPU (shaders $=$ programs for light calculations, see Ch. 20).

Actually, on modern programmable GPUs, the classic pipeline is just a default shader program. (Used to be hardwired into GPUs).

Color

Photons/light waves have frequencies:



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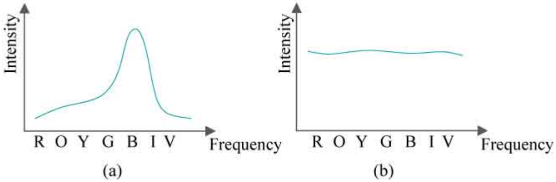
The lights following a ray has in real life a spectrum:



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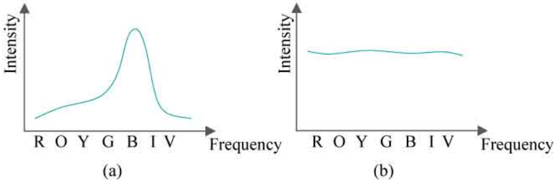

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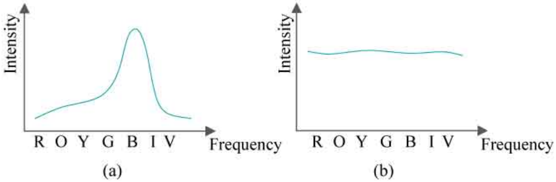

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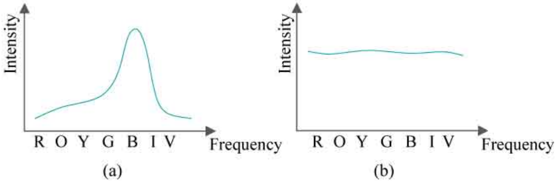

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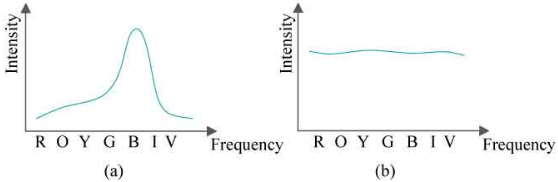

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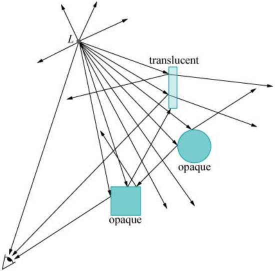
Hence, displays (and hence OpenGL) work with (R,G,B)-tuples as color values. [Or four-tuples, if alpha/transparency information is included.]

Lightning Models

- Define virtual lights.
- Define light/surface interactions.



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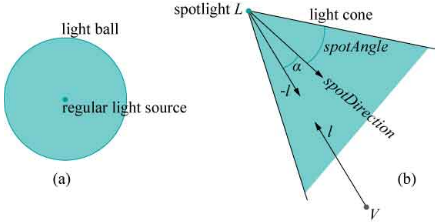

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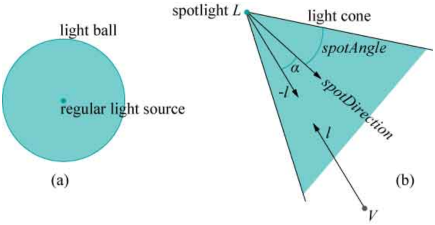
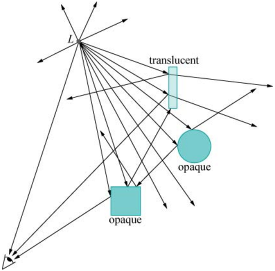


Attenuation factor for positional/spot lights (d = distance from surface point to light position):

$$\frac{1}{a + b \cdot d + c \cdot d^2}$$

Phongs Lightning Model



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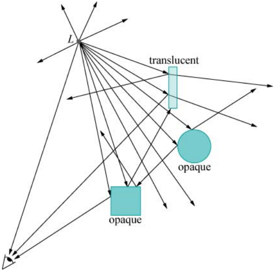

- Models only opaque objects.
- Models only one level of light/surface interactions (except ambient term, see below).
- Light/surface interaction is modeled by two simple submodels, diffuse and specular term.
- Models indirect light effects very crudely (ambient term).
- Light actually generated at surface can be added (emissive term).
- Occlusion is not modeled (all objects see all lights).

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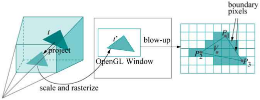
(Note: actually one light intensity triple (lights) and one attenuation factor (material) for each of the terms ambient, diffuse, specular (see later). But this flexibility often not used/needed.)

Shading models

So we have information in each vertex. How spread color calculation over entire triangle pixels?



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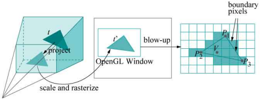

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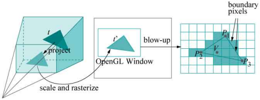

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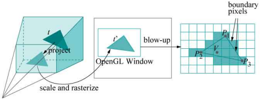

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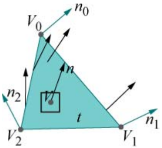

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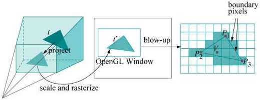

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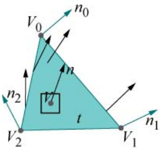

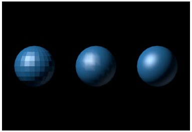

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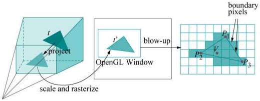

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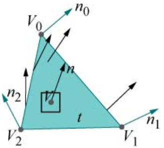

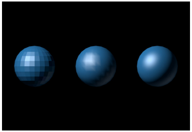

Calculation time increases down the list. Phong shading needs programmable shaders (not part of OpenGL).

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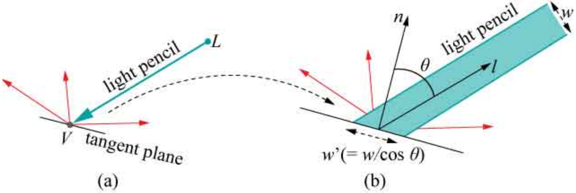

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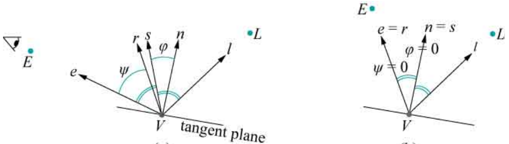

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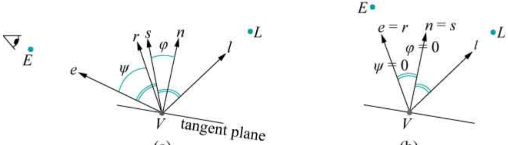

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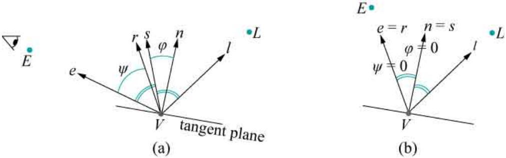

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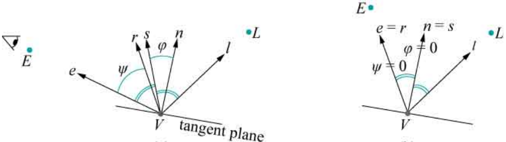

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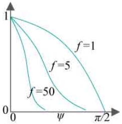

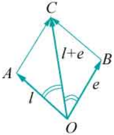

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More precisely: there is one global ambient term, plus one ambient term for each light. The latter allows for individually colored light, and distance and spot attenuation. Besides distance and spot attenuation, the calculation is just the basic multiplication of material and light.

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Thus, having a bulb both visible and giving light in a scene will involve:

- Creating polygons for the bulb and setting their emissive properties to non-zero (probably close to (1,1,1)).
- Creating a virtual light at the center of the bulb.

Lighting Equation

Add basic interactions between material and light as follows:

- One term for global ambient light.
- For each light defined: add terms for per-light ambient term, diffuse term, and specular term (with distance and spot attenuation where appropriate).

This is done once for each RGB-channel. A resulting value above 1.0 is just truncated to 1.0.

Lighting Equation in Math

$$\begin{aligned}
\text{channel value} &= \text{emissive\_term} \\
&+ \text{amb\_material} \times \text{amb\_global} \\
&+ \textstyle\sum_{\text{all lights}} \text{dist\_attenuation} \times \text{spot\_attenuation} \times \\
&\quad (\text{amb\_material} \times \text{amb\_light} + \\
&\quad \max\{\vec{L} \cdot \vec{n}, 0\} \times \text{diff\_material} \times \text{diff\_light} + \\
&\quad (\max\{\vec{s} \cdot \vec{n}, 0\})^f \times \text{spec\_material} \times \text{spec\_light})
\end{aligned}$$