CS380: Computer Graphics
Illumination

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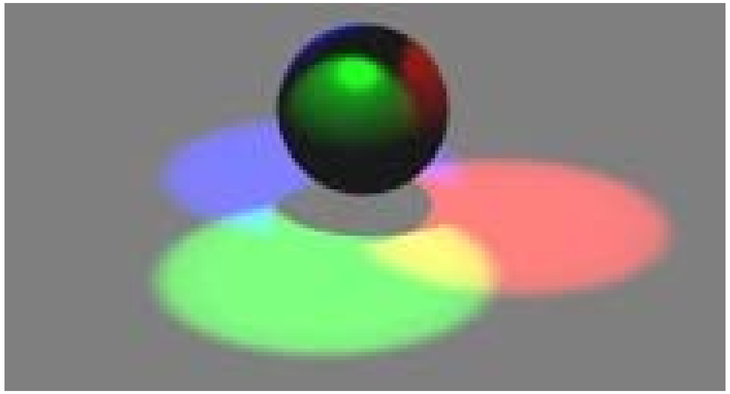
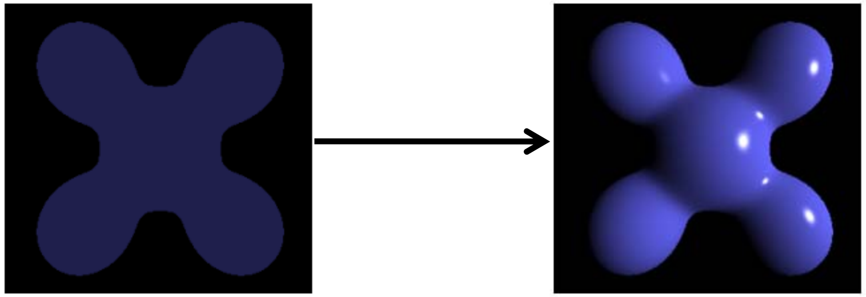
(윤성의)

Course URL:
http://sgvr.kaist.ac.kr/~sungeui/CG/

Course Objectives (Ch. 8)

- **Know how to consider lights during rendering models**
  - **Light sources**
  - **Illumination models**





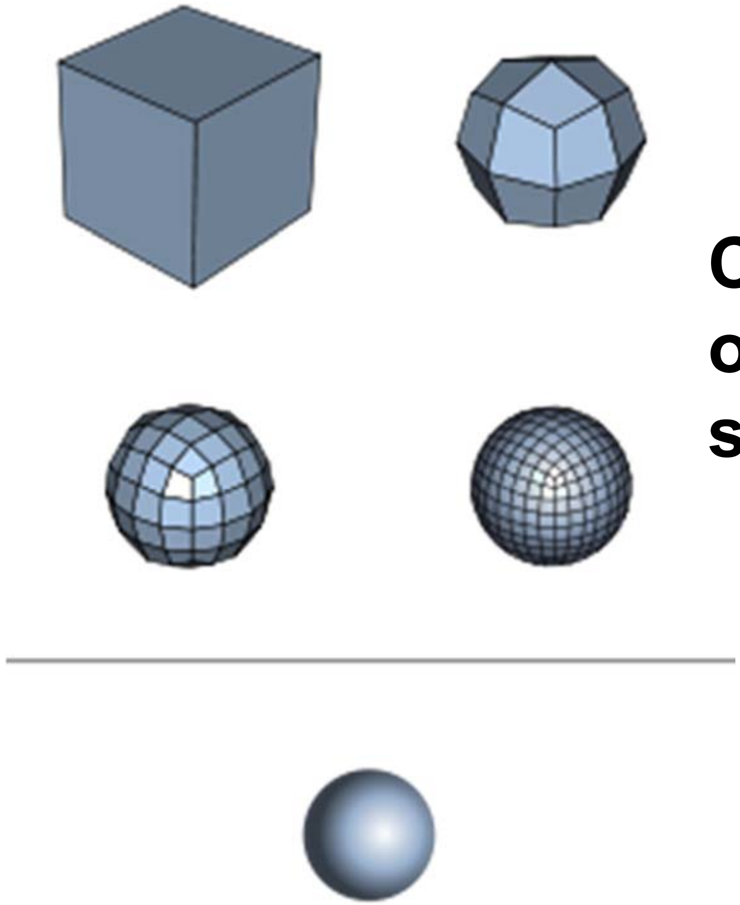
- **At the last class:**
  - **Studied triangle rasterization using edge-equations**
  - **Discussed mechanics for parameter interpolations**

Questions

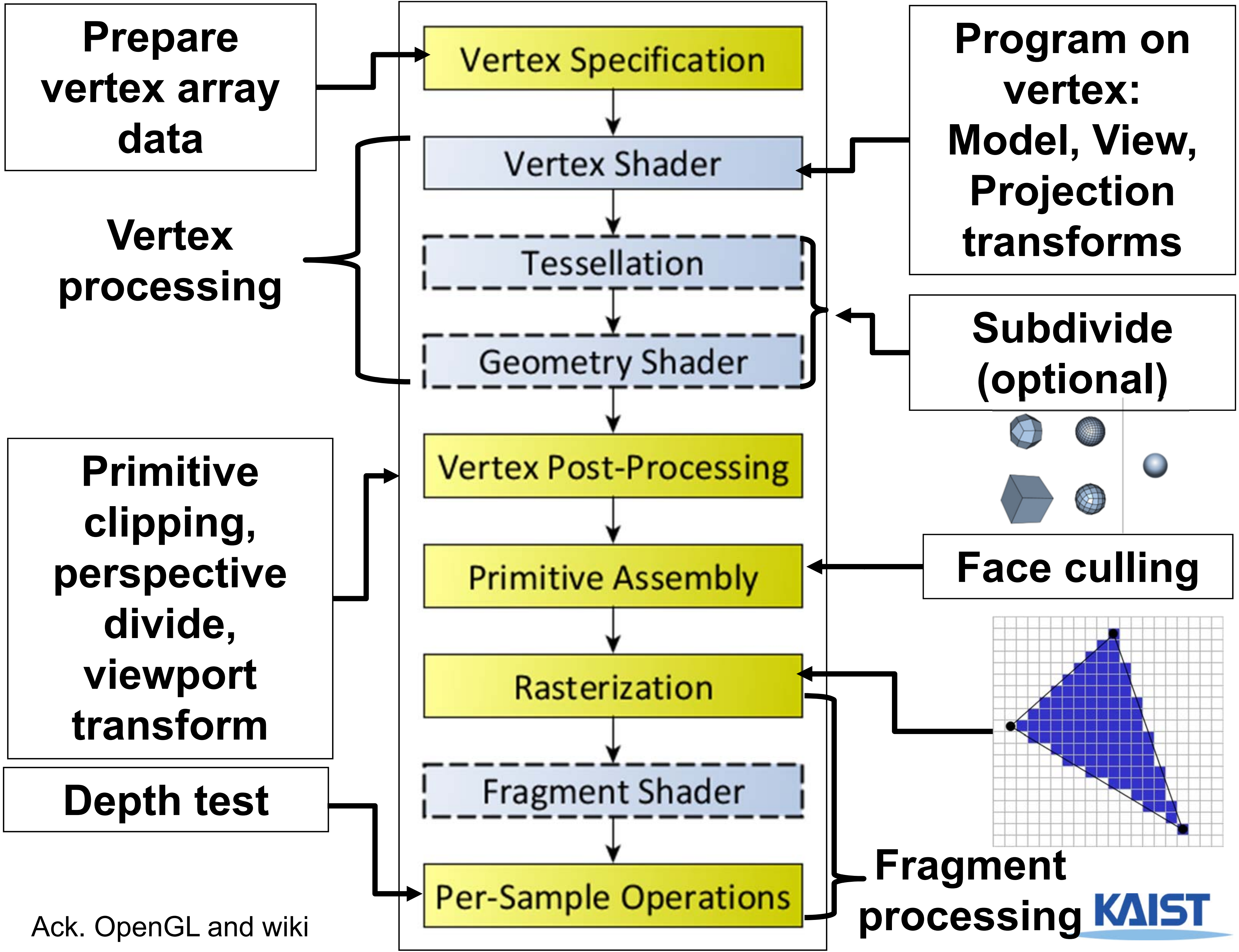
- According to the pictures covered in the lectures, all kinds of structures, including those with very complex shapes, appear to be composed of numerous triangles. But do we have to use many triangles to represent a huge sphere? Since the perfect sphere is uniquely determined by its center and radius, I think it's very inefficient to split the sphere into triangles and apply rasterization.

Subdivision Meshes (Catmull-Clark Surface)

- **Provides infinite resolution for achieving smooth surfaces**



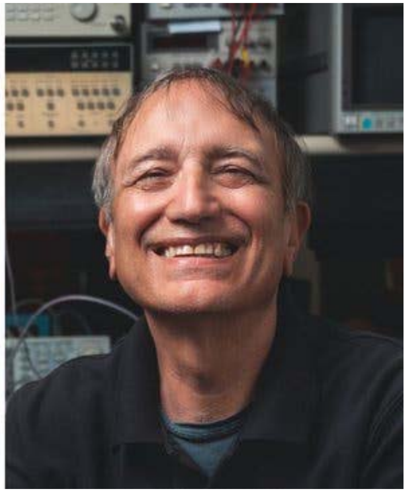
Catmull–Clark level-3 subdivision of a cube with the limit subdivision surface shown below (wiki)



Prepare vertex array data
Vertex Specification
Program on vertex: Model, View, Projection transforms
Vertex Shader
Vertex processing
Tessellation
Geometry Shader
Subdivide (optional)
Vertex Post-Processing
Primitive clipping, perspective divide, viewport transform
Primitive Assembly
Face culling
Rasterization
Fragment Shader
Depth test
Per-Sample Operations
Fragment processing
Ack. OpenGL and wiki

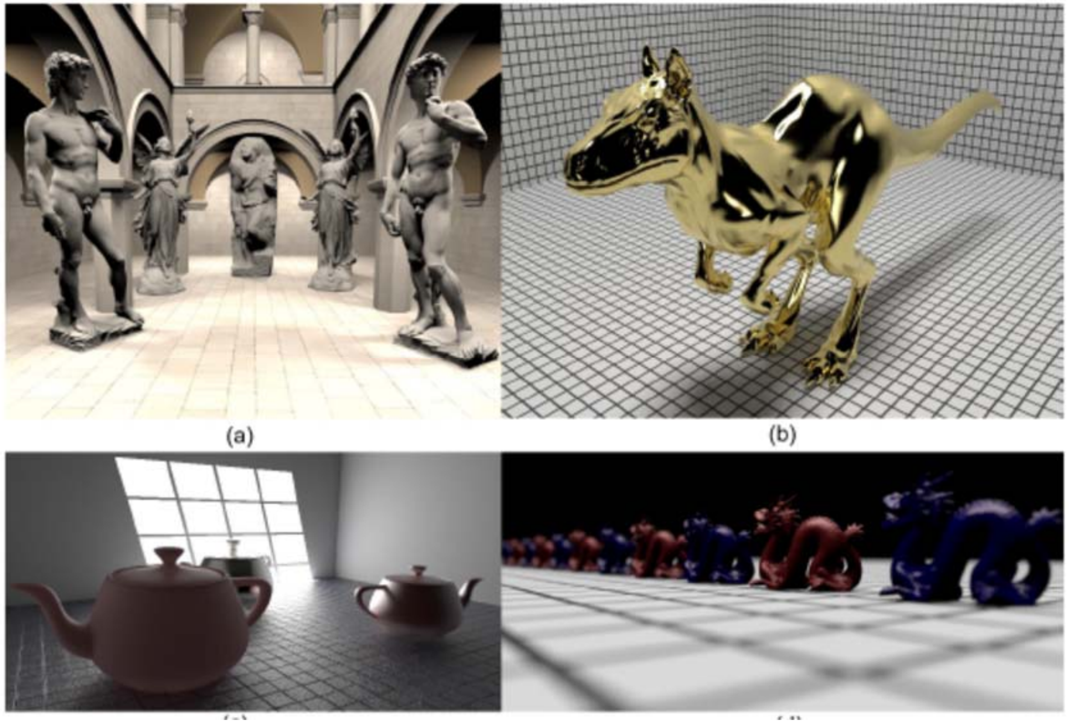
Pixar Pioneers Win $1 Million Turing Award, 2020

- **From NYTimes**



Subdivision Meshes (Catmull-Clark Surface)

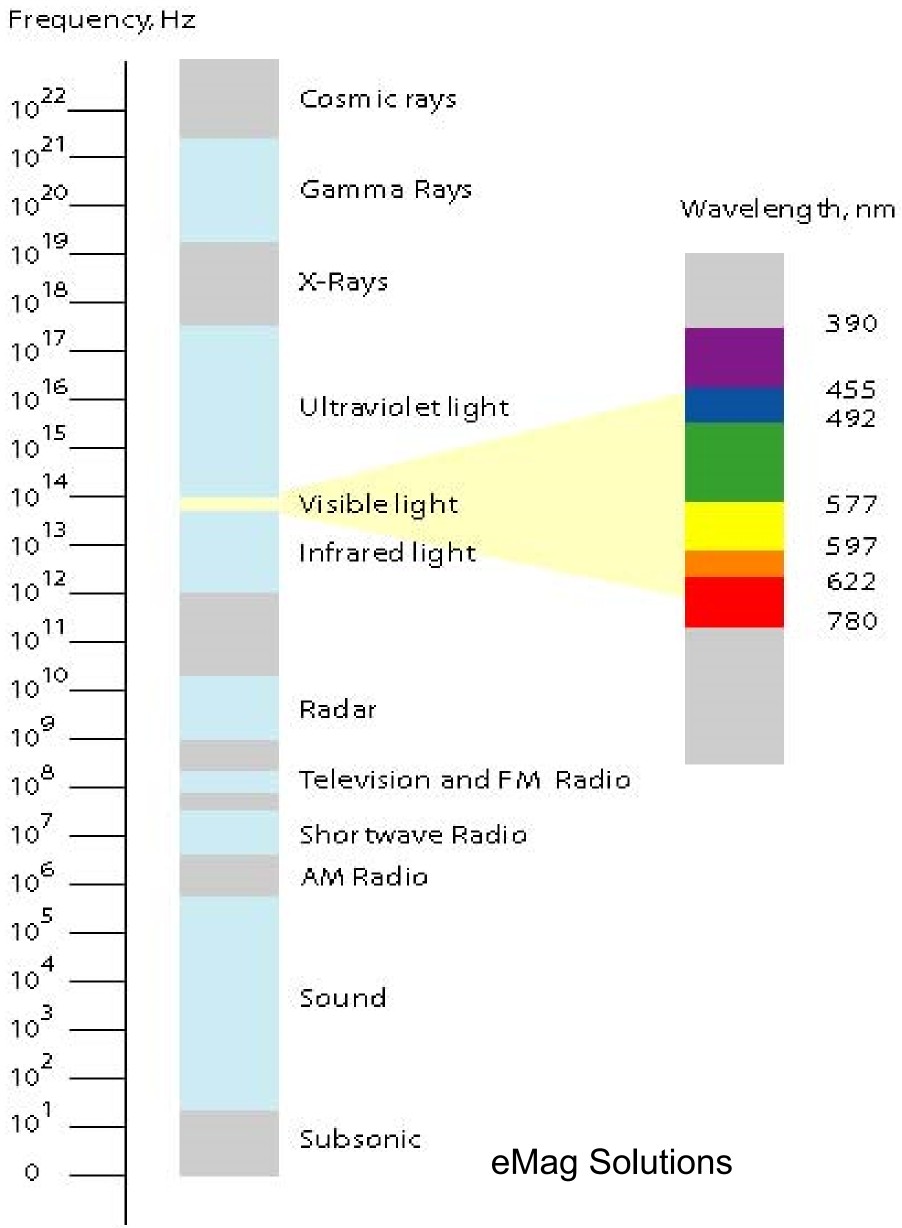
- **Provides infinite resolution for achieving smooth surfaces**
  - **TSS BVHs: Tetrahedron Swept Sphere BVHs for Ray Tracing Subdivision Surfaces, Pacific Graphics, 2016**



Question: How Can We See Objects?

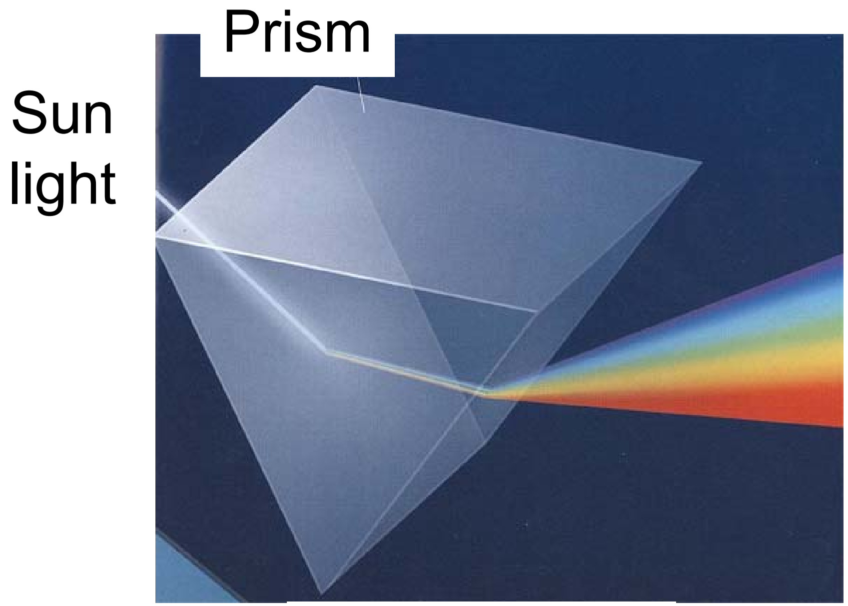
- **Emission and *reflection*!**

Question: How Can We See Objects?



eMag Solutions

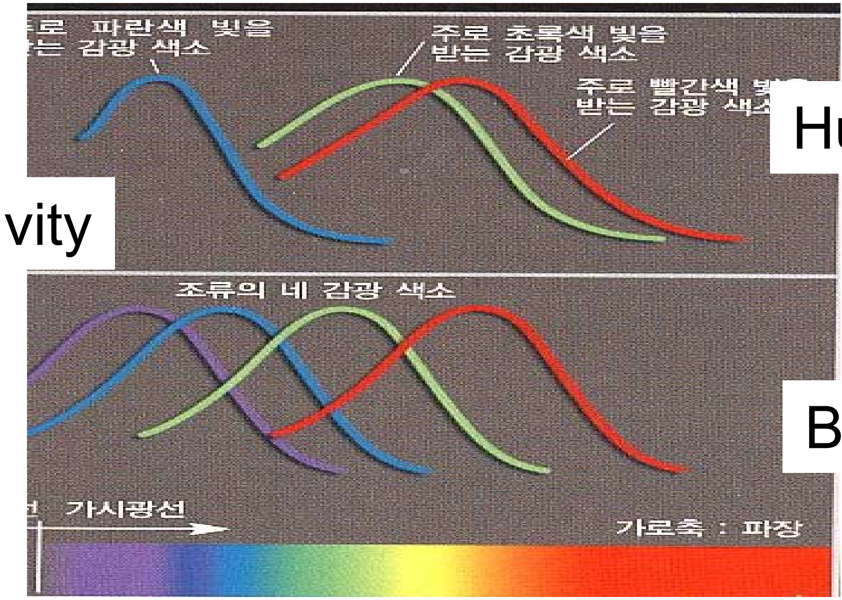
Light (sub-class of electromagnetic waves)



From Newton magazine

Question: How Can We See Objects?

Sensitivity



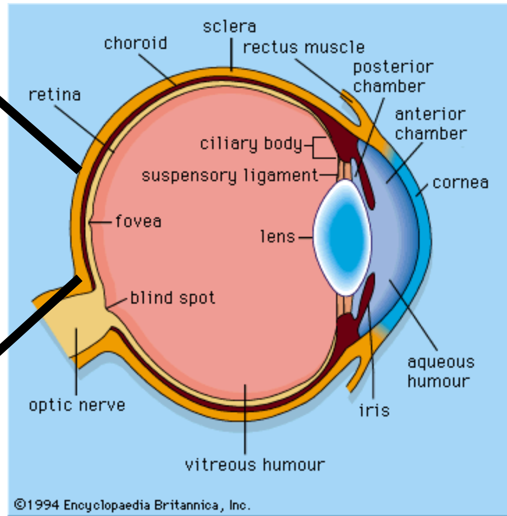
Human

Birds

Light
(sub-class of electromagnetic waves)

Rod and cone

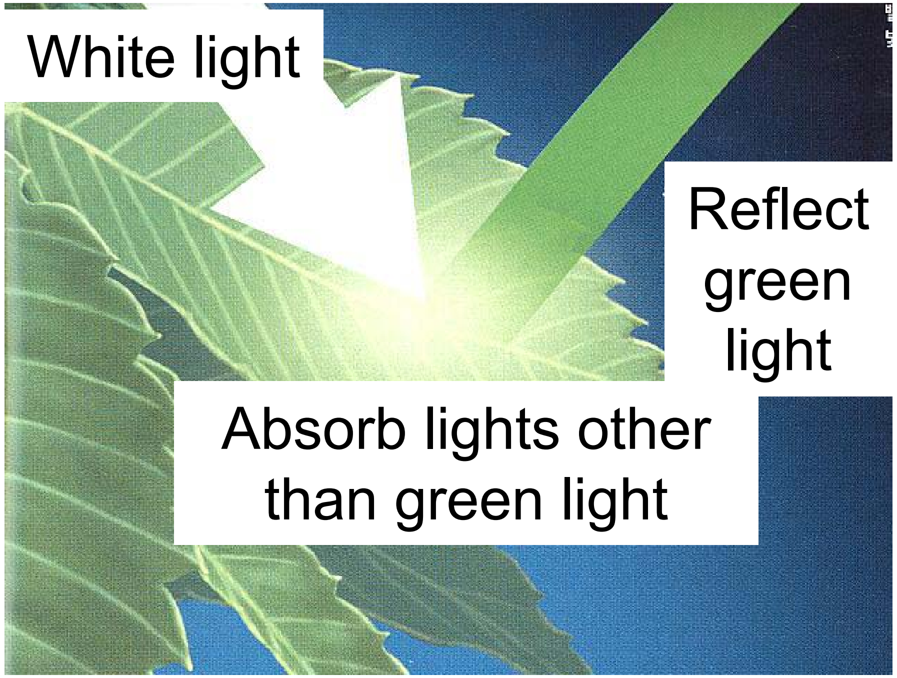
From Newton magazine



Eye

Question: How Can We See Objects?

- **Emission and *reflection*!**



From Newton magazine

Light (sub-class of electromagnetic waves)

Eye

- **How about mirrors and white papers?**

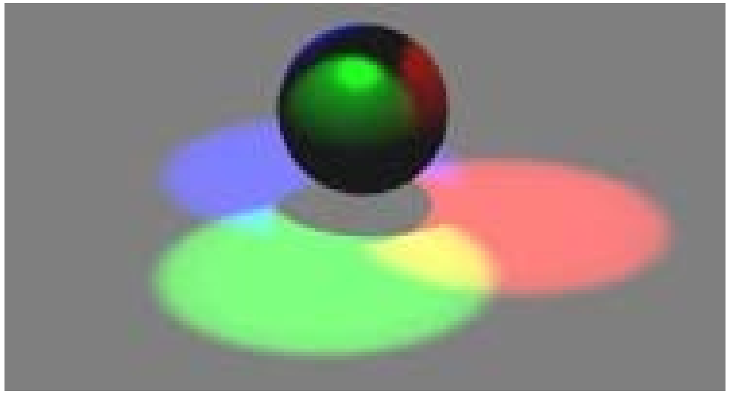
Illumination Models

- Physically-based
  - **Models based on the actual physics of light's interactions with matter**
- Empirical
  - **Simple formulations that approximate observed phenomenon**

- **Used to use many empirical models, but move towards using physically-based models**

Two Components of Illumination

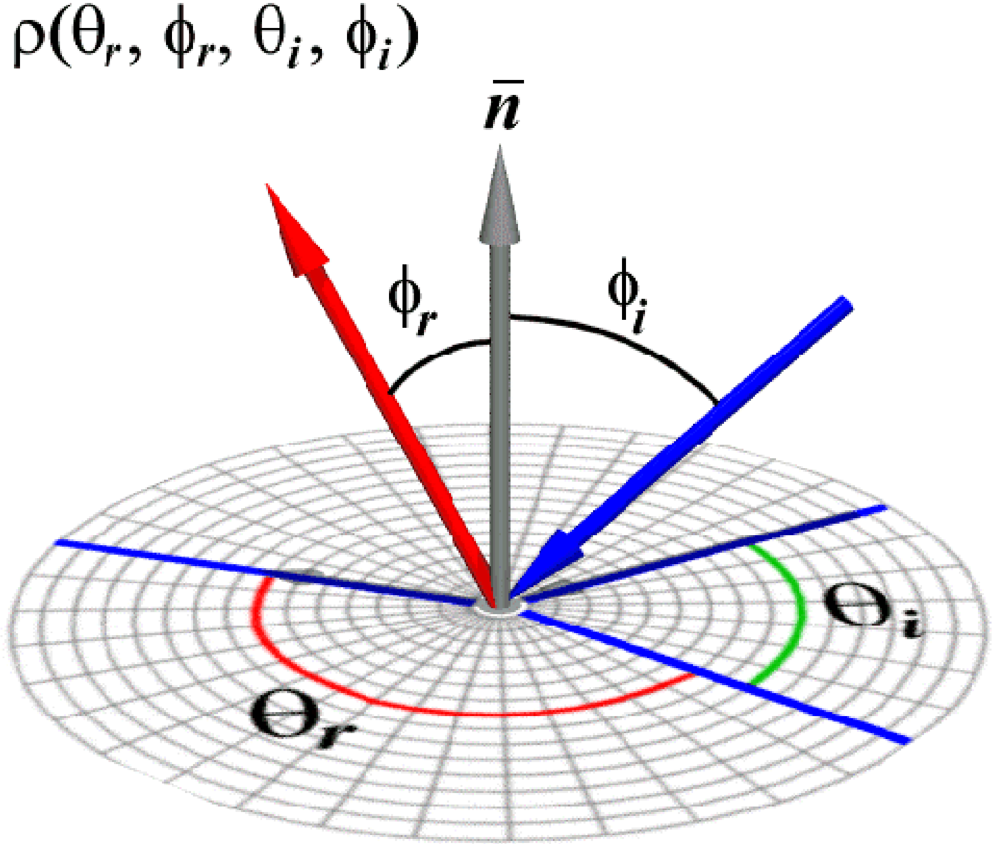
- **Light sources:**
  - **Emittance spectrum (color)**
  - **Geometry (position and direction)**
  - **Directional attenuation**



- **Surface properties:**
  - **Reflectance spectrum (color)**
  - **Geometry (position, orientation, and micro-structure)**
  - **Absorption**

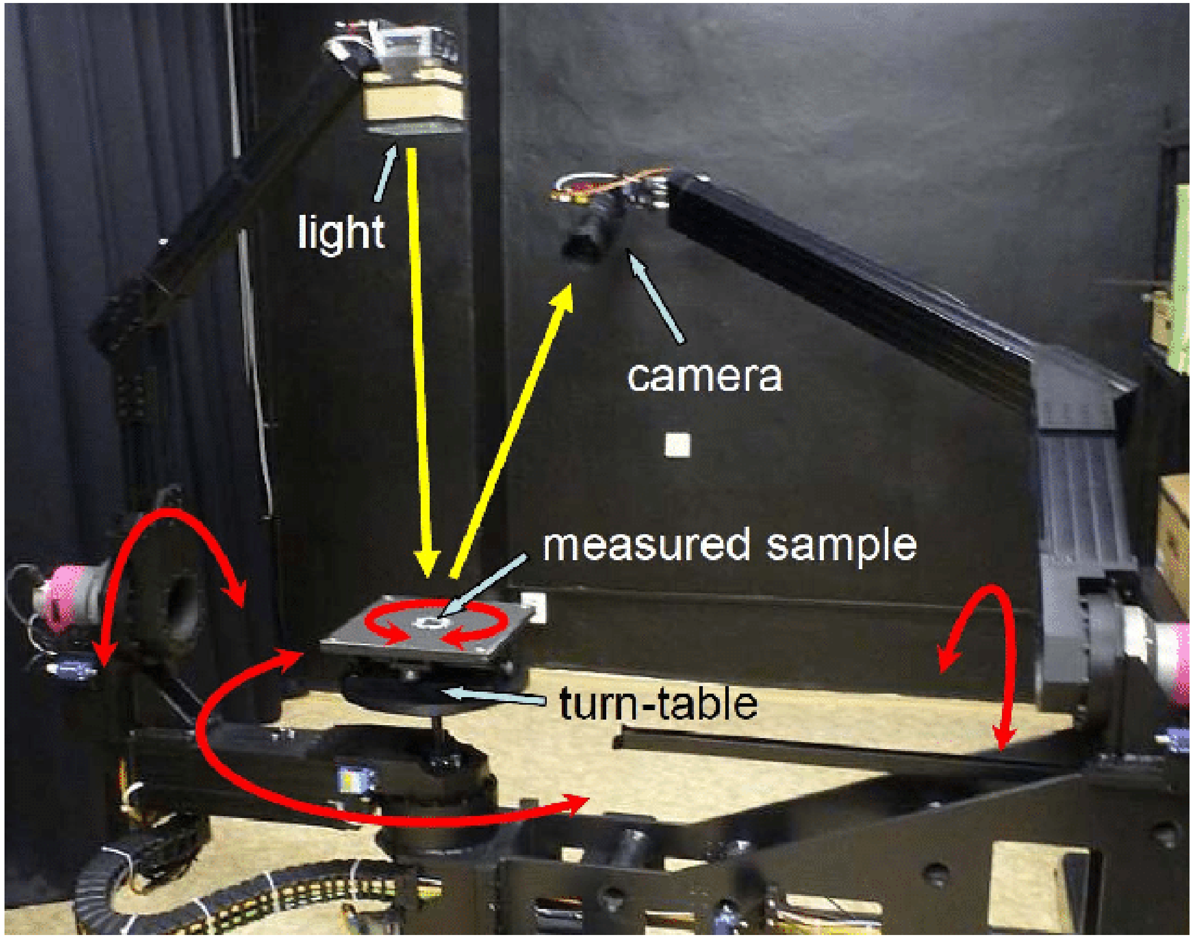
Bi-Directional Reflectance Distribution Function (BRDF)

- **Describes the transport from incoming energy to outgoing energy, i.e., radiance**



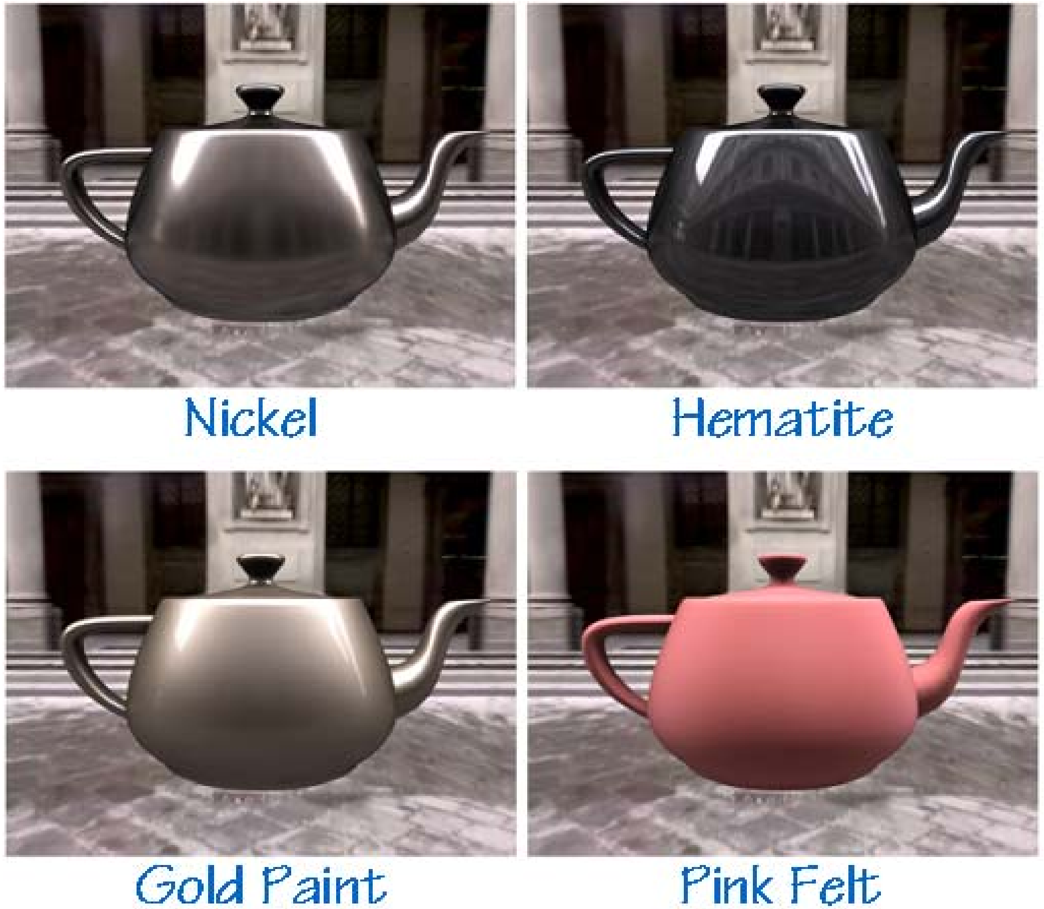
Measuring BRDFs

- **Gonioreflectometer**
  - **One 4D measurement at a time (slow)**



Ack. Filip

How to use BRDF Data?



One can make direct use of acquired BRDFs in a renderer

Two Components of Illumination

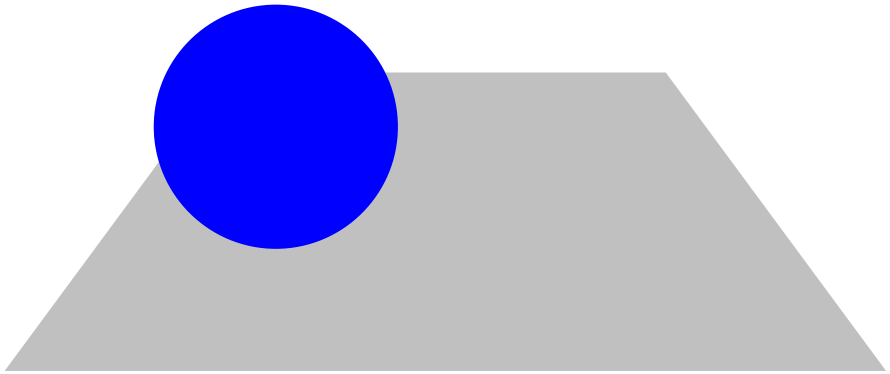
- **Simplifications used by most computer graphics systems:**
  - **Compute only direct illumination from the emitters to the reflectors of the scene**
  - **Ignore the geometry of light emitters, and consider only the geometry of reflectors**

Ambient Light Source

- **A simple <u>hack</u> for indirect illumination**
  - **Incoming ambient illumination ($I_{i,a}$) is constant for all surfaces in the scene**
  - **Reflected ambient illumination ($I_{r,a}$) depends only on the surface's ambient reflection coefficient (k_a) and not its position or orientation**

$$I_{r,a} = k_a I_{i,a}$$

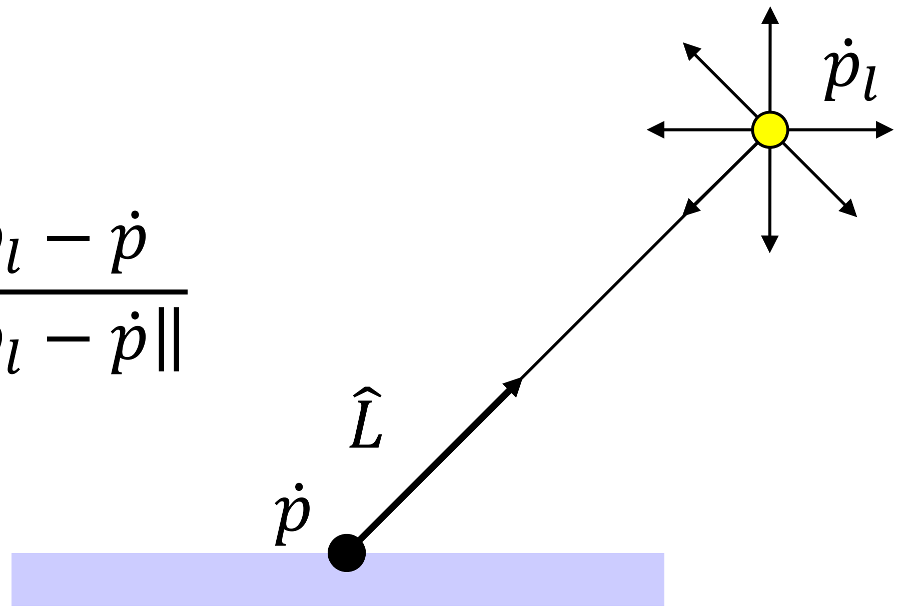
  - **These quantities typically specified as (R, G, B) triples**



Point Light Sources

- **Point light sources emit rays from a single point**
  - **Simple approximation to a local light source such as a light bulb**

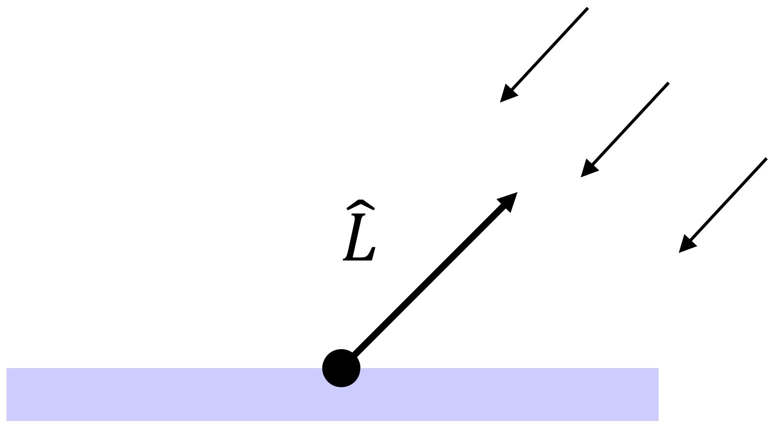
$$\hat{L} = \frac{\dot{p}_l - \dot{p}}{||\dot{p}_l - \dot{p}||}$$



- **The direction to the light changes across the surface**

Directional Light Sources

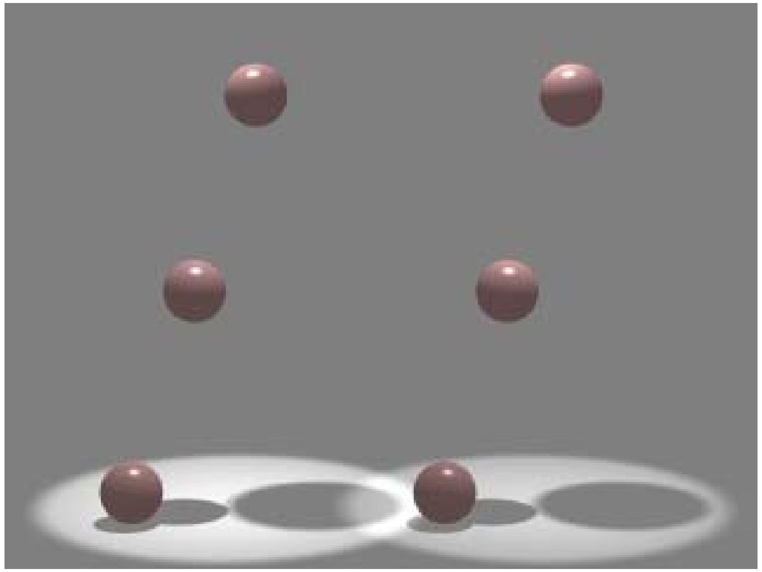
- **Light rays are parallel and have no origin**
  - **Can be considered as a point light at infinity**
  - **A good approximation for sunlight**

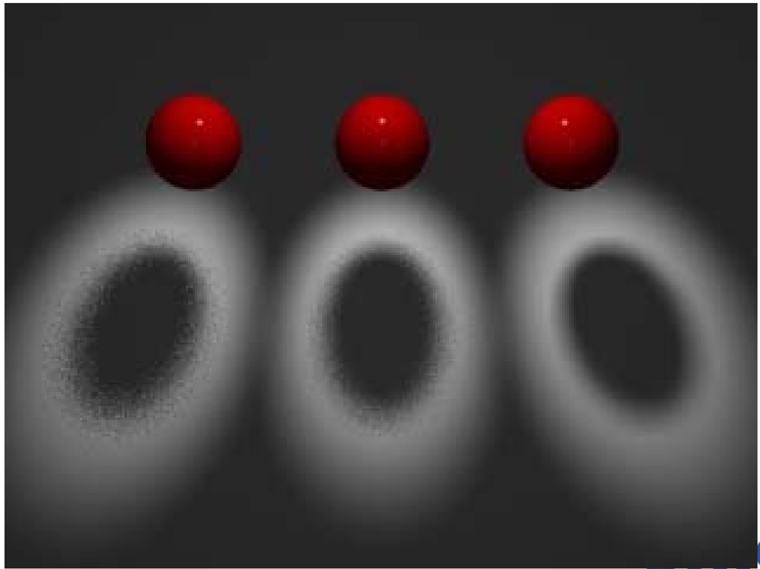


- **The direction to the light source is constant over the surface**
- **How can we specify point and directional lights?**

Other Light Sources

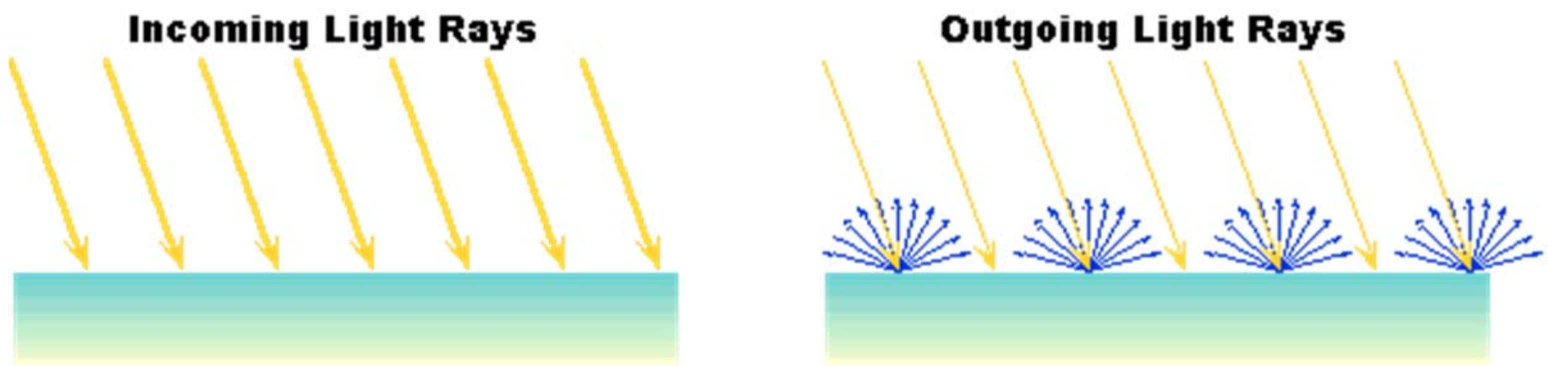
- **Spotlights**
  - **Point source whose intensity falls off away from a given direction**
- **Area light sources**
  - **Occupies a 2D area (e.g. a polygon or a disk)**
  - **Generates *soft* shadows**





Ideal Diffuse Reflection

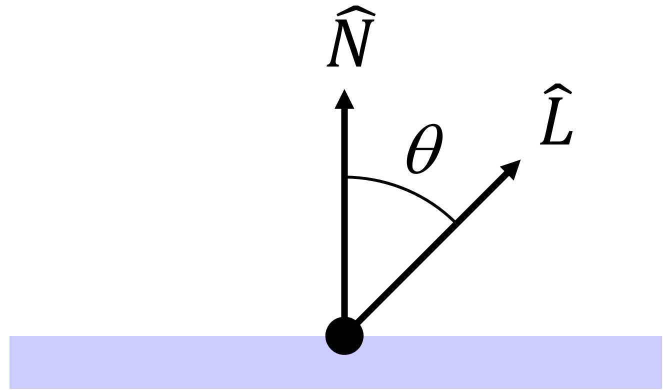
- Ideal diffuse reflectors (e.g., chalk)
  - Reflect uniformly over the hemisphere
  - Reflection is view-independent
  - Very rough at the microscopic level
- Follow Lambert's cosine law

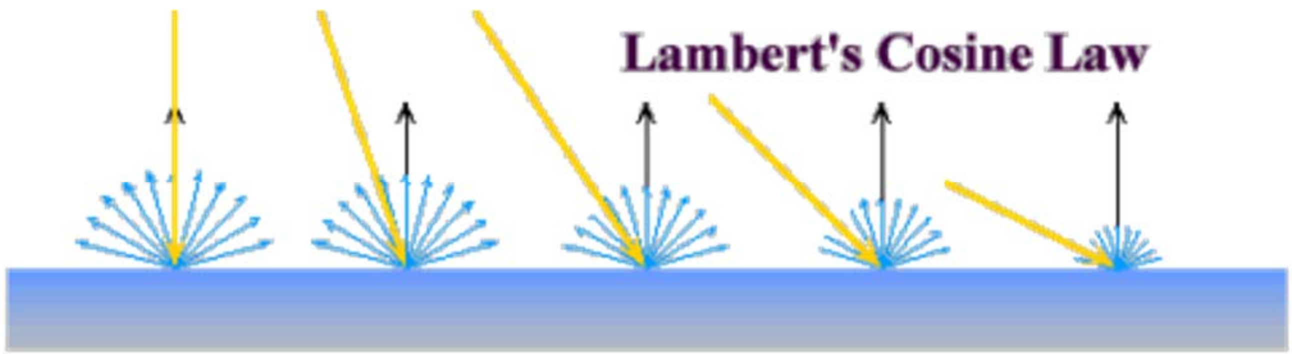


Lambert's Cosine Law

- **The reflected energy from a small surface area from illumination arriving from direction $\hat{L}$ is proportional to the cosine of the angle between $\hat{L}$ and the surface normal**

$$I_r \approx I_i \cos\theta$$
$$\approx I_i(\hat{N} \bullet \hat{L})$$





Computing Diffuse Reflection

- **Constant of proportionality depends on surface properties**

$$I_{r,d} = k_d I_i(\hat{N} \bullet \hat{L})$$

  - **The constant k_d specifies how much of the incident light I_i is diffusely reflected**

Diffuse reflection for varying light directions

  - **When $(\hat{N} \cdot \hat{L}) < 0$ the incident light is blocked by the surface itself and the diffuse reflection is 0**

Specular Reflection

- Specular reflectors have a bright, view dependent highlight
  - E.g., polished metal, glossy car finish, a mirror
  - At the microscopic level a specular reflecting surface is very smooth
  - Specular reflection obeys Snell's law

Image source: astochimp.com and wiki

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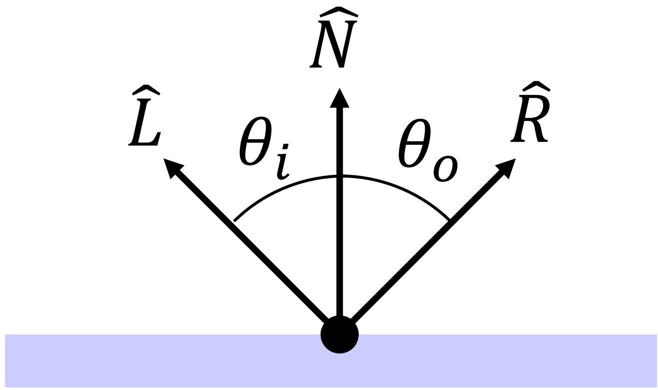
Snell's Law

- **The relationship between the angles of the incoming and reflected rays with the normal is given by:**

$$n_i \sin\theta_i = n_o \sin\theta_o$$



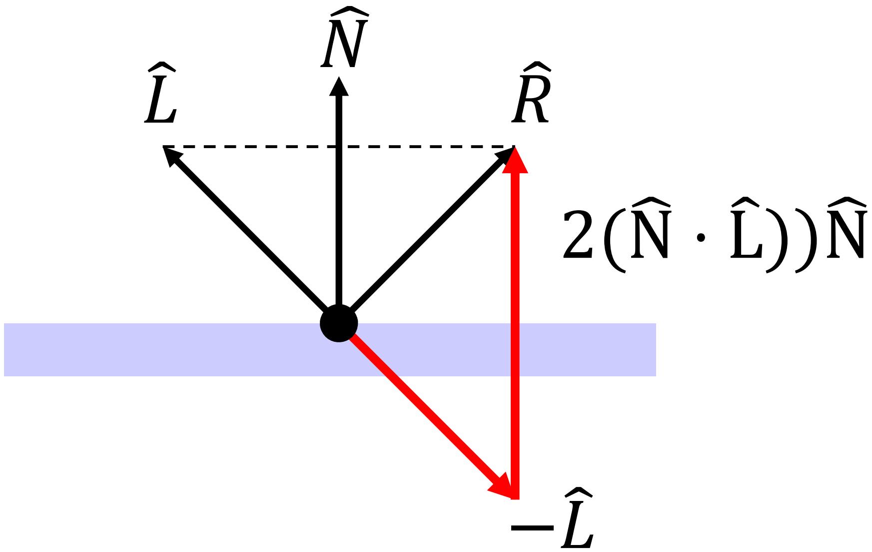
  - **n_i and n_o are the indices of refraction for the incoming and outgoing ray, respectively**
  - **Reflection is a special case where $n_i = n_o$ so $\theta_o = \theta_i$**
  - **The incoming ray, the surface normal, and the reflected ray all lie in a common plane**

Computing the Reflection Vector

- **The vector $\hat{R}$ can be computed from the incoming light direction and the surface normal as shown below:**

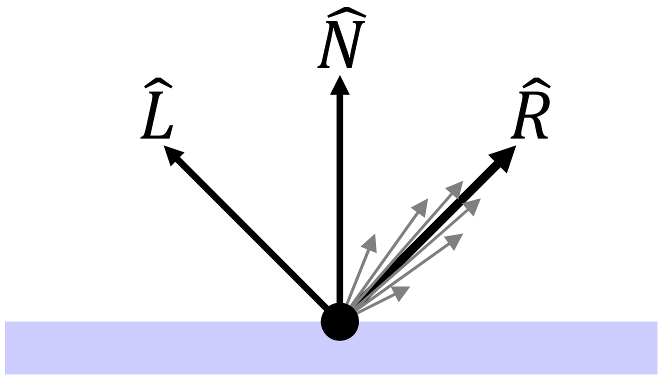
$$\hat{R} = (2(\hat{N} \cdot \hat{L}))\hat{N} - \hat{L}$$

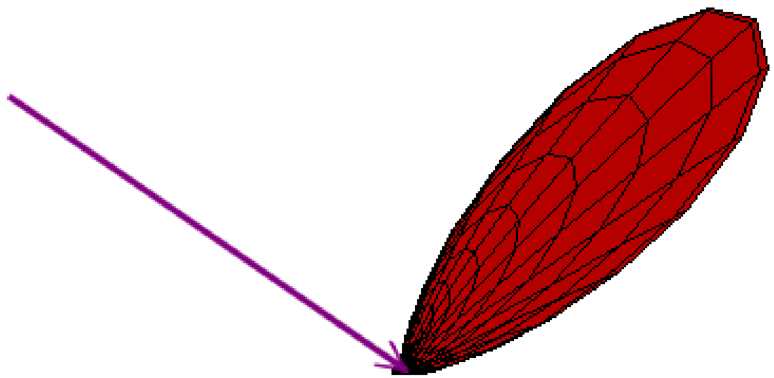
- **How?**



Non-Ideal Reflectors

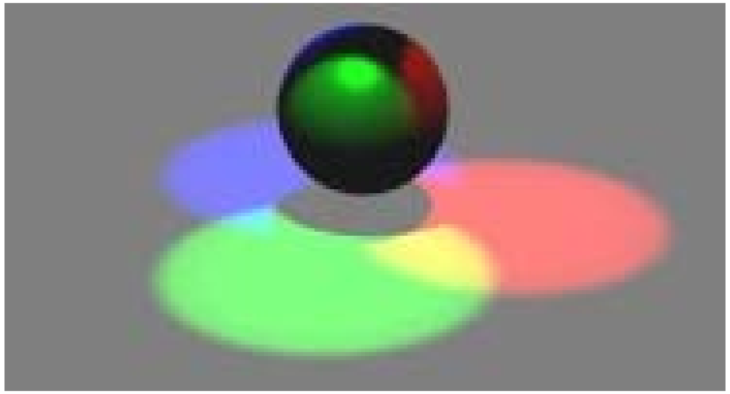
- **Snell's law applies only to *ideal* specular reflectors**
  - **Roughness of surfaces causes highlight to "spread out"**
  - **Empirical models try to simulate the appearance of this effect, without trying to capture the physics of it**

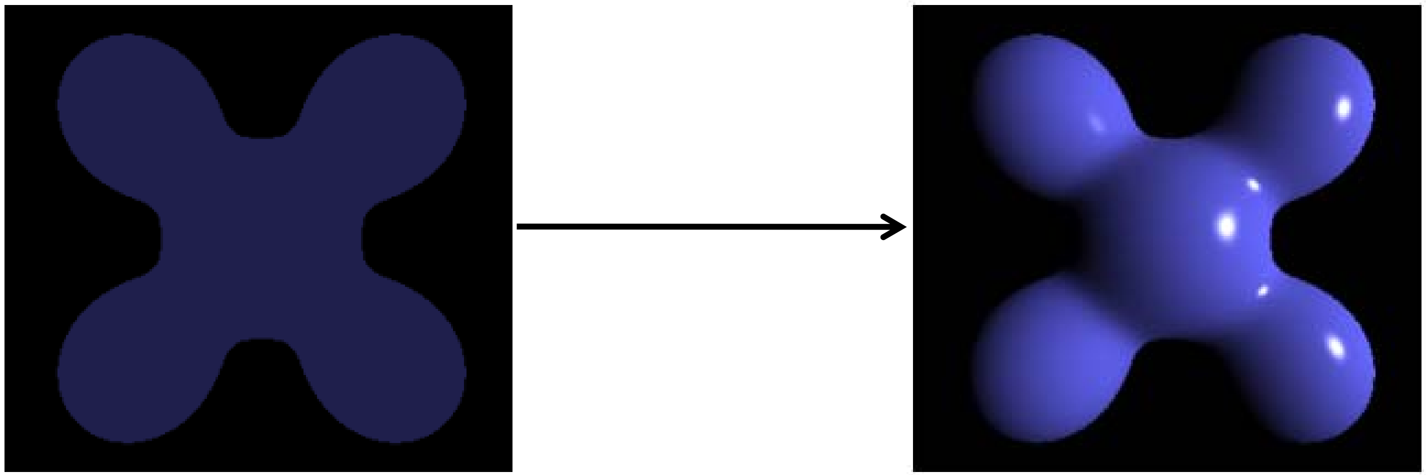




Course Objectives were:

- Know how to consider lights during rendering models
  - Light sources
  - Ambient, diffuse, and ideal specular terms





Homework

- **Go over the next lecture slides before the class**
- **Watch 2 SIGGRAPH videos and submit your summaries before every Mon. class**
  - **Just one paragraph for each summary**
- **Submit questions two times during the whole semester**

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Next Time

- **Putting them all together**
- **Shading**