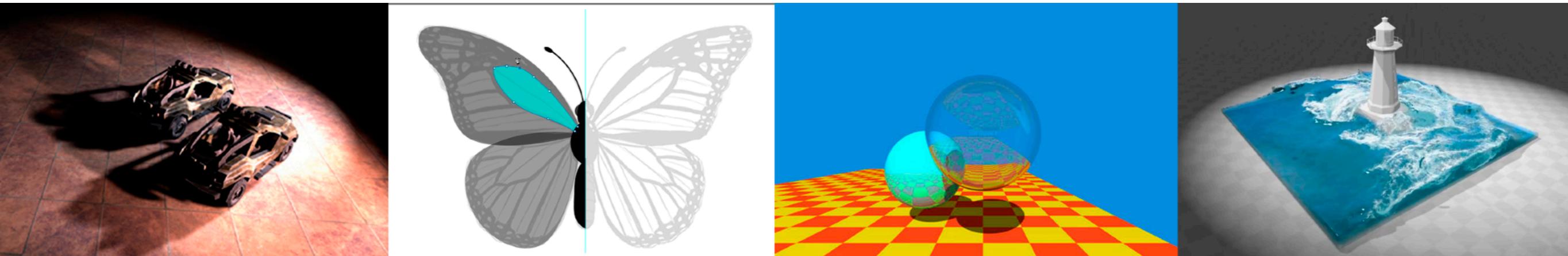


Introduction to Computer Graphics

GAMES101, Lingqi Yan, UC Santa Barbara

Lecture 7: Shading 1 (Illumination, Shading and Graphics Pipeline)



Announcements

- Homework 1
 - 300+ submissions
 - Will start TA recruiting (from existing applications) soon
- Homework 2 will be out today
 - About Z-buffering
 - Much easier than HW1
- May need an additional lecture for shading

Last Lectures

- Rasterization
 - Rasterizing **one triangle**
 - Sampling theory
 - Antialiasing

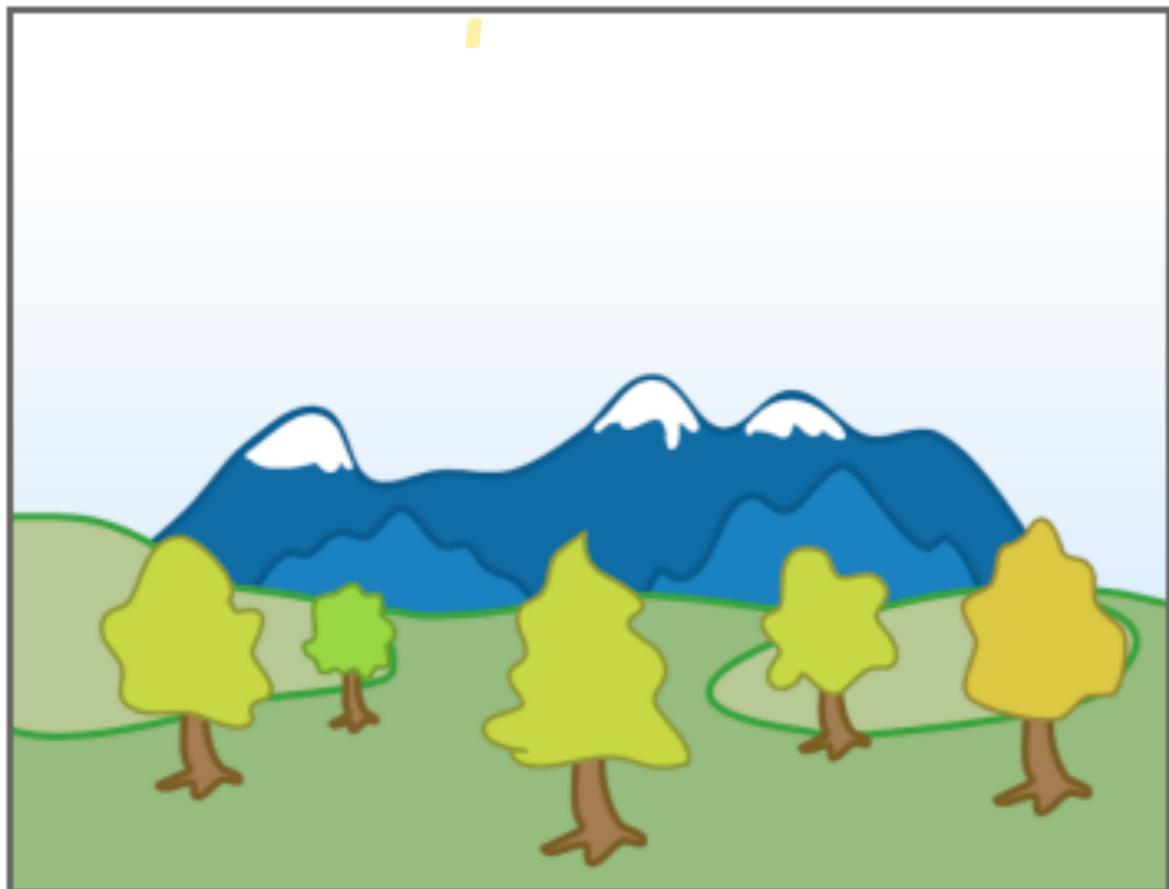
Today

- **Visibility / occlusion**
 - Z-buffering
- Shading
 - Illumination & Shading
 - Graphics Pipeline

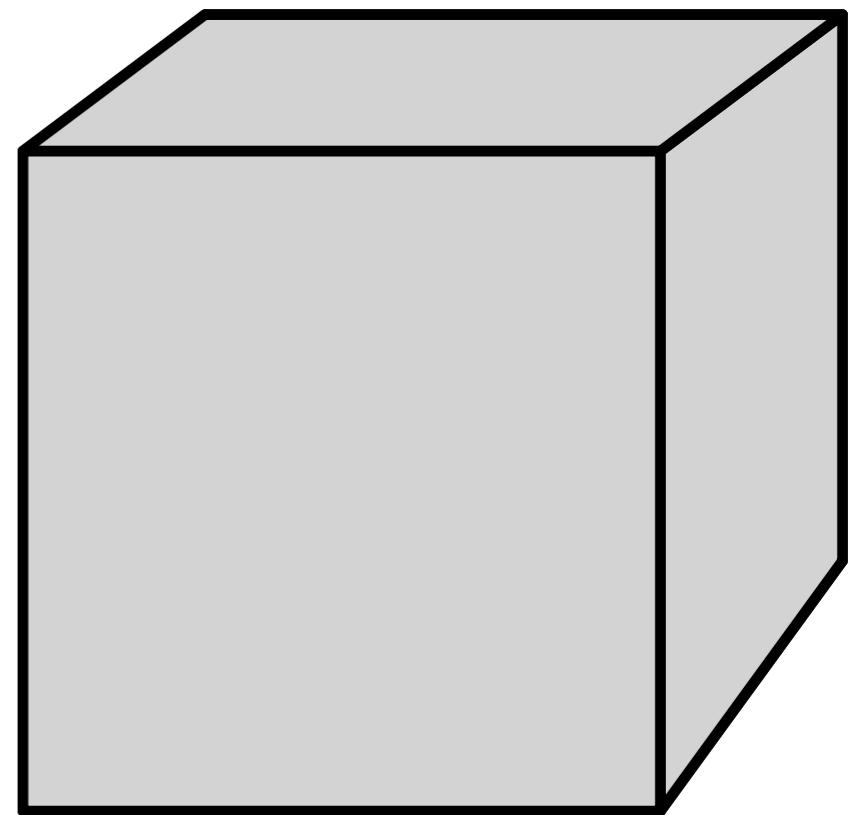
Painter's Algorithm

Inspired by how painters paint

Paint from back to front, **overwrite** in the framebuffer



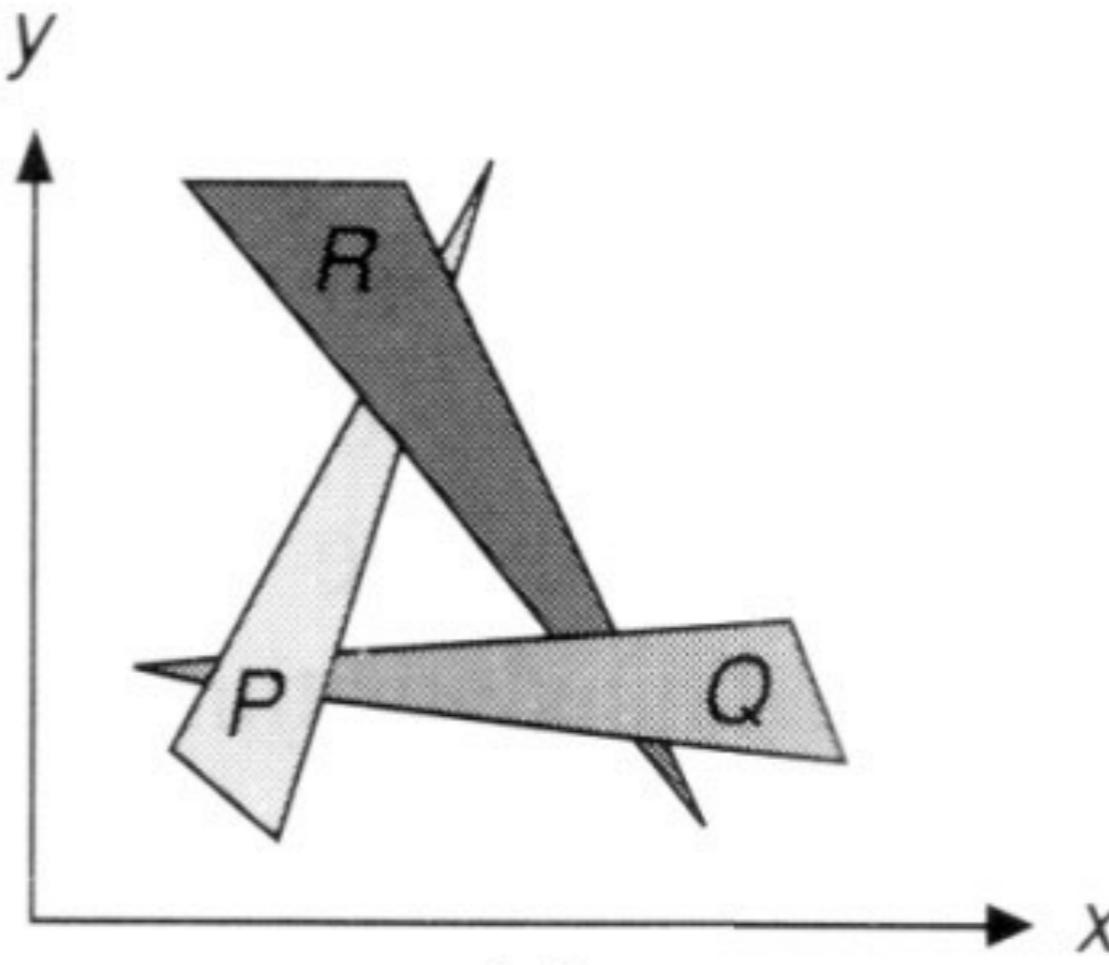
[Wikipedia]



Painter's Algorithm

Requires sorting in depth ($O(n \log n)$ for n triangles)

Can have unresolvable depth order



[Foley et al.]

Z-Buffer

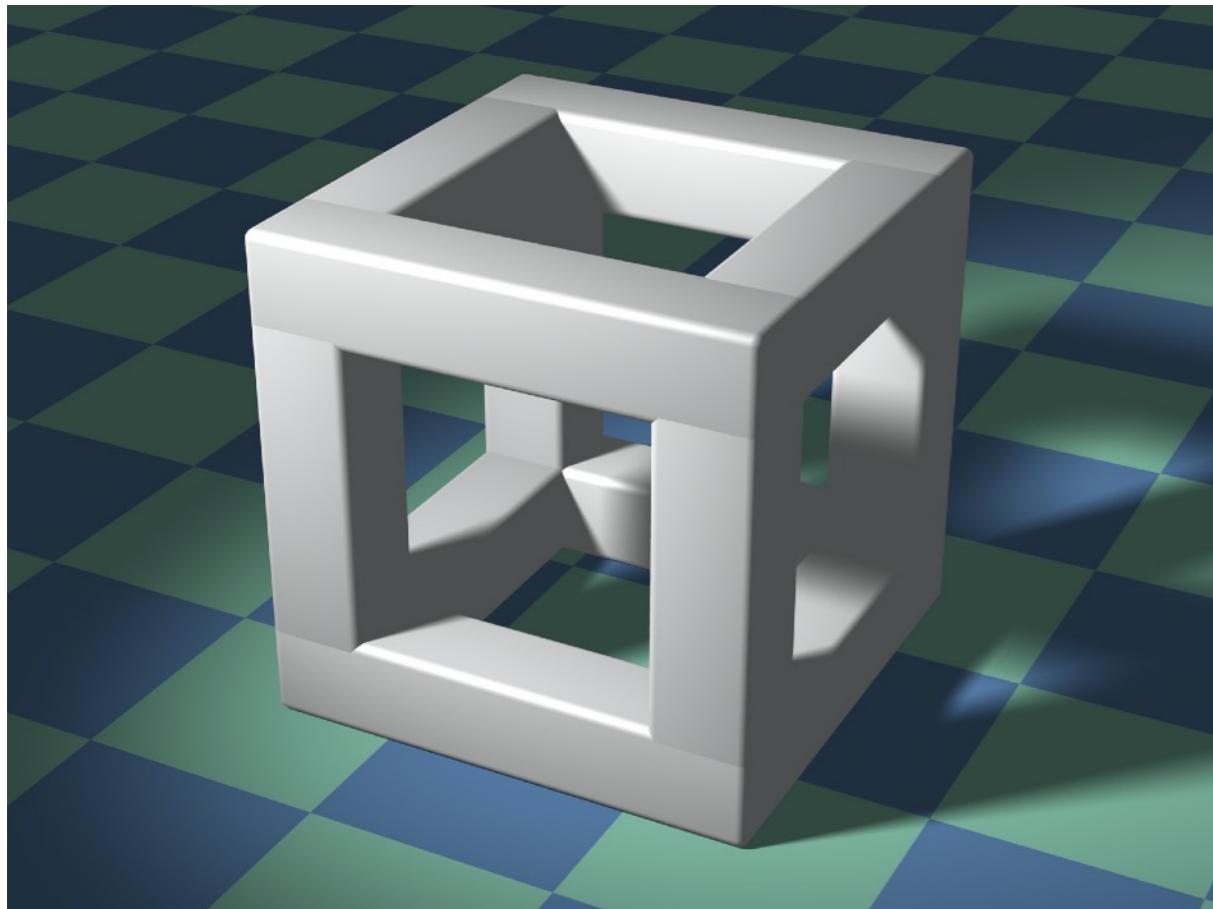
This is the algorithm that eventually won.

Idea:

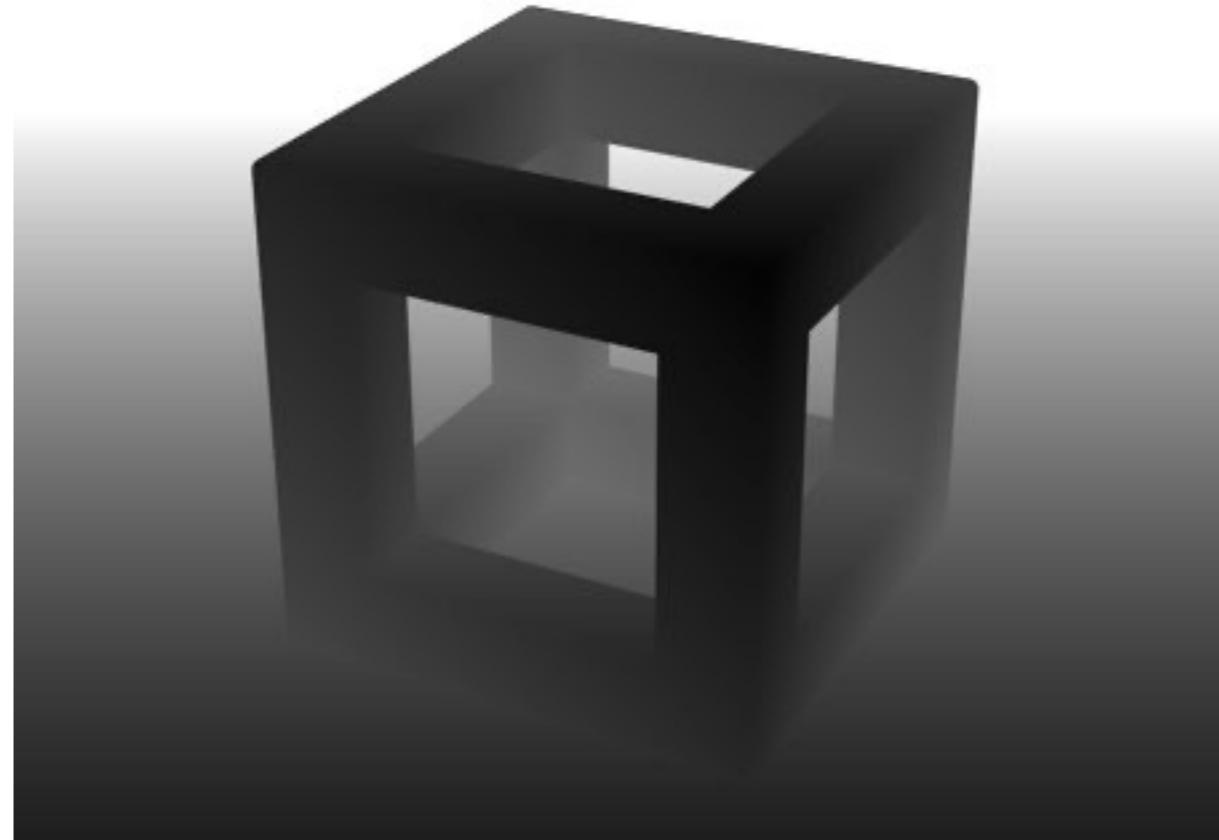
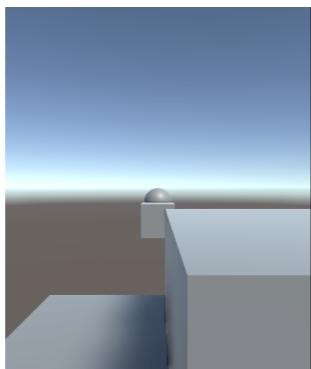
- Store current min. z-value **for each sample (pixel)**
- Needs an additional buffer for depth values
 - frame buffer stores color values
 - depth buffer (z-buffer) stores depth

IMPORTANT: For simplicity we suppose
z is always positive
(smaller $z \rightarrow$ closer, larger $z \rightarrow$ further)

Z-Buffer Example



Rendering



Depth / Z buffer



Yanqiqi Yan, UC Santa Barbara

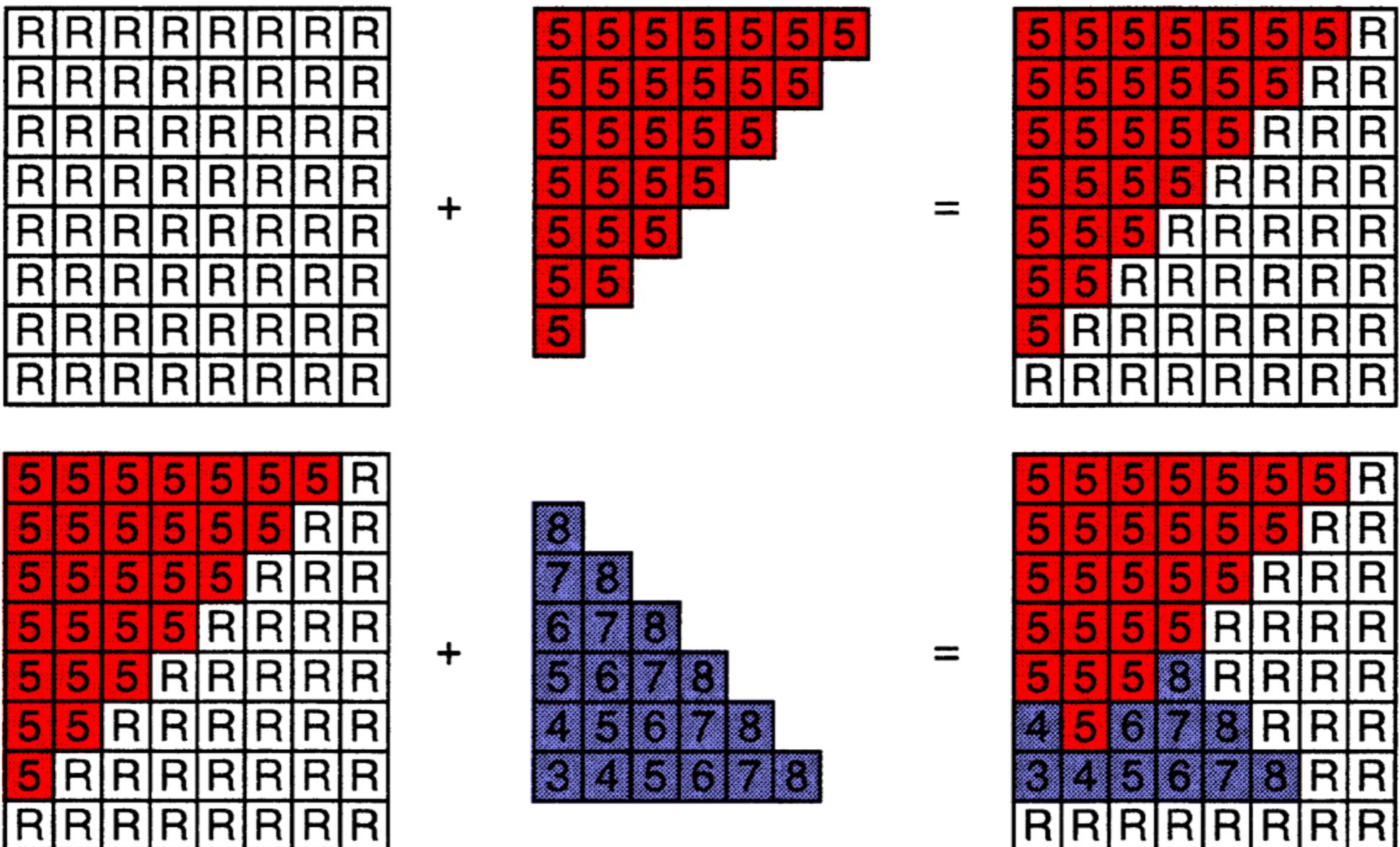
Z-Buffer Algorithm

Initialize depth buffer to ∞

During rasterization:

```
for (each triangle T)
    for (each sample (x,y,z) in T)
        if (z < zbuffer[x,y])                // closest sample so far
            framebuffer[x,y] = rgb;           // update color
            zbuffer[x,y] = z;                 // update depth
        else
            ;                                // do nothing, this sample is occluded
```

Z-Buffer Algorithm



Z-Buffer Complexity

Complexity

- $O(n)$ for n triangles (assuming constant coverage)
- How is it possible to sort n triangles in linear time?

Drawing triangles in different orders?

Most important visibility algorithm

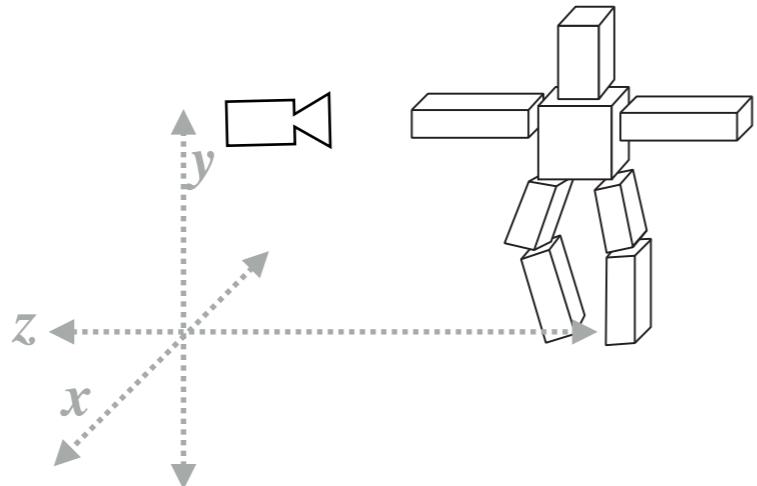
- Implemented in hardware for all GPUs

Questions?

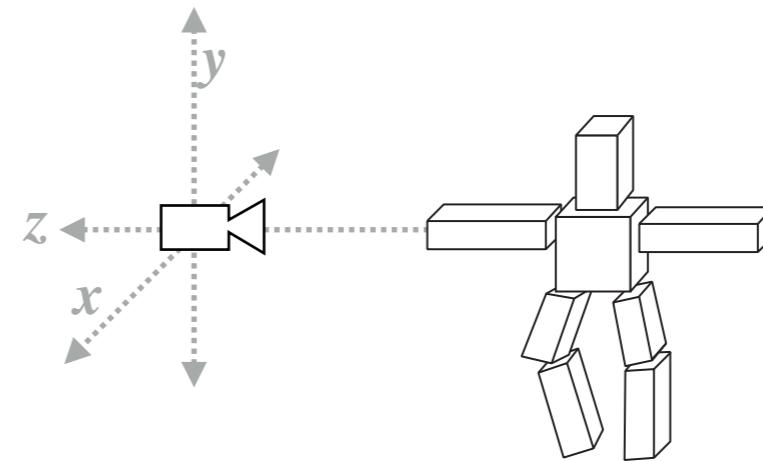
Today

- Visibility / occlusion
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- Shading
 - Illumination & Shading
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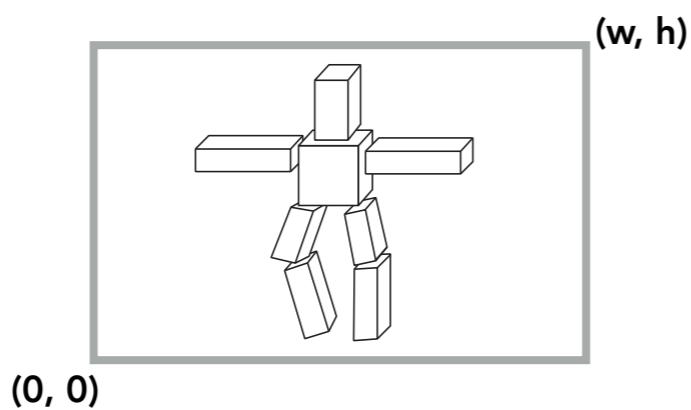
What We've Covered So Far



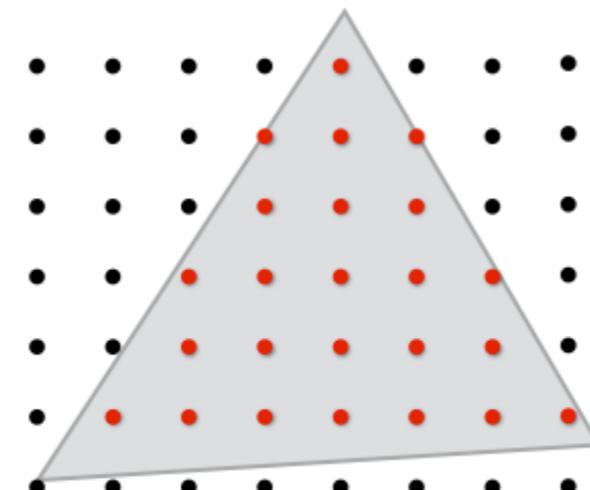
Position objects and the camera in the world



Compute position of objects relative to the camera

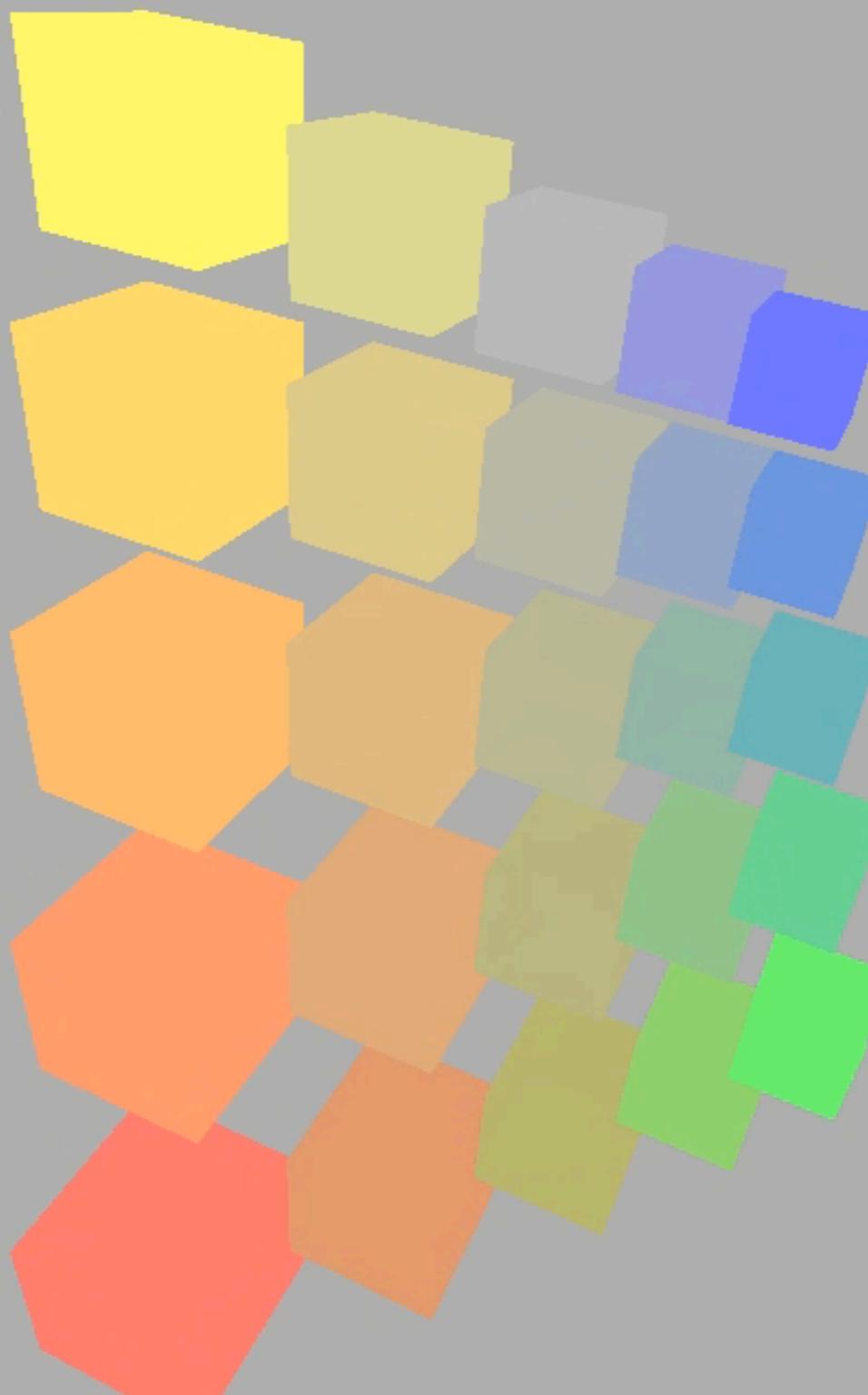


Project objects onto the screen

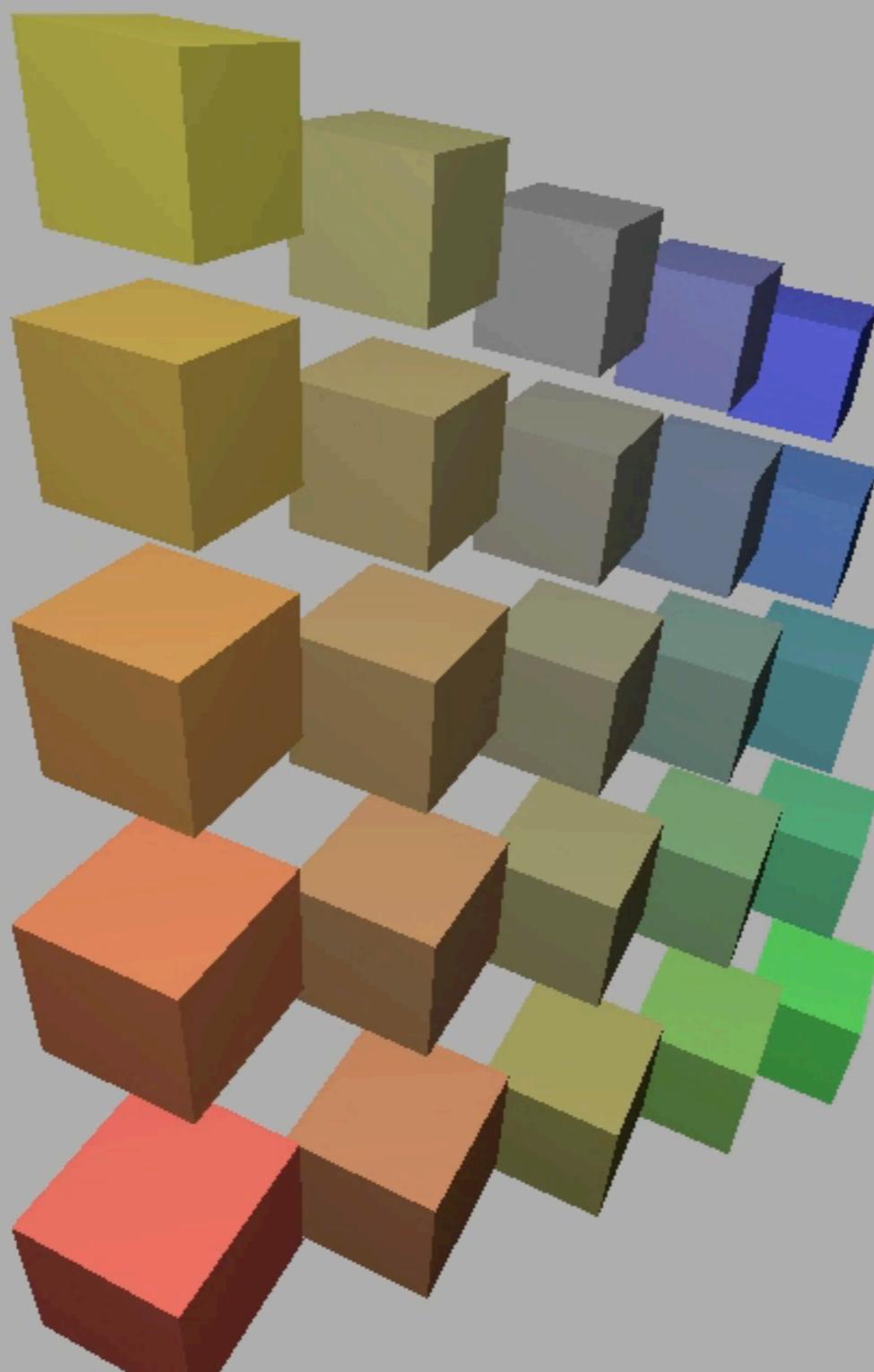


Sample triangle coverage

Rotating Cubes (Now You Can Do)



Rotating Cubes (Expected)



What Else Are We Missing?



Credit: Bertrand Benoit. "Sweet Feast," 2009. [Blender /VRay]

Shading

Shading: Definition

- * In Merriam-Webster Dictionary

shad·ing, ['ʃeɪdɪŋ], noun

The darkening or coloring of an illustration or diagram with parallel lines or a block of color.

- * In this course

The process of applying a material to an object.

A Simple Shading Model (Blinn-Phong Reflectance Model)

Perceptual Observations

Specular highlights

当光照射到一个光滑的表面时，光会沿着镜面反射附近的方向反射

Diffuse reflection

当光照射到一个粗糙的表面时，光被反射到不同的方向

Ambient lighting

物体不仅会收到主光源的影响，还会受到环境光的影响



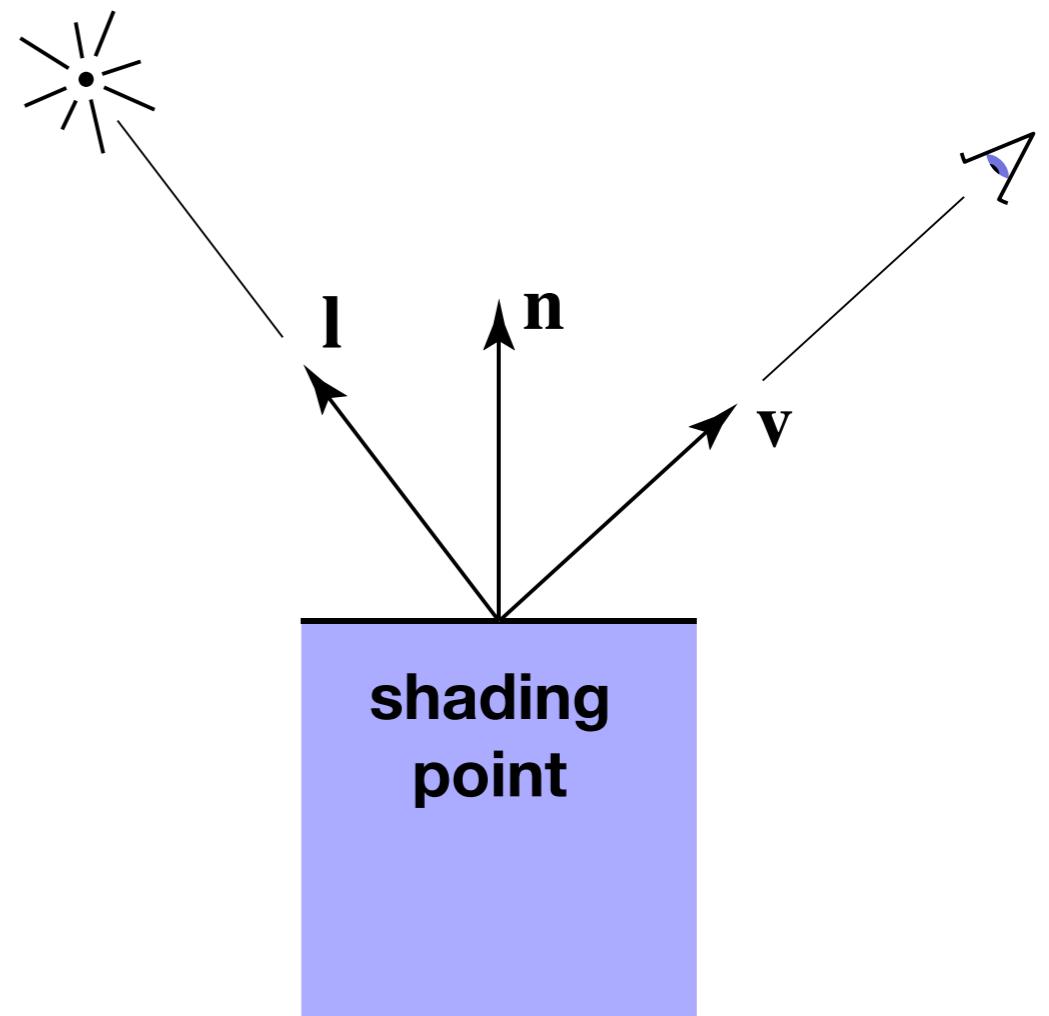
Photo credit: Jessica Andrews, flickr

Shading is Local

Compute light reflected toward camera
at a specific **shading point**

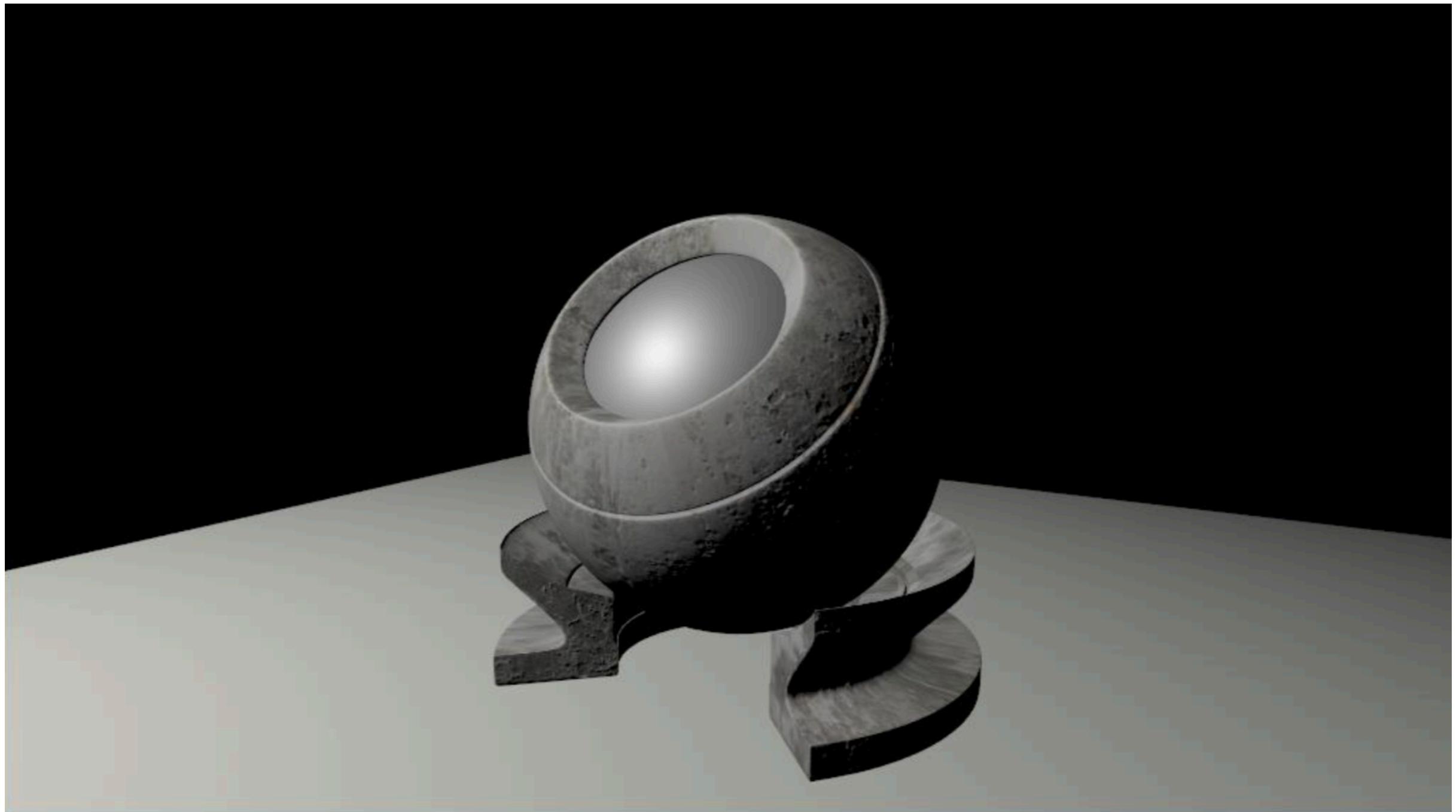
Inputs:

- Viewer direction, v
- Surface normal, n
- Light direction, l
(for each of many lights)
- Surface parameters
(color, shininess, ...)



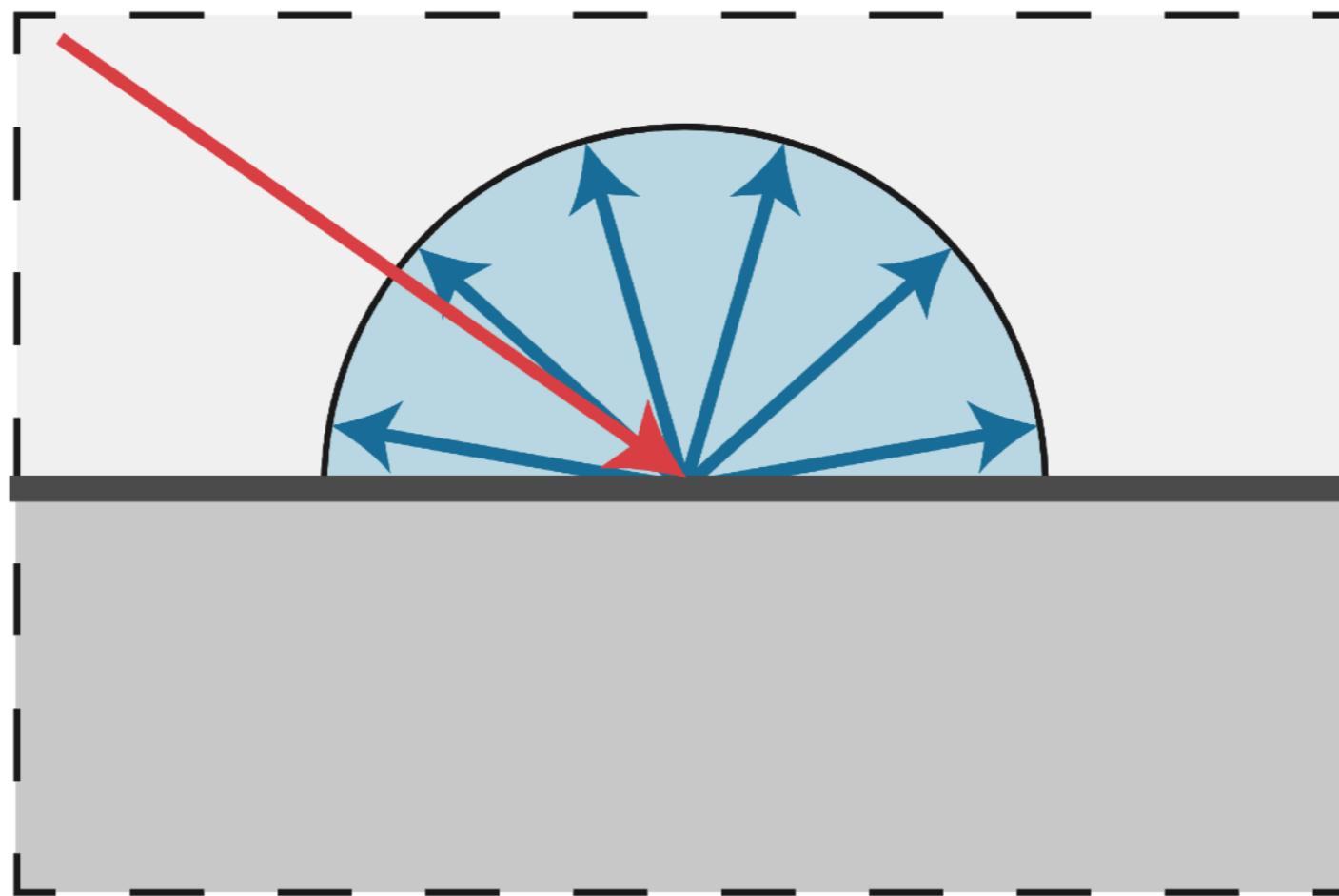
Shading is Local

No shadows will be generated! (**shading ≠ shadow**)



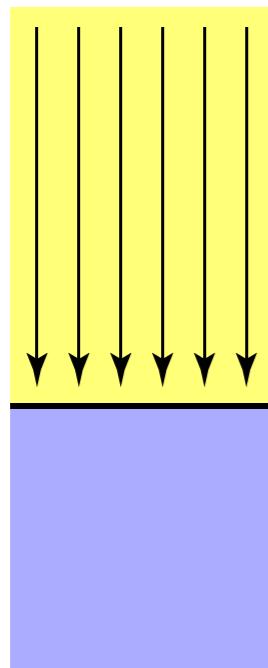
Diffuse Reflection

- Light is scattered uniformly in all directions
 - Surface color is the same for all viewing directions

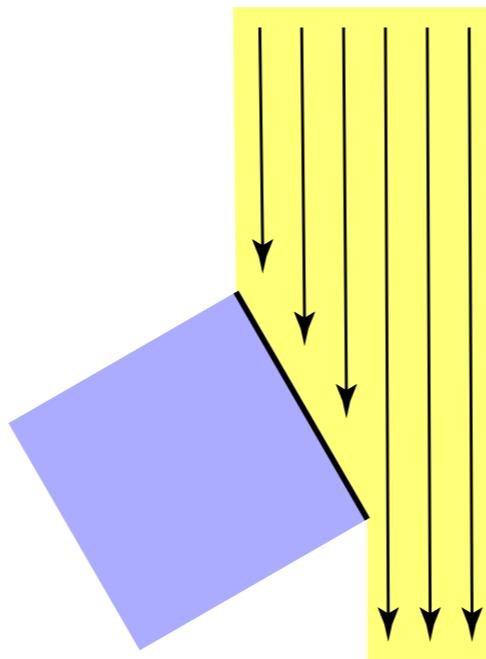


Diffuse Reflection

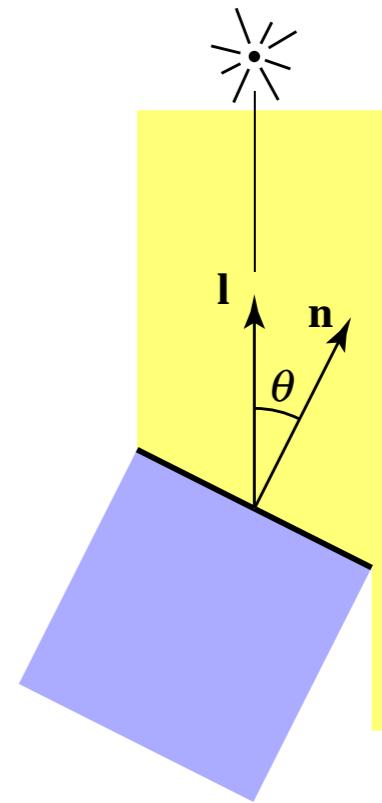
- But how much light (energy) is received?
 - Lambert's cosine law



Top face of cube receives a certain amount of light



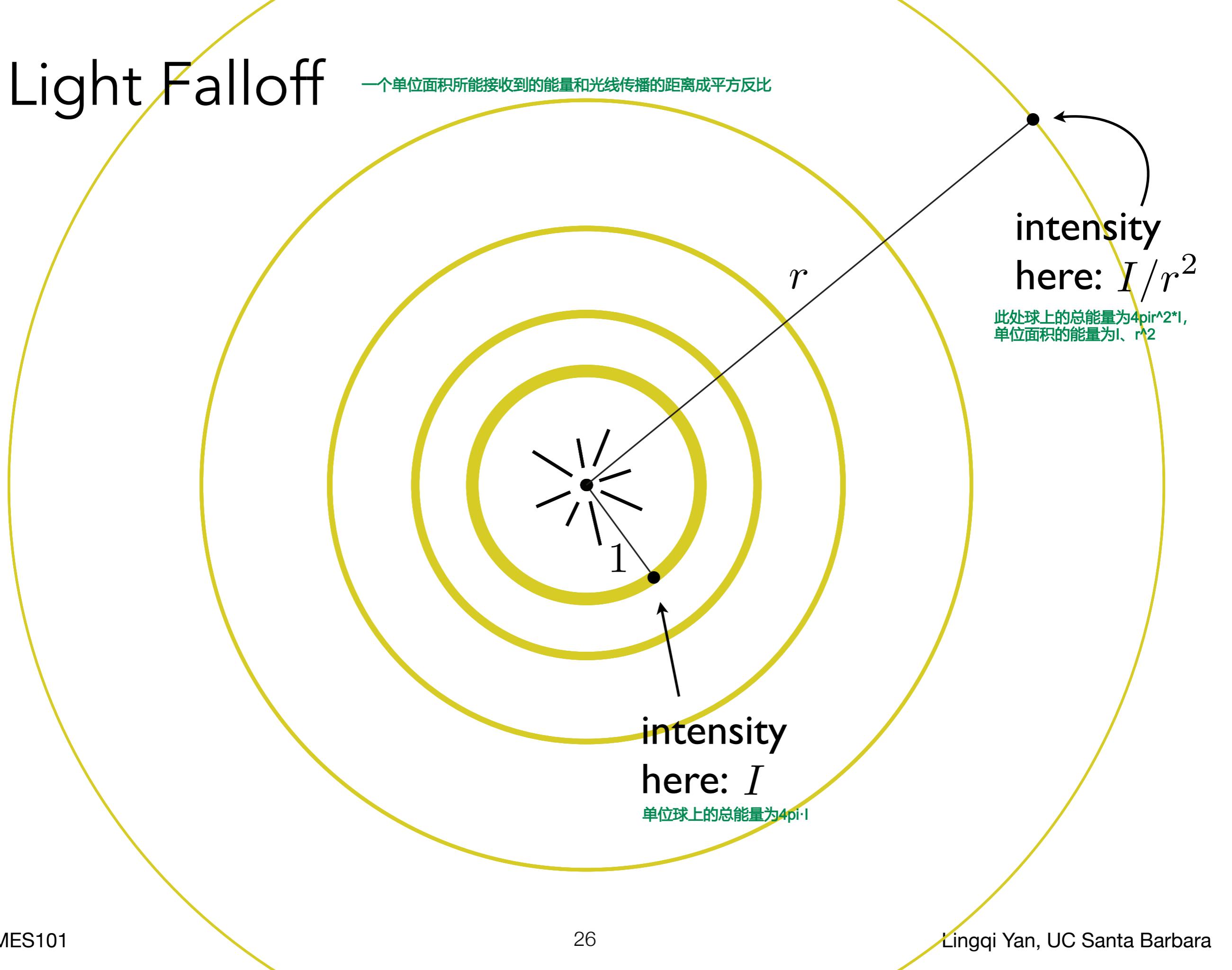
Top face of 60° rotated cube intercepts half the light



In general, light per unit area is proportional to $\cos \theta = l \cdot n$

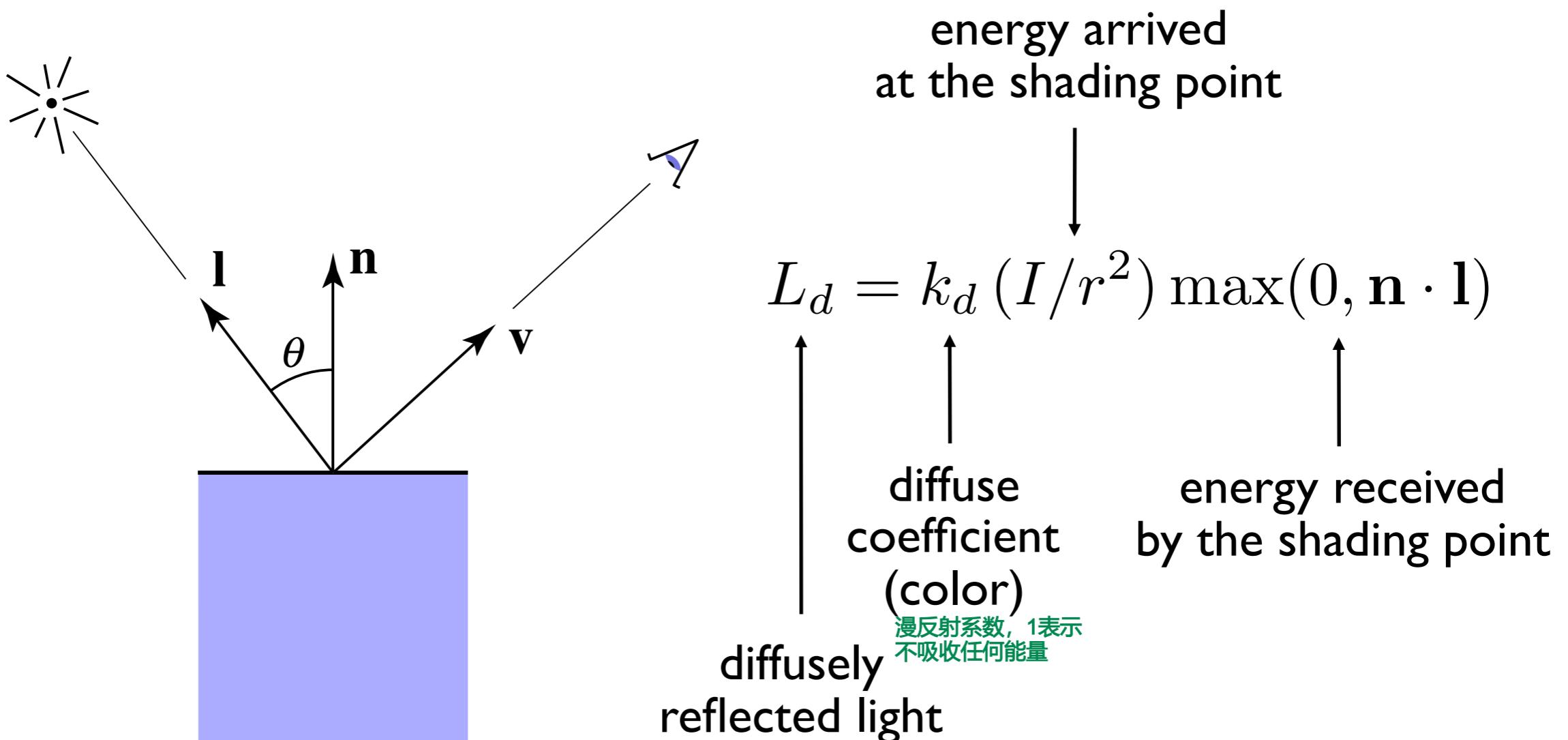
Light Falloff

一个单位面积所能接收到的能量和光线传播的距离成平方反比



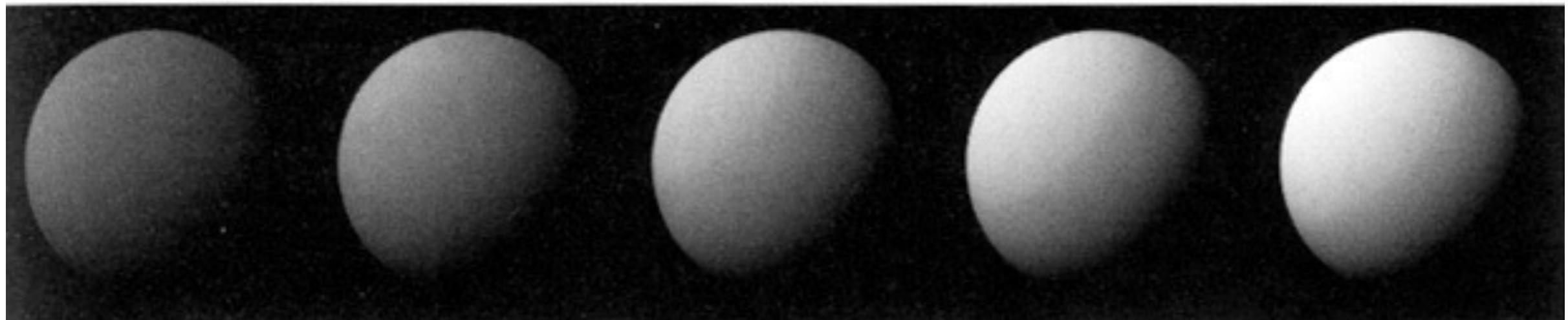
Lambertian (Diffuse) Shading

Shading **independent** of view direction



Lambertian (Diffuse) Shading

Produces diffuse appearance



$$k_d \longrightarrow$$

[Foley et al.]

Thank you!

(And thank Prof. Ravi Ramamoorthi and Prof. Ren Ng for many of the slides!)