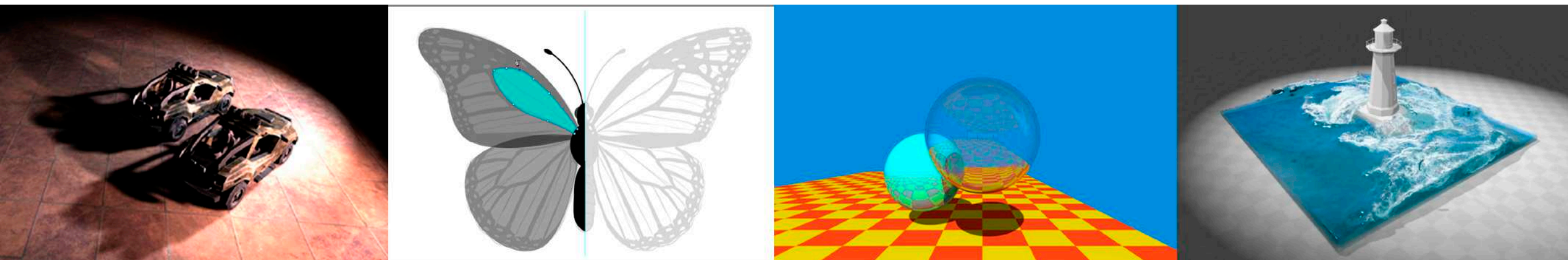


Introduction to Computer Graphics

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

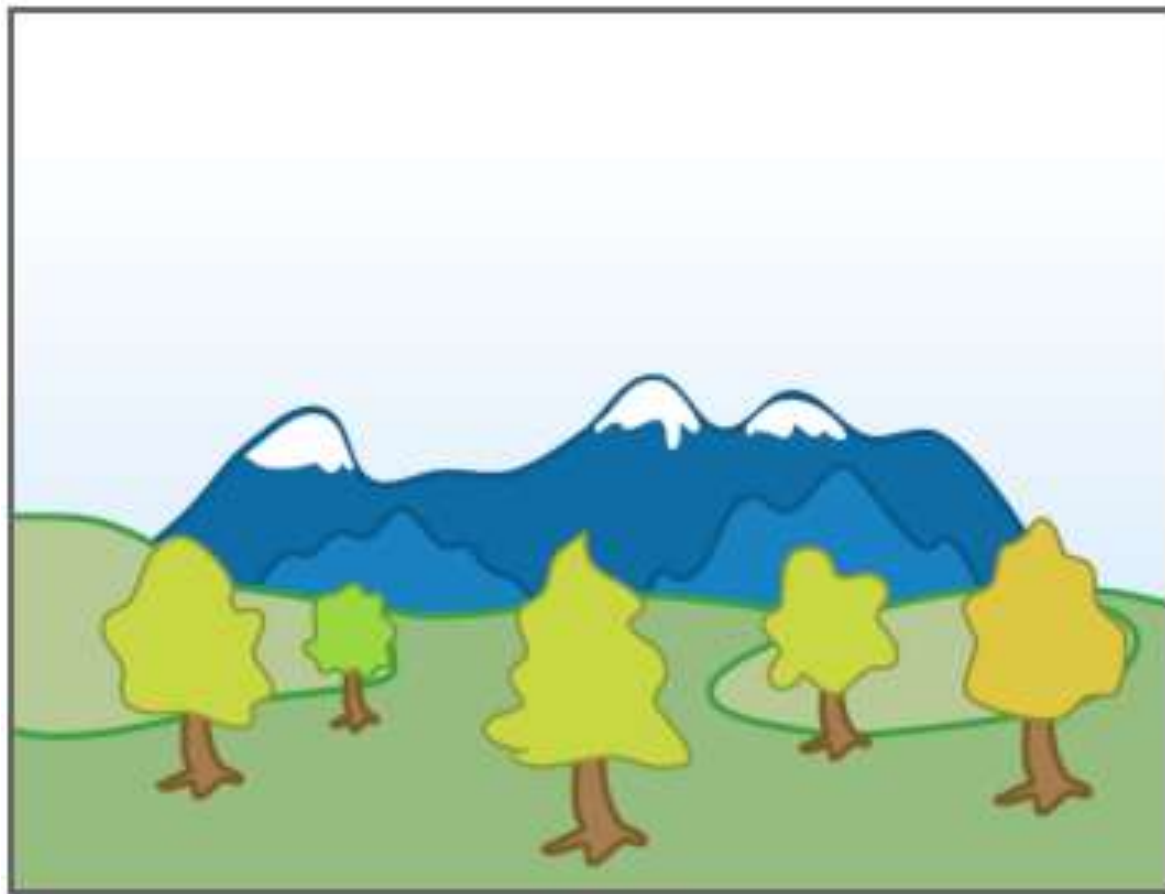
Today

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

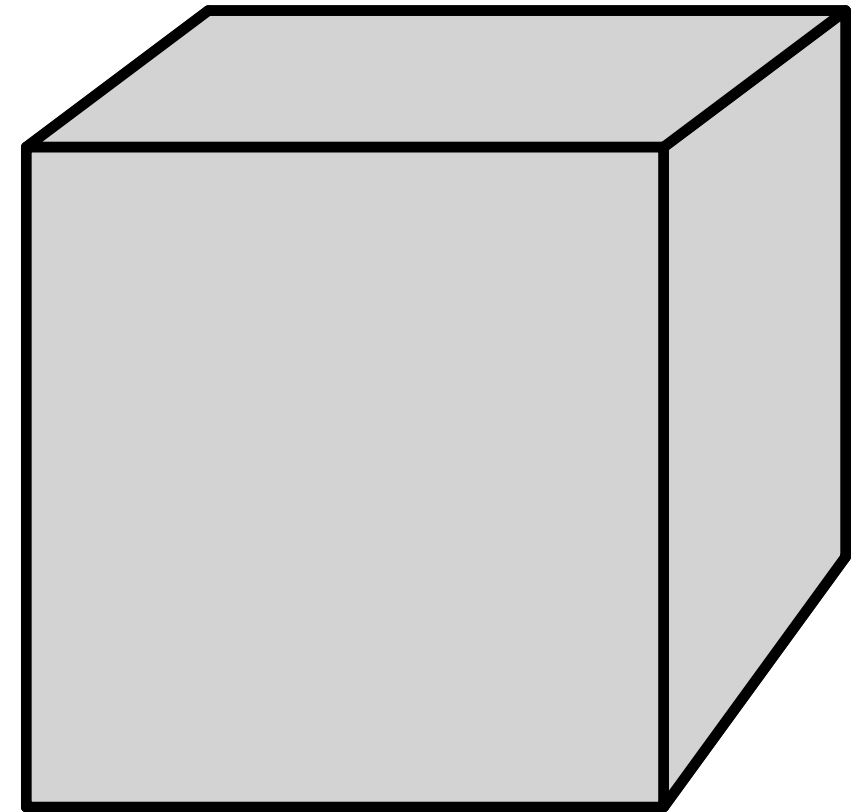
Painter's Algorithm

Inspired by how painters paint

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



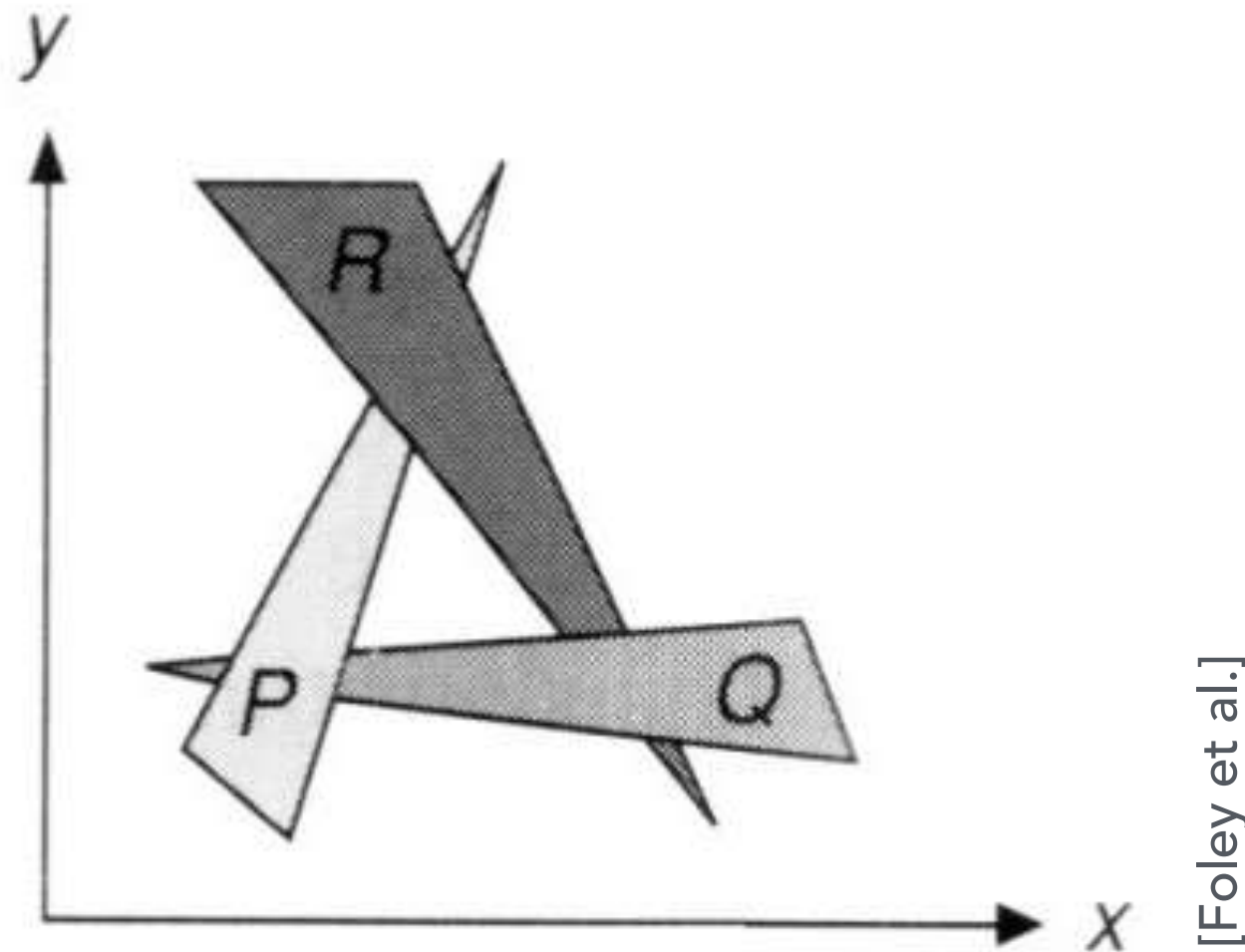
[Wikipedia]



Painter's Algorithm

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

Can have unresolvable depth order



Z-Buffer

This is the algorithm that eventually won.

Idea:

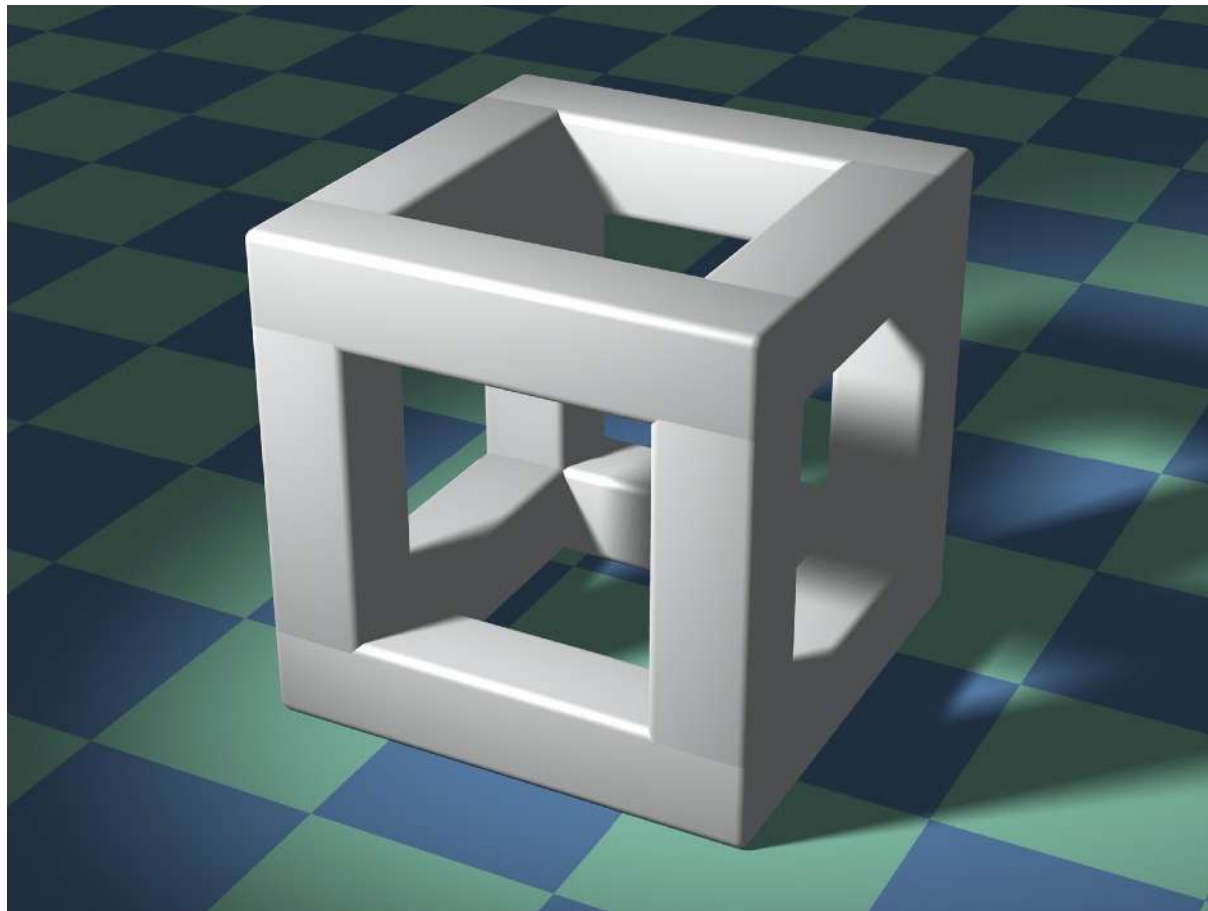
- Store current min. z-value **for each sample (pixel)**
- Needs an additional buffer for depth values
 - frame buffer stores color values
 - depth buffer (z-buffer) stores depth

IMPORTANT: For simplicity we suppose

z is always positive

(smaller z -> closer, larger z -> further)

Z-Buffer Example



Rendering

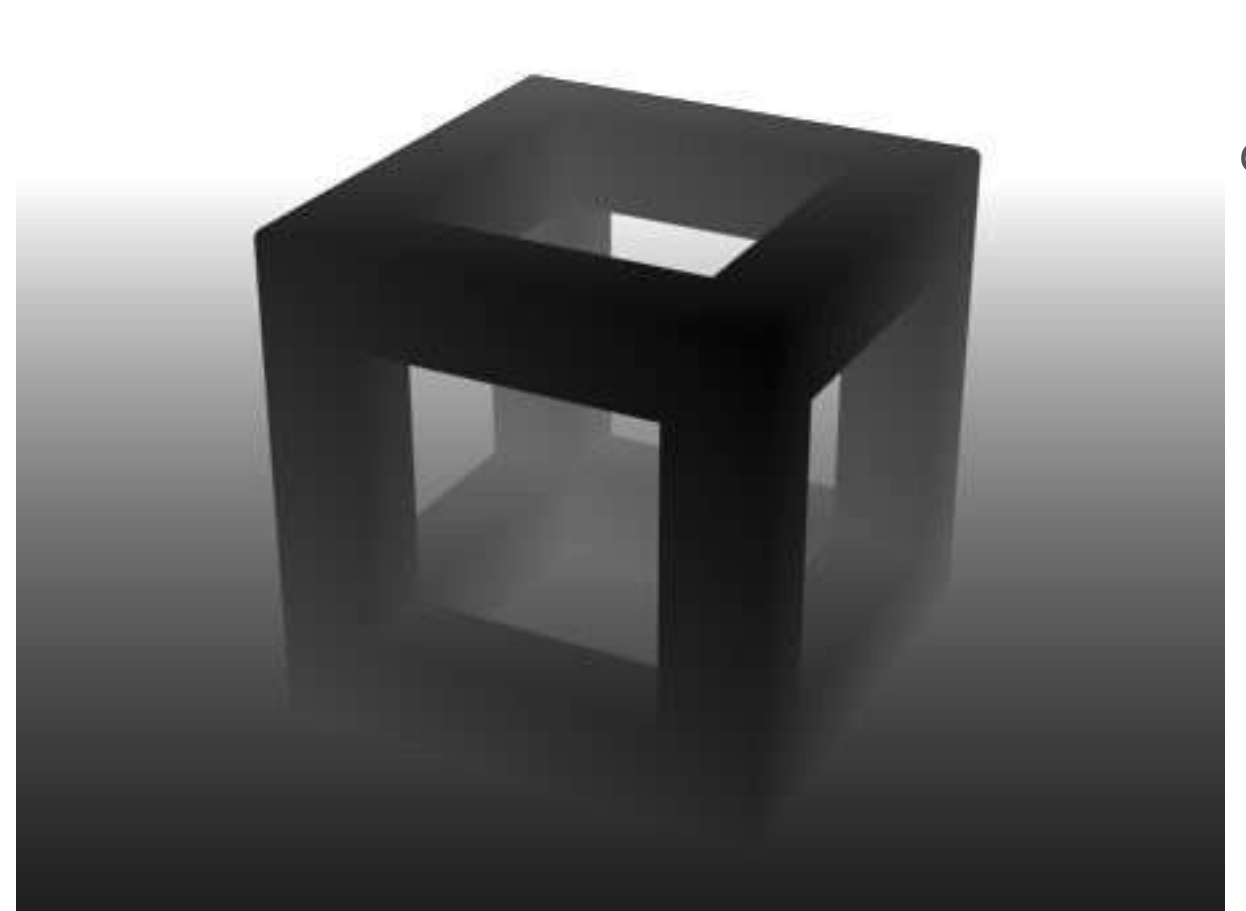


Image source: Dominic Alves, flickr.

Depth / Z buffer

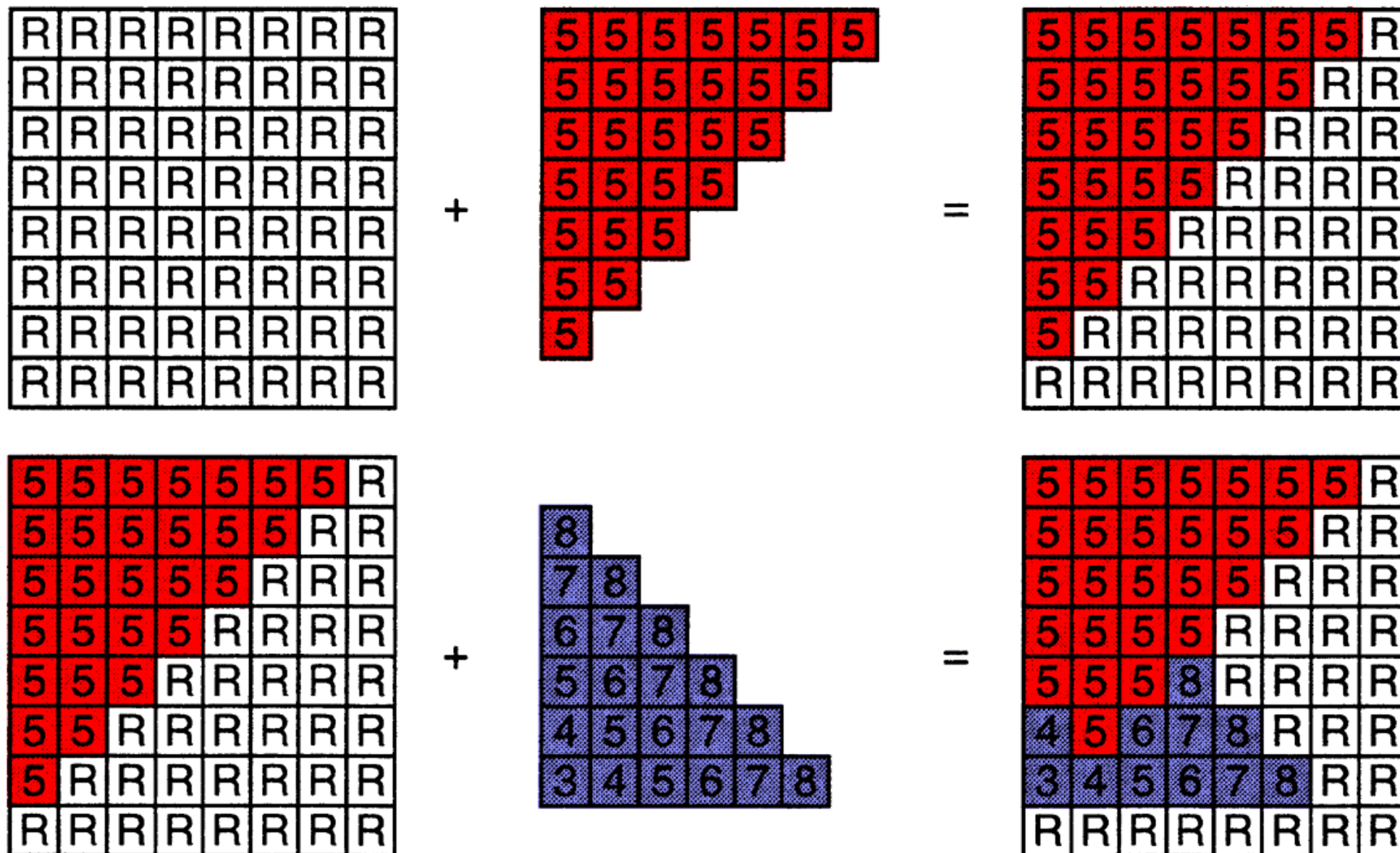
Z-Buffer Algorithm

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

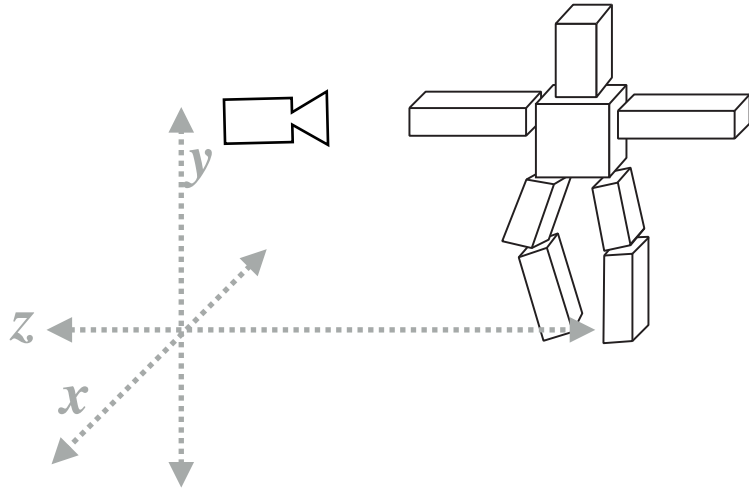
- Implemented in hardware for all GPUs

Questions?

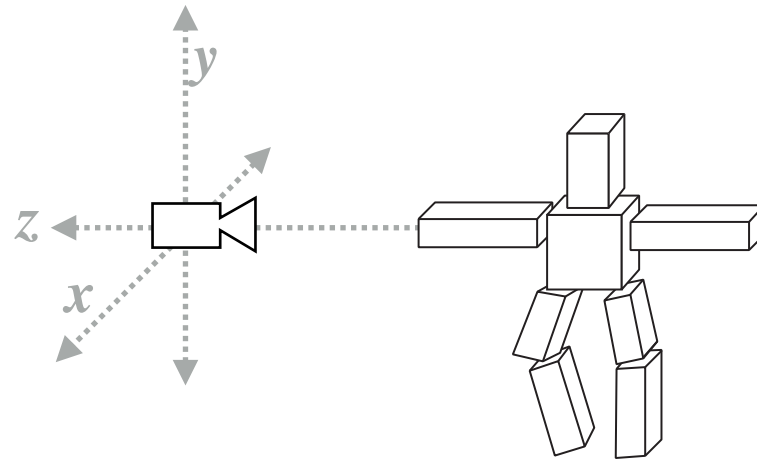
Today

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

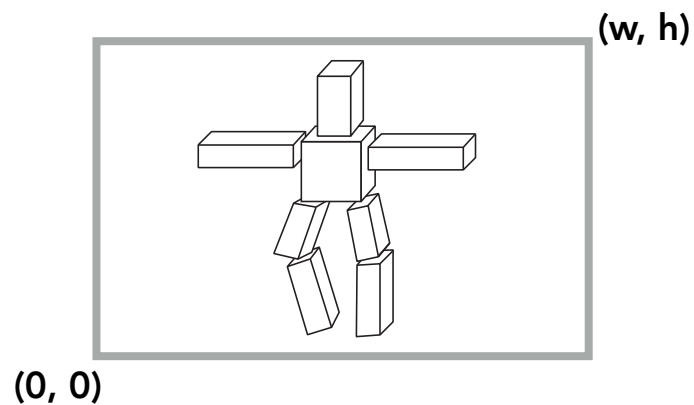
What We've Covered So Far



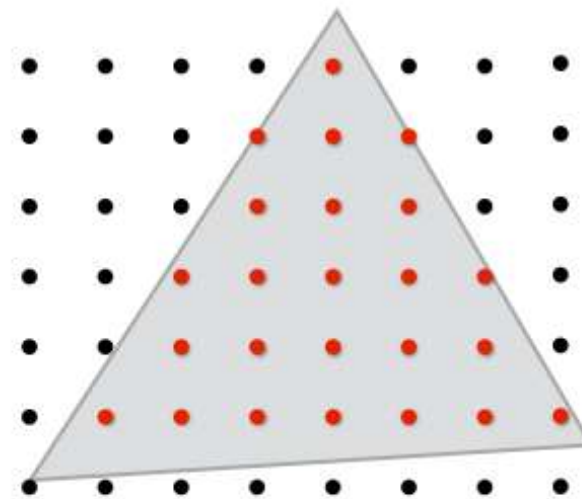
Position objects and the camera in the world



Compute position of objects relative to the camera

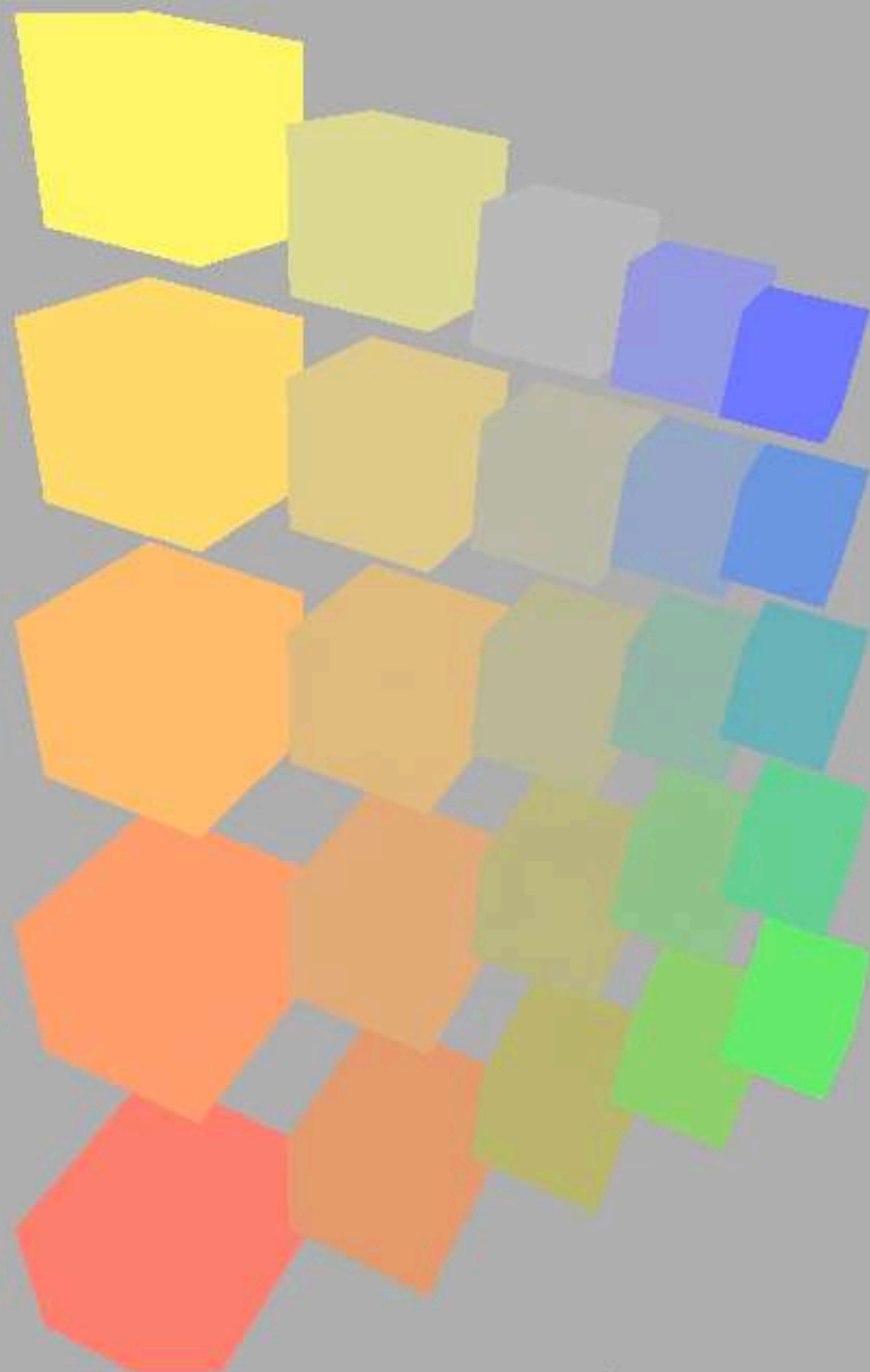


Project objects onto the screen

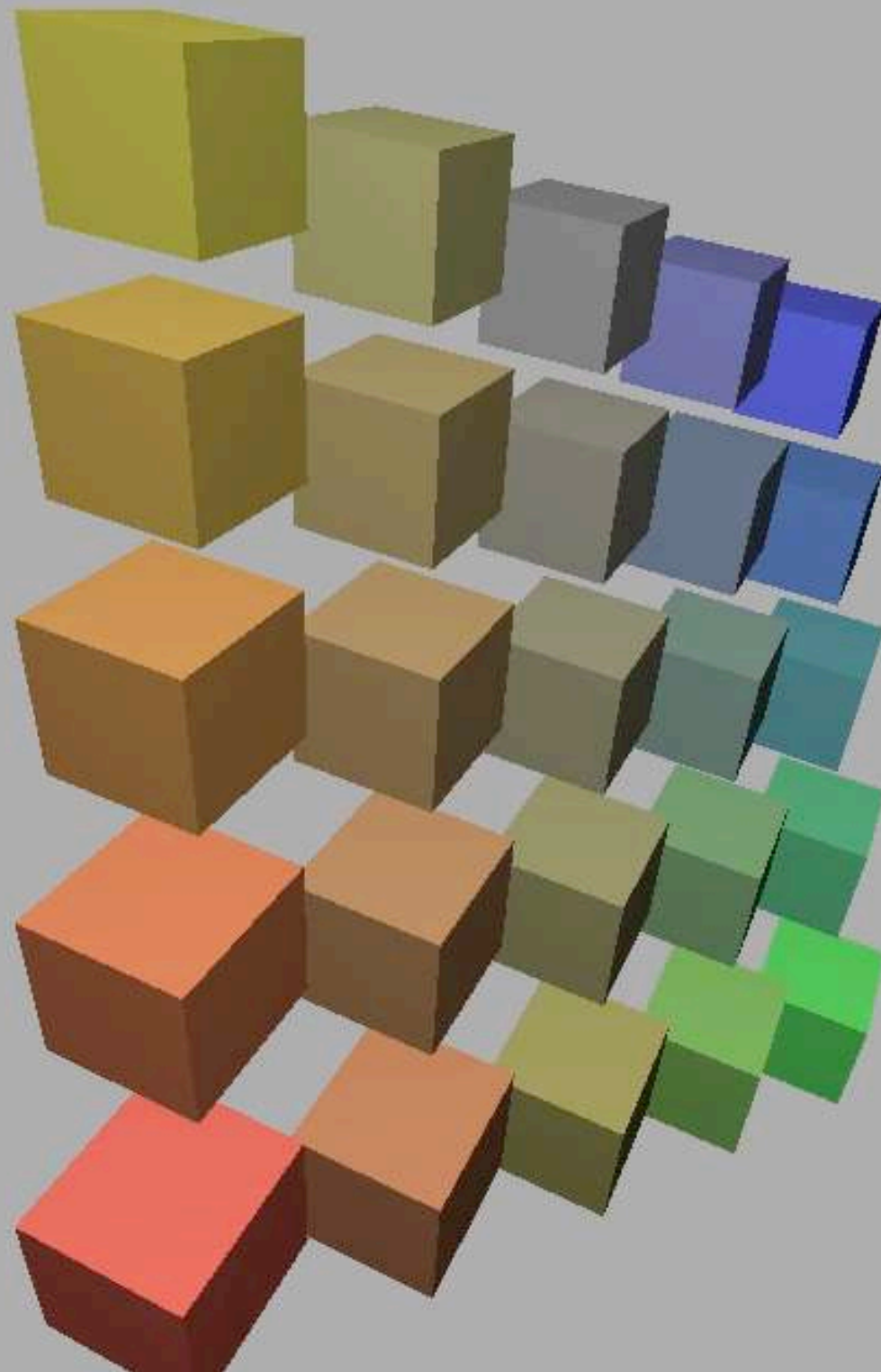


Sample triangle coverage

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.

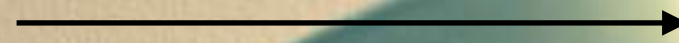
A Simple Shading Model

(Blinn-Phong Reflectance Model)

Perceptual Observations



Specular highlights



Diffuse reflection



Ambient lighting

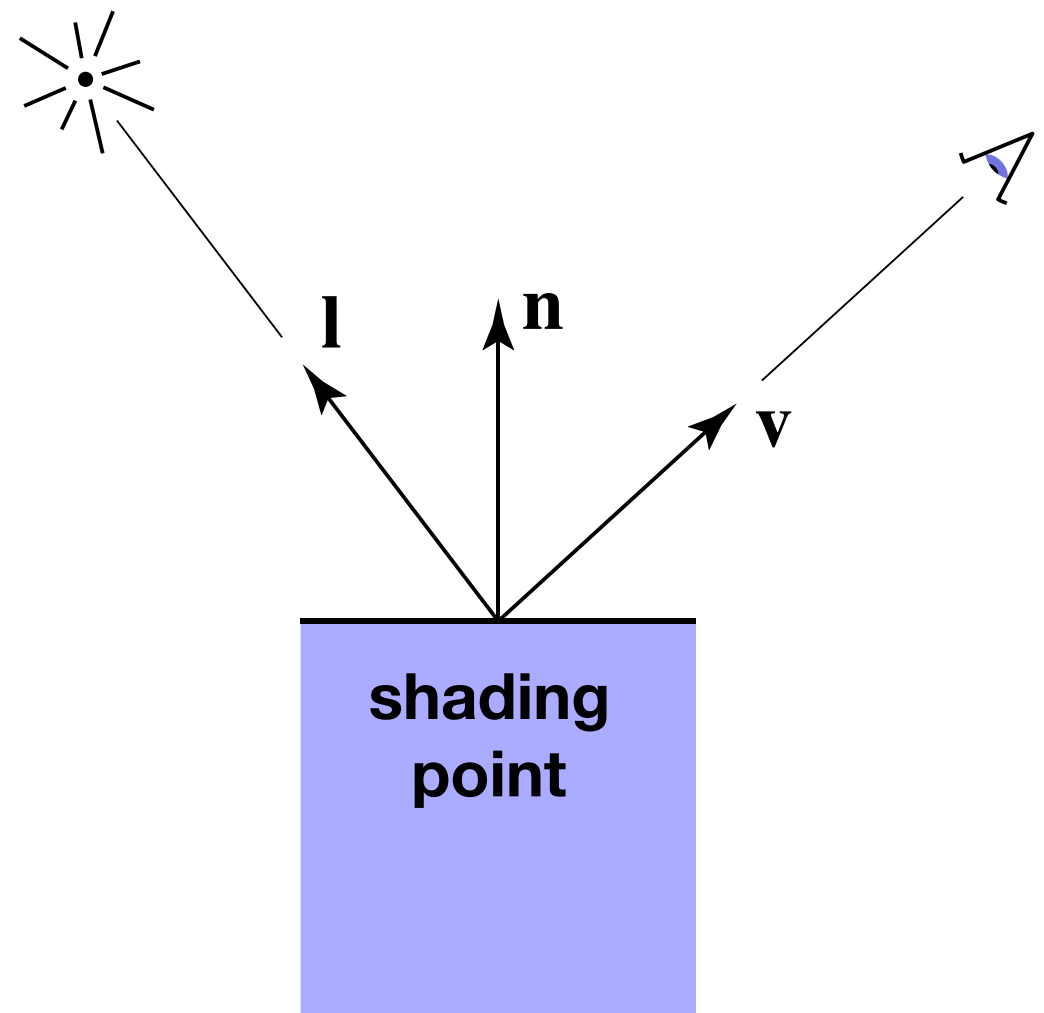


Shading is Local

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

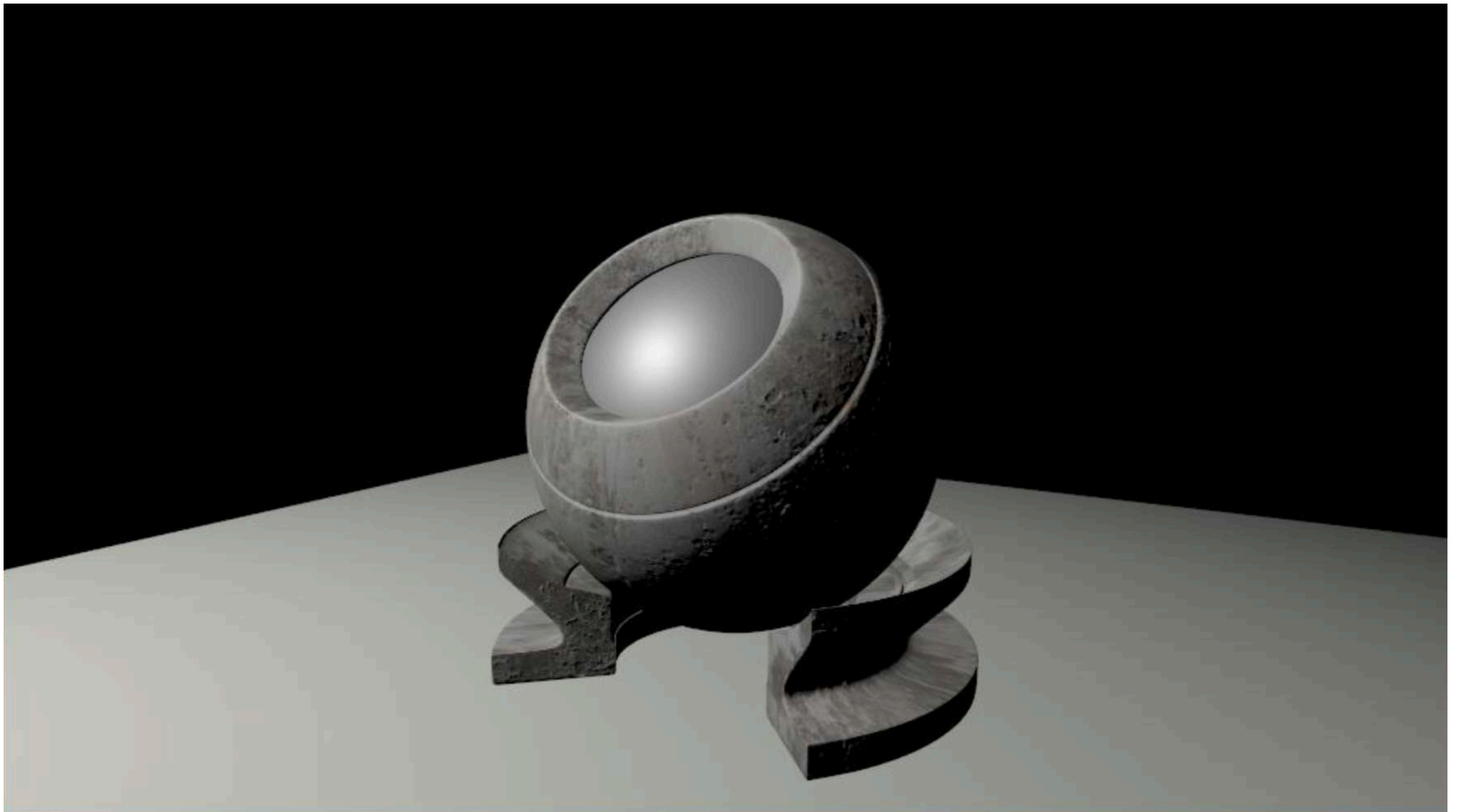
Inputs:

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



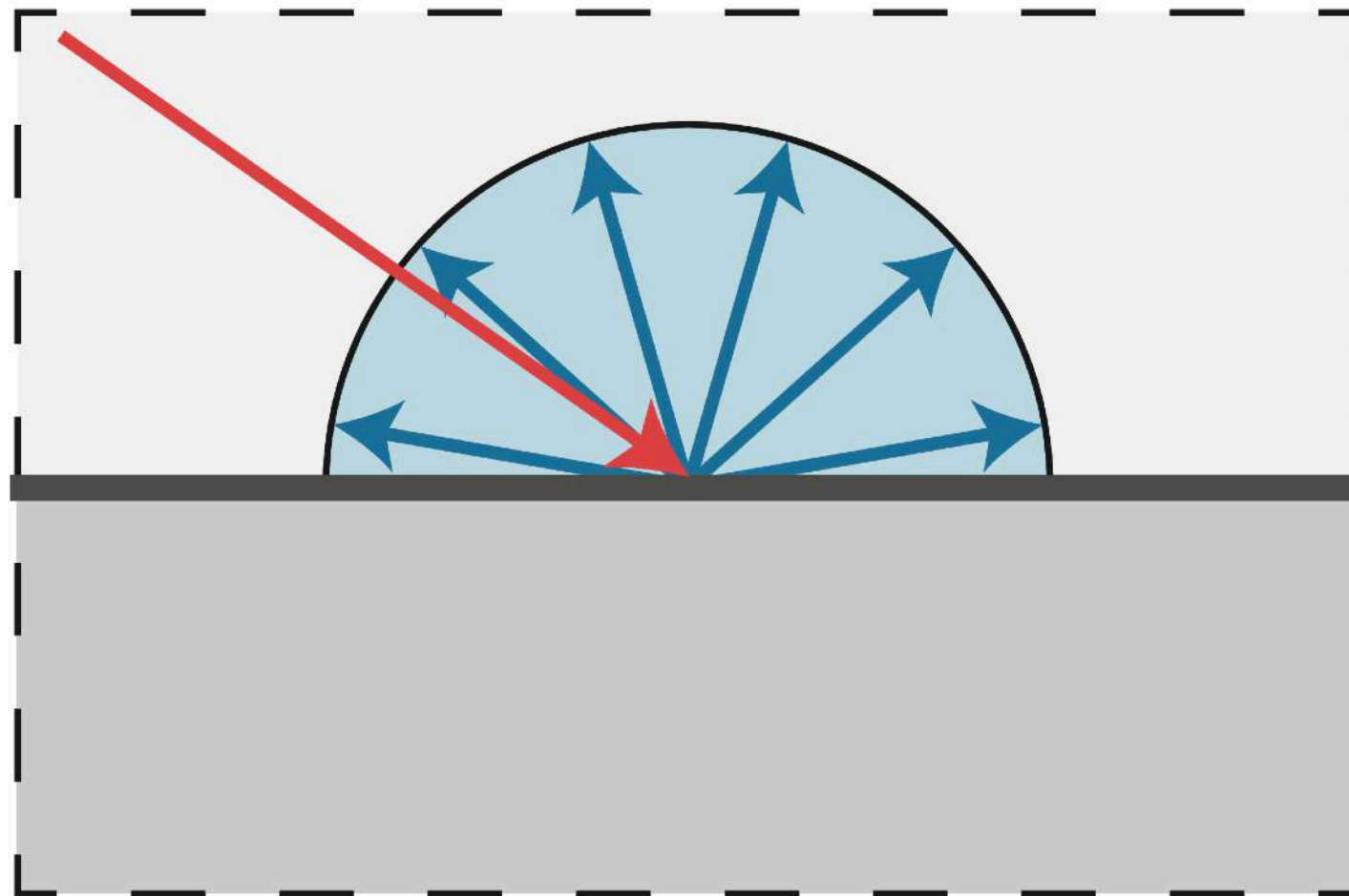
Shading is Local

No shadows will be generated! (**shading** \neq **shadow**)



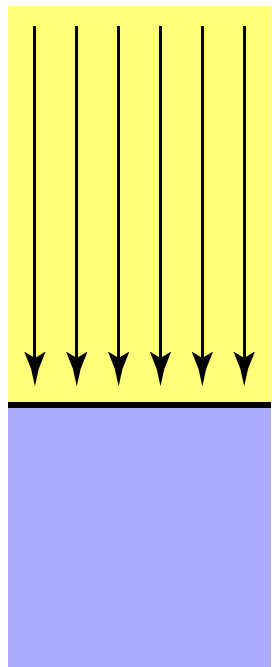
Diffuse Reflection

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

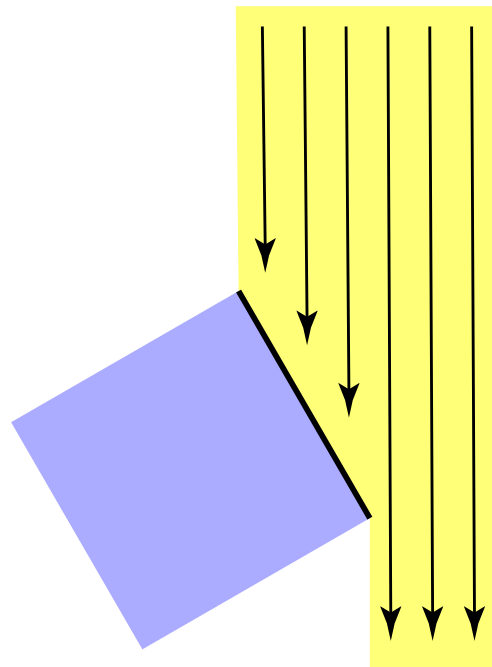


Diffuse Reflection

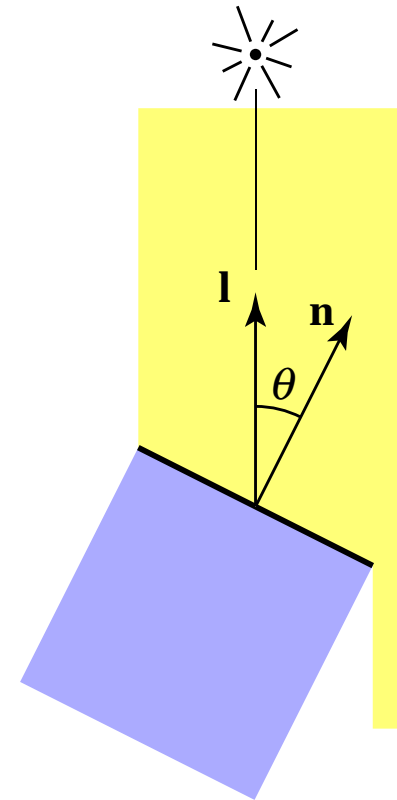
- But how much light (energy) is received?
 - Lambert's cosine law



Top face of cube
receives a certain
amount of light

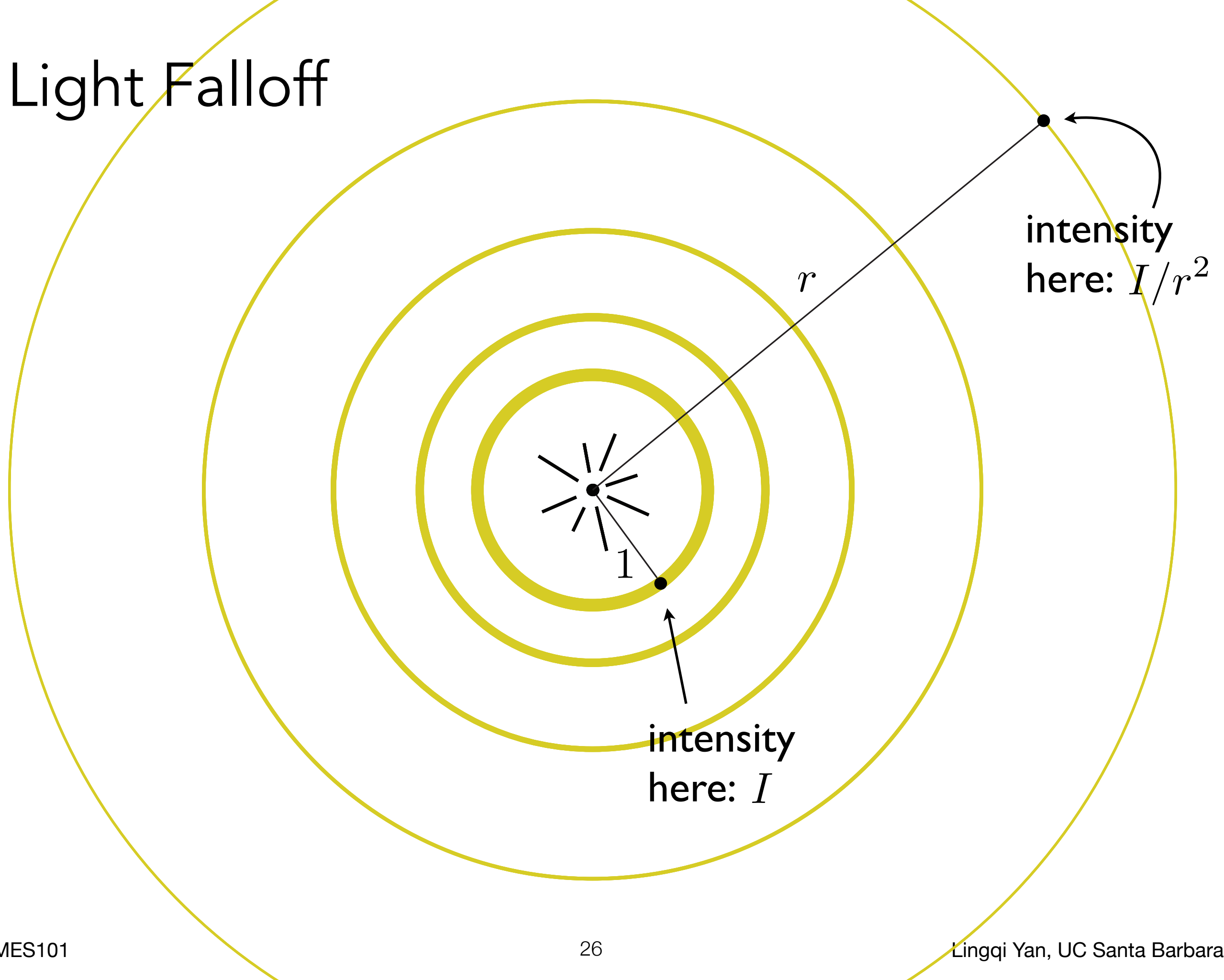


Top face of
60° rotated cube
intercepts half the light



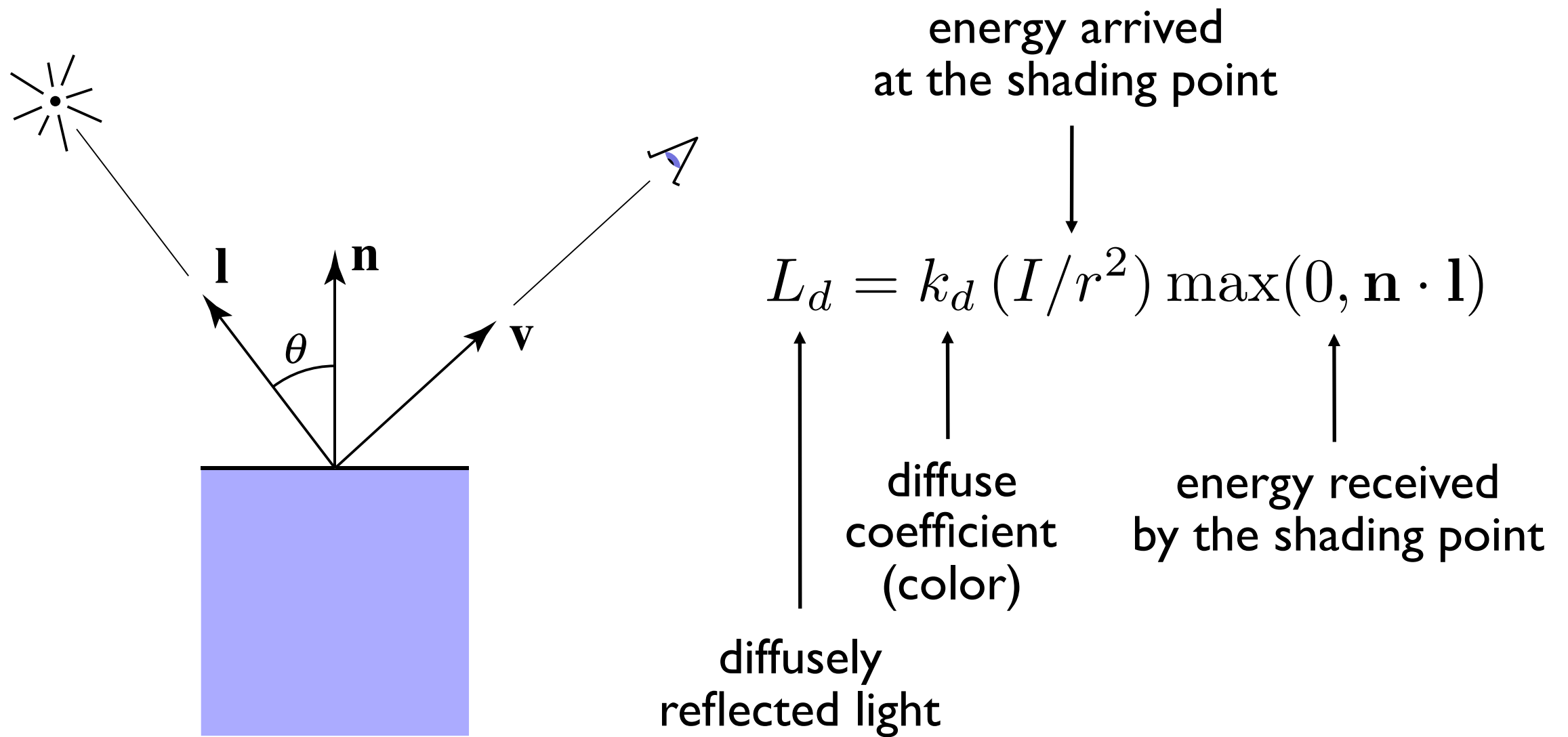
In general, light per unit
area is proportional to
 $\cos \theta = l \cdot n$

Light Falloff



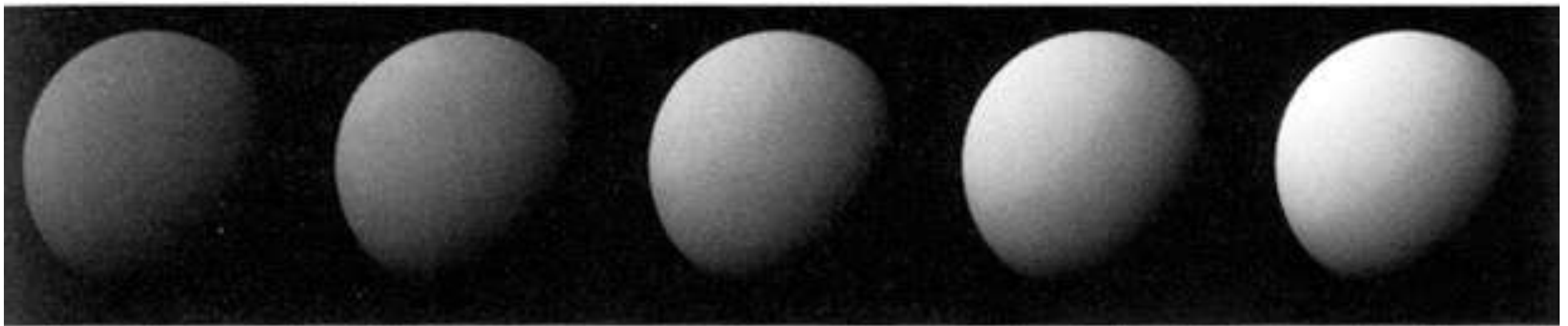
Lambertian (Diffuse) Shading

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!)