Phong Shading and Lighting

Lighting formulas

Light equation

- The two shaders must put together some equation to come up with pixel brightness

- We can find out what sort of equation we can make by looking at what the inputs of the shader are - what information is available?

Info that a light equation could use.
What contributes most to final brightness?

- Per element (triangle):
  - Per vertex in each element:
    - Positions
    - Normals (perpendicular vectors for all points)
    - Colors if you want some per vertex
    - Coords in texture space
- Per whole draw call:
  - Matrices
  - Texture image to lookup, if any
  - Flags - color this shape solid? etc.
  - Light position (and specify if point or vector)
  - Material properties of shape - how chalky/shiny its interaction with light source is

Info that a light equation could use.
What contributes most to final brightness?

- Normals (perpendicular vectors for all points)

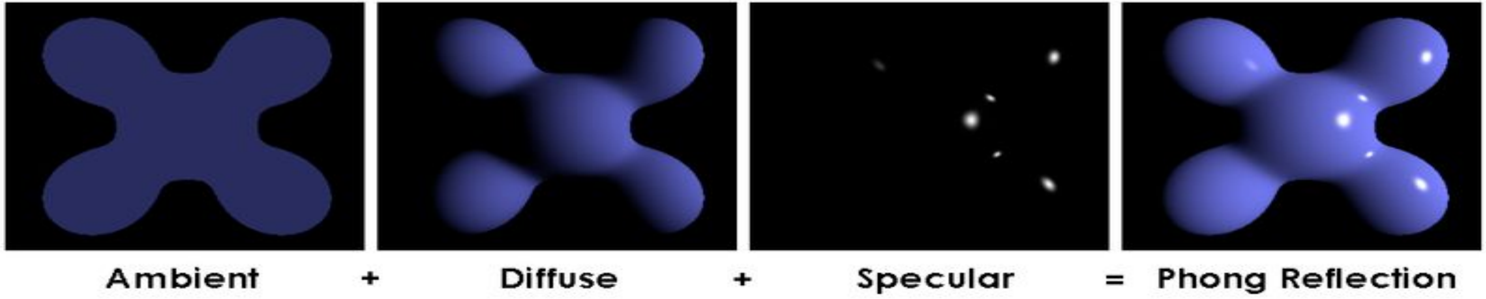
Light equation starts with just all this info

- Normal is the most important input to light equation

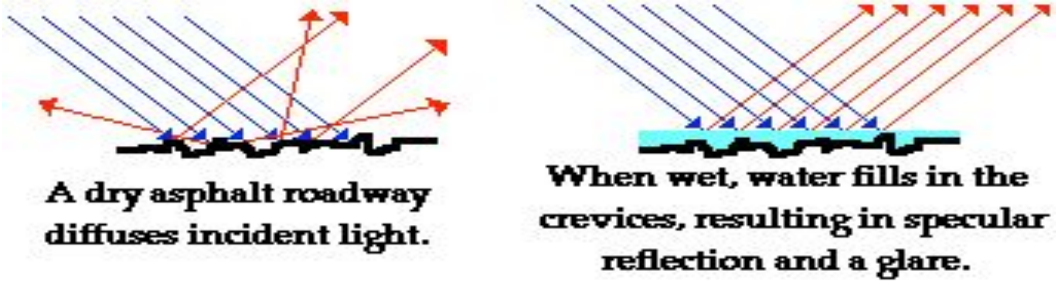
- Intermediate calculations: Compute eye, L

- Our equation choice: Phong model

Components of light



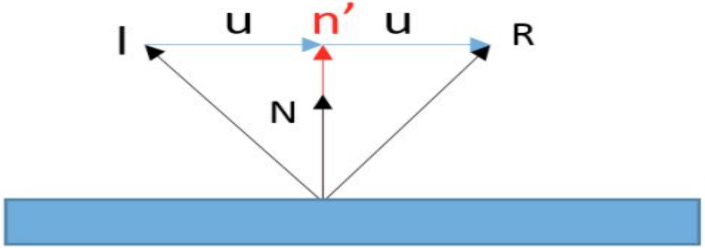
Combining components of light



Specular, diffuse, and spread reflection from a surface.

Light equation

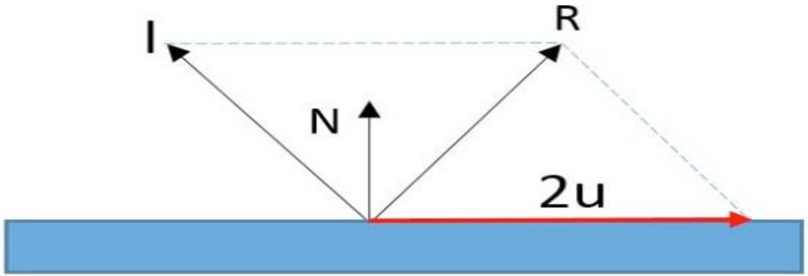
- Calculating R, the (non-physical, made-up) reflection of the point light source



The $\vec{n'}$ is the projection of $\vec{I}$ on $\vec{N}$

$\vec{n'} = (\vec{N} \cdot \vec{I})\, \vec{N}$, with $||\vec{N}||^2 = 1$

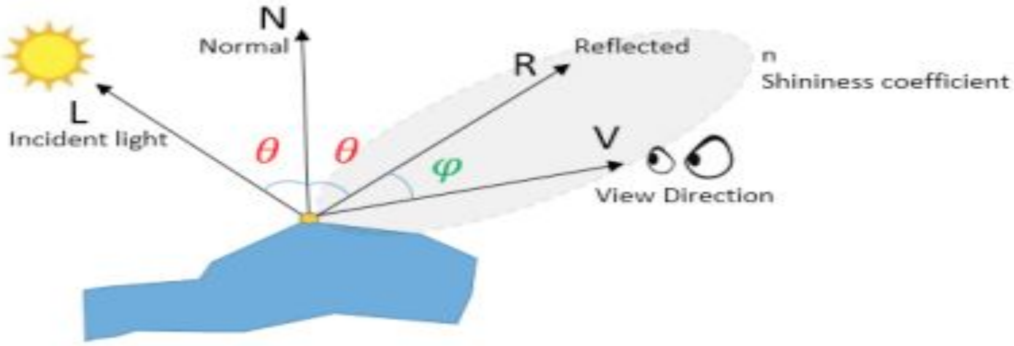
$\vec{u} = \vec{n'} - \vec{I}$



$$\vec{R} = \vec{I} + 2\vec{u} = \vec{I} + 2(\vec{n'} - \vec{I})$$

$$\vec{R} = 2(\vec{N} \cdot \vec{I})\, \vec{N} - \vec{I}$$

Light equation



I = emissive + ambient + diffuse + specular

emissive = k_e

ambient = $k_a * ambientColor$

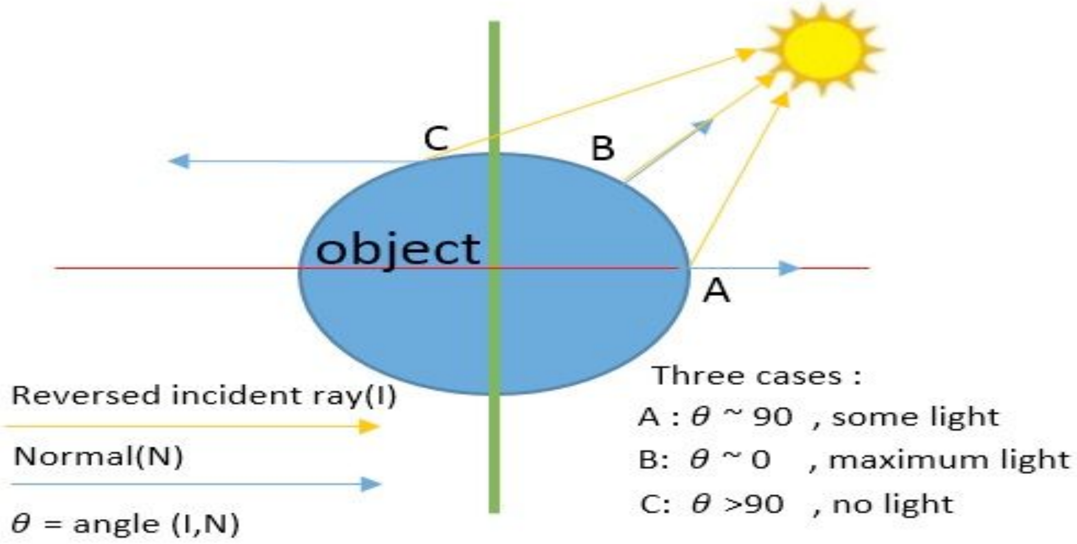
diffuse = $k_d * lightColor * \cos(\theta)$

= $k_d * lightColor$ * max(0,N · L)

specular = $k_s * lightColor * \cos(\varphi)^n$

= $k_s * lightColor$ * max(0,R · V) ^{n}

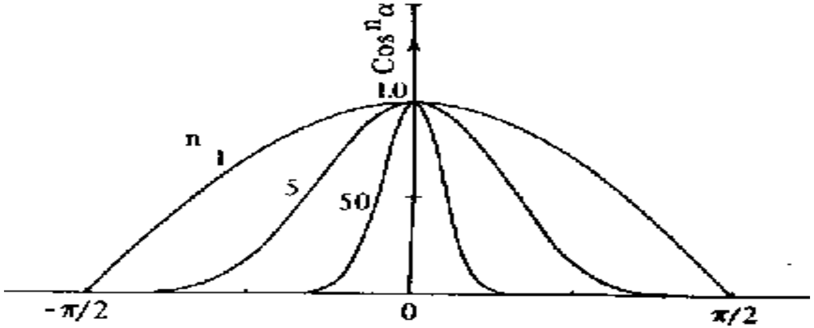
Lambert's law



"The amount of reflected light is proportional with the cosine (dot product) of the angle between the normal and incident vector"

Specular term - Smoothness exponent effect

- Exponentiating a function that has values < 1 draws those values closer to zero
- Higher exponent = smaller region where point light's reflection is considered "aligned" with the viewer.
- Smaller shiny spot



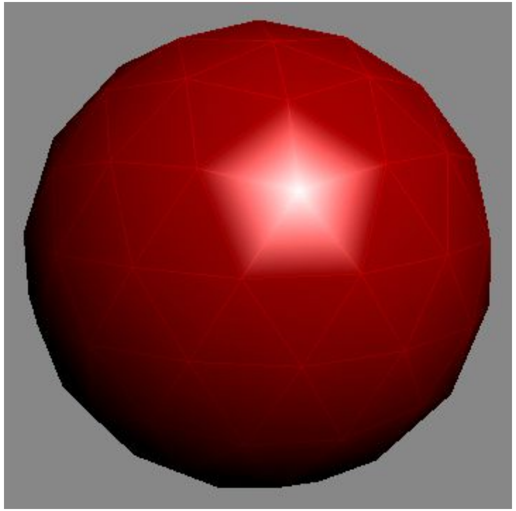
Material properties - coefficients

Name	Ambient			Diffuse			Specular			Shininess
emerald	0.0215	0.1745	0.0215	0.07568	0.61424	0.07568	0.633	0.727811	0.633	0.6
jade	0.135	0.2225	0.1575	0.54	0.89	0.63	0.316228	0.316228	0.316228	0.1
obsidian	0.05375	0.05	0.06625	0.18275	0.17	0.22525	0.332741	0.328634	0.346435	0.3
pearl	0.25	0.20725	0.20725	1	0.829	0.829	0.296648	0.296648	0.296648	0.088
ruby	0.1745	0.01175	0.01175	0.61424	0.04136	0.04136	0.727811	0.626959	0.626959	0.6
turquoise	0.1	0.18725	0.1745	0.396	0.74151	0.69102	0.297254	0.30829	0.306678	0.1
brass	0.329412	0.223529	0.027451	0.780392	0.568627	0.113725	0.992157	0.941176	0.807843	0.21794872
bronze	0.2125	0.1275	0.054	0.714	0.4284	0.18144	0.393548	0.271906	0.166721	0.2
chrome	0.25	0.25	0.25	0.4	0.4	0.4	0.774597	0.774597	0.774597	0.6
copper	0.19125	0.0735	0.0225	0.7038	0.27048	0.0828	0.256777	0.137622	0.086014	0.1
gold	0.24725	0.1995	0.0745	0.75164	0.60648	0.22648	0.628281	0.555802	0.366065	0.4
silver	0.19225	0.19225	0.19225	0.50754	0.50754	0.50754	0.508273	0.508273	0.508273	0.4
black plastic	0.0	0.0	0.0	0.01	0.01	0.01	0.50	0.50	0.50	.25
cyan plastic	0.0	0.1	0.06	0.0	0.50980392	0.50980392	0.50196078	0.50196078	0.50196078	.25
green plastic	0.0	0.0	0.0	0.1	0.35	0.1	0.45	0.55	0.45	.25
red plastic	0.0	0.0	0.0	0.5	0.0	0.0	0.7	0.6	0.6	.25
white plastic	0.0	0.0	0.0	0.55	0.55	0.55	0.70	0.70	0.70	.25
yellow plastic	0.0	0.0	0.0	0.5	0.5	0.0	0.60	0.60	0.50	.25
black rubber	0.02	0.02	0.02	0.01	0.01	0.01	0.4	0.4	0.4	.078125
cyan rubber	0.0	0.05	0.05	0.4	0.5	0.5	0.04	0.7	0.7	.078125
green rubber	0.0	0.05	0.0	0.4	0.5	0.4	0.04	0.7	0.04	.078125
red rubber	0.05	0.0	0.0	0.5	0.4	0.4	0.7	0.04	0.04	.078125
white rubber	0.05	0.05	0.05	0.5	0.5	0.5	0.7	0.7	0.7	.078125
yellow rubber	0.05	0.05	0.0	0.5	0.5	0.4	0.7	0.7	0.04	.078125

Multiply the shininess by 128!

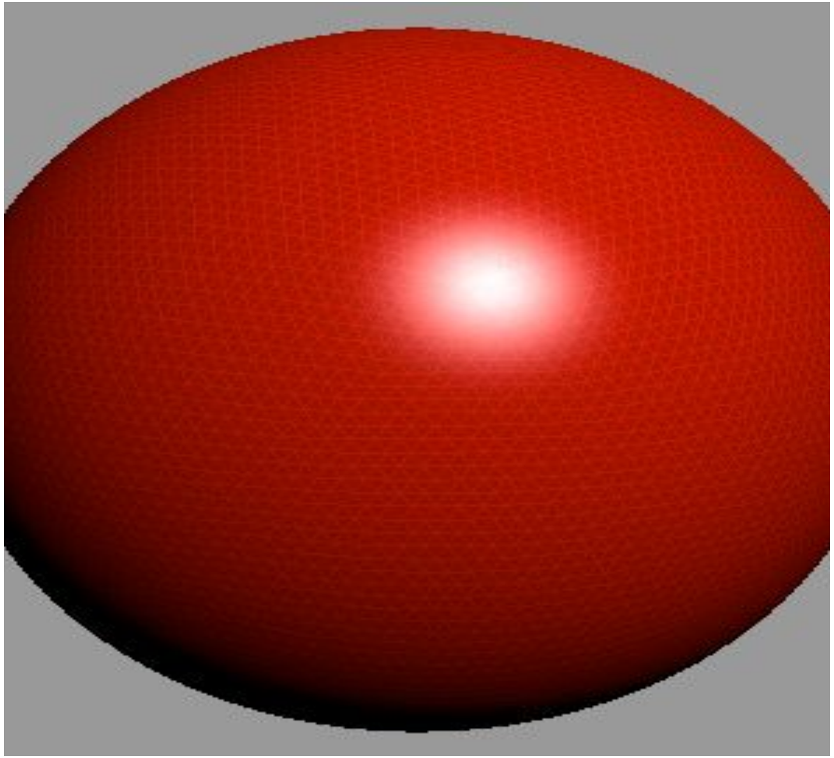
Gouraud shading

- It’s the simplest method. Just assign brightnesses per vertex and interpolate.
- The specular highlight performs poorly at edges.



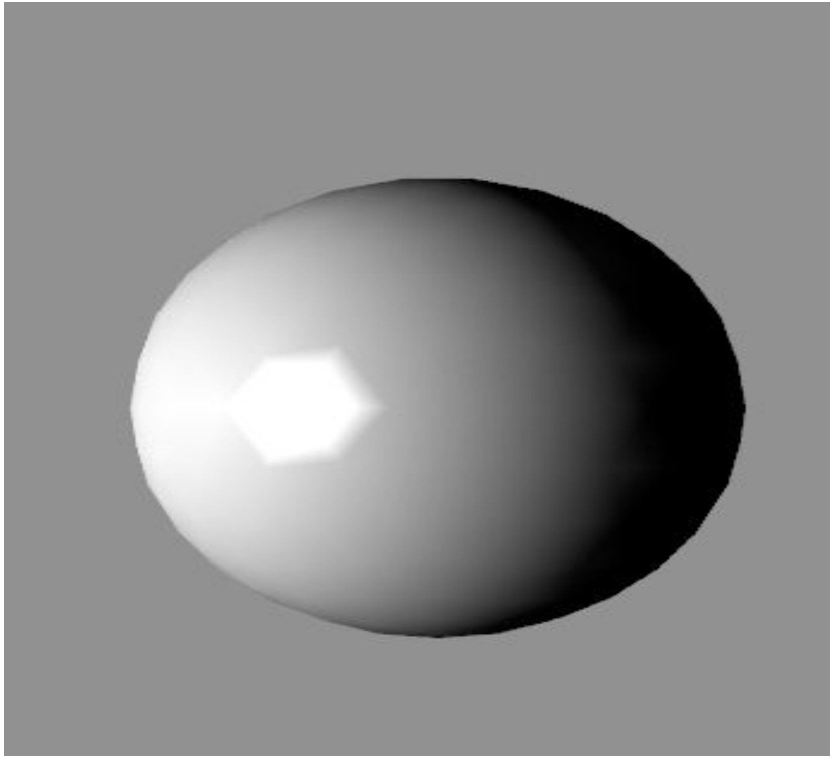
Gouraud shading

- Only solution - make edges matter less by increasing polygon count.



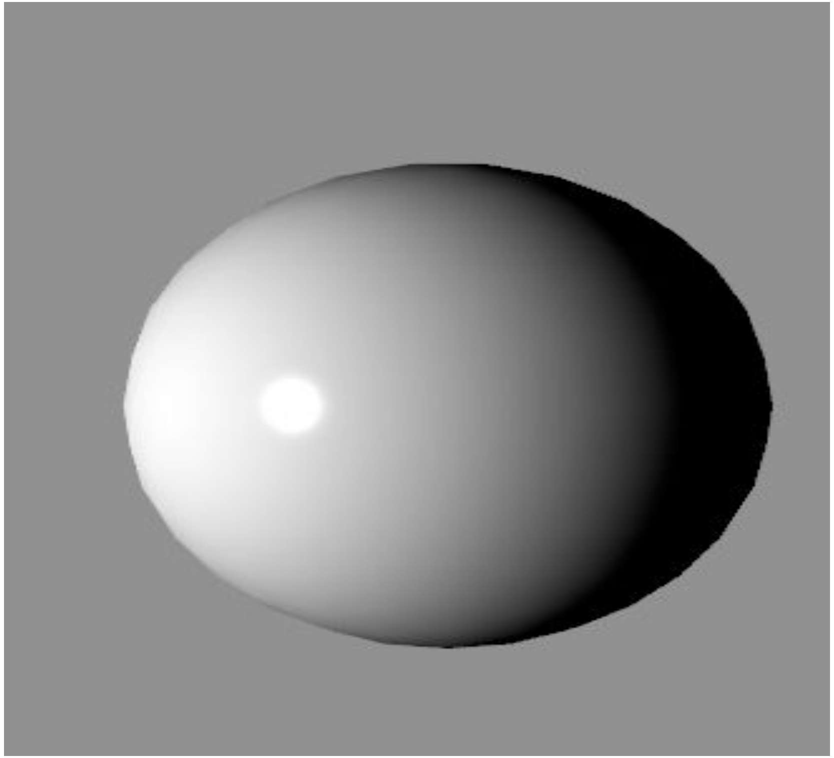
Light equation

- Gouraud shading
  - Diffuse and specular components calculated at every <u>point</u> and added together
  - Linearly interpolate the <u>brightnesses</u>



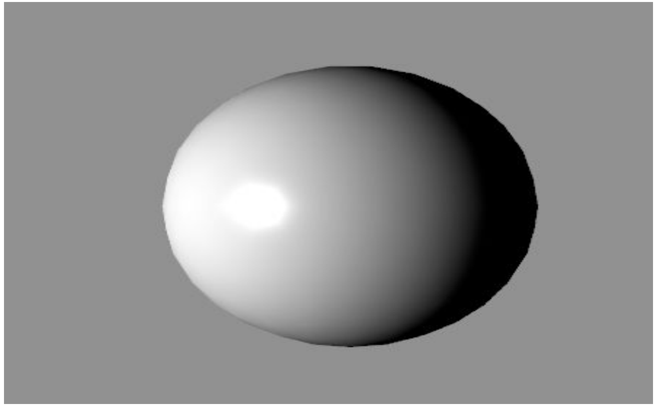
Light equation

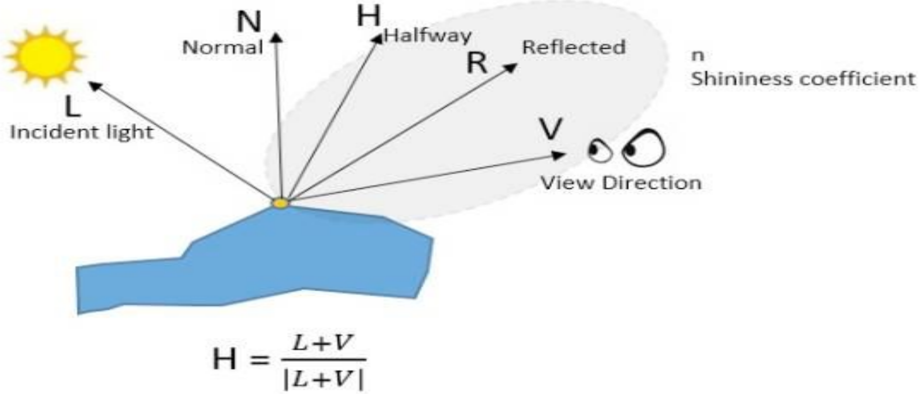
- Phong shading
  - Linearly interpolate the <u>normals</u> across each triangle
  - Only when you get to an actual pixel do you calculate the specular and diffuse brightnesses
  - At <u>every pixel</u>, a much finer scale than Gouraud



Phong-Blinn

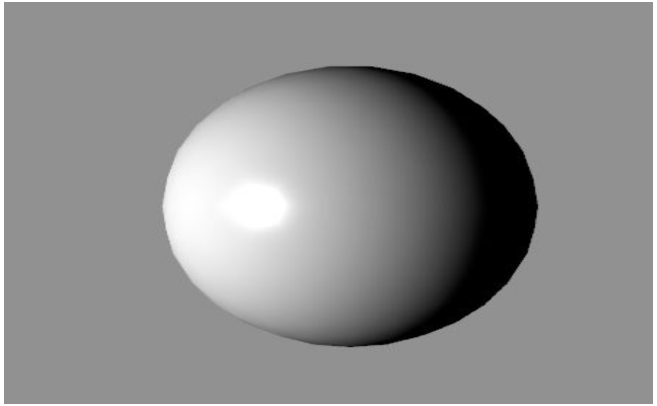
- Combine V and L, the two constants in the scene, into one vector
- Given H = halfway between V and L, Use (H dot N) instead of (R dot V)

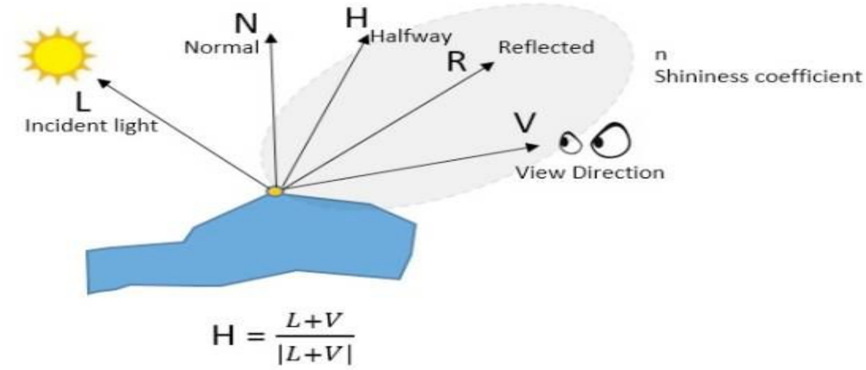




Phong-Blinn

- If directional light, you can compute H once per frame per light source and it's the same everywhere in the scene - no dependence on normal, just viewer and light
- Re-use it instead of re-calcuating in shader - shader only has to dot H with each N - Cheaper.
- Also behaves better at glancing angles





Light equation

- How many times to do the lighting equation?
  - Once per triangle - flat
  - Once per point - gouraud
  - Once per pixel - smooth / "phong shading"