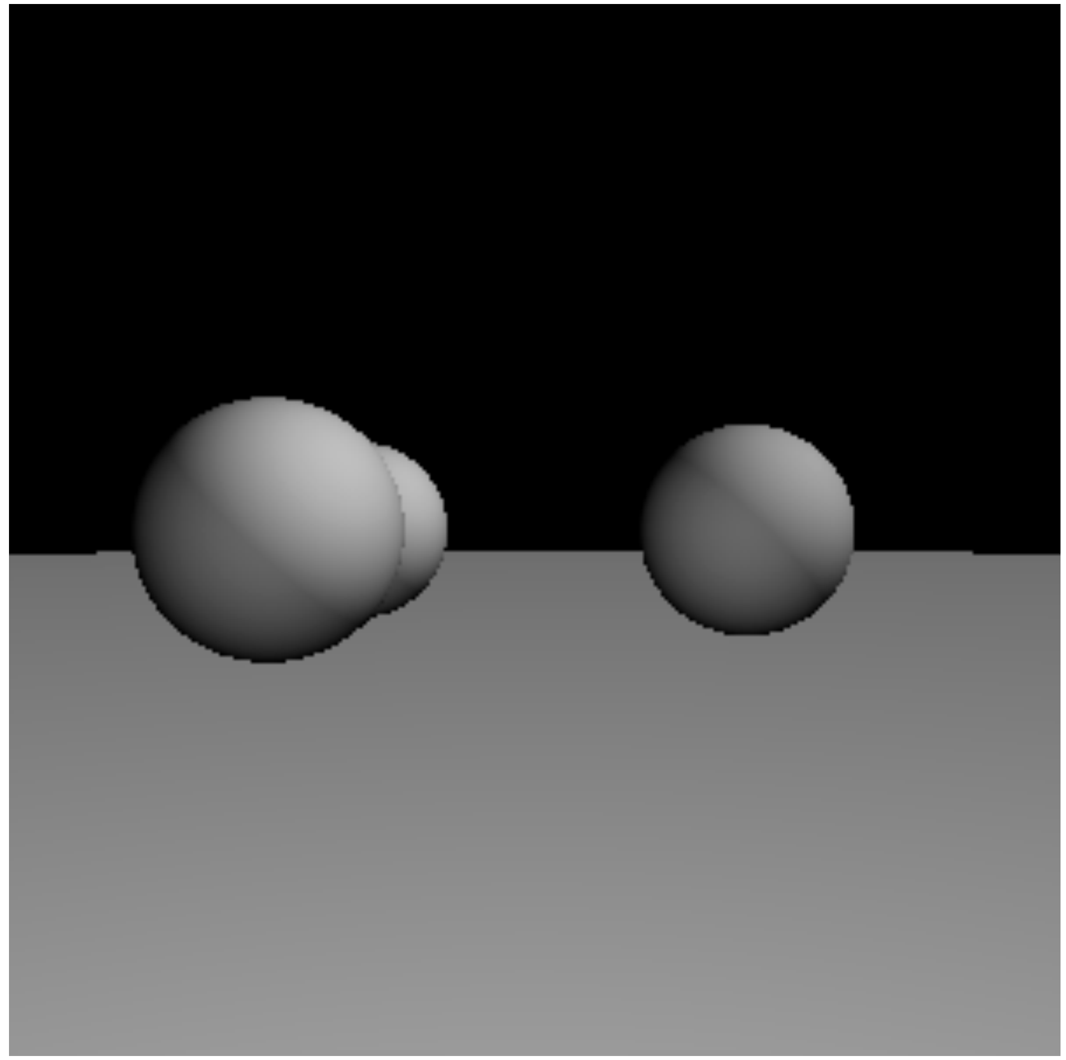


Computer Graphics

Lecture 9

Light Sources

Diffuse Shading

Announcements

- Monday and Tuesday flipped (videos are posted):
  - 3 videos on mirrors, gloss, and shadows for Monday
  - 2 videos on ray-triangle intersection for Tuesday
- Plan: post artifact showcase today, vote for your favorite over the weekend.

Announcements

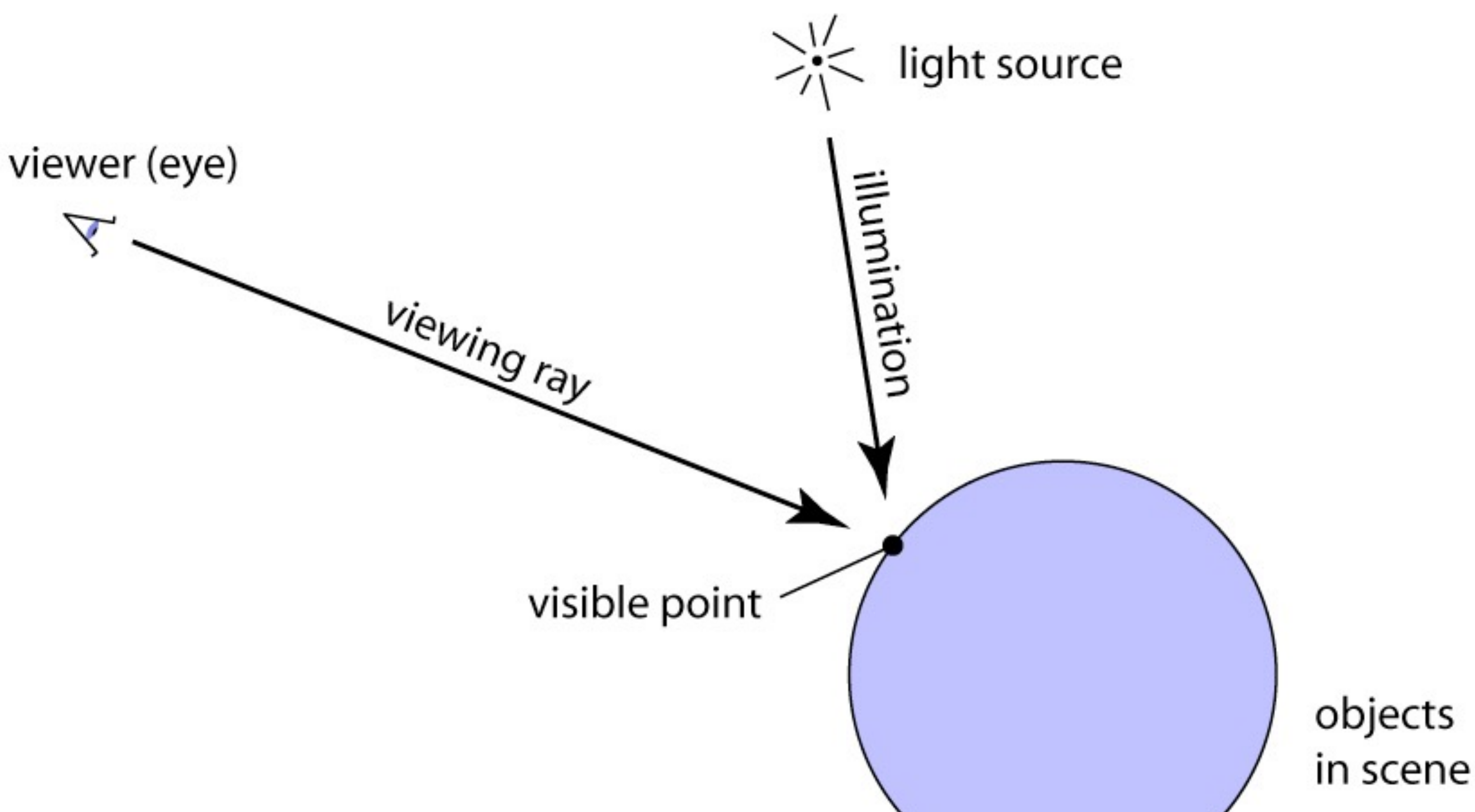
- Some A1 stats:
  - Time since release: 4 days
  - Time to deadline: 5 days
  - Office hours remaining before deadline: 3
  - A1 questions in office hours so far: 0
  - Pairs that have created a repository: 11
  - Pairs that have made any commits to their repo: 6

Goals

- Understand the definition of point and directional light sources.
- Know how to calculate diffuse shading for Lambertian surfaces.

Ray Tracing: Pseudocode

```
for each pixel:
    generate a viewing ray for the pixel
    find the closest object it intersects
    determine the color of the object
```



Ray-Sphere: Code Sketch

```
function ray_intersect(ray, sphere, tmin, tmax):
```

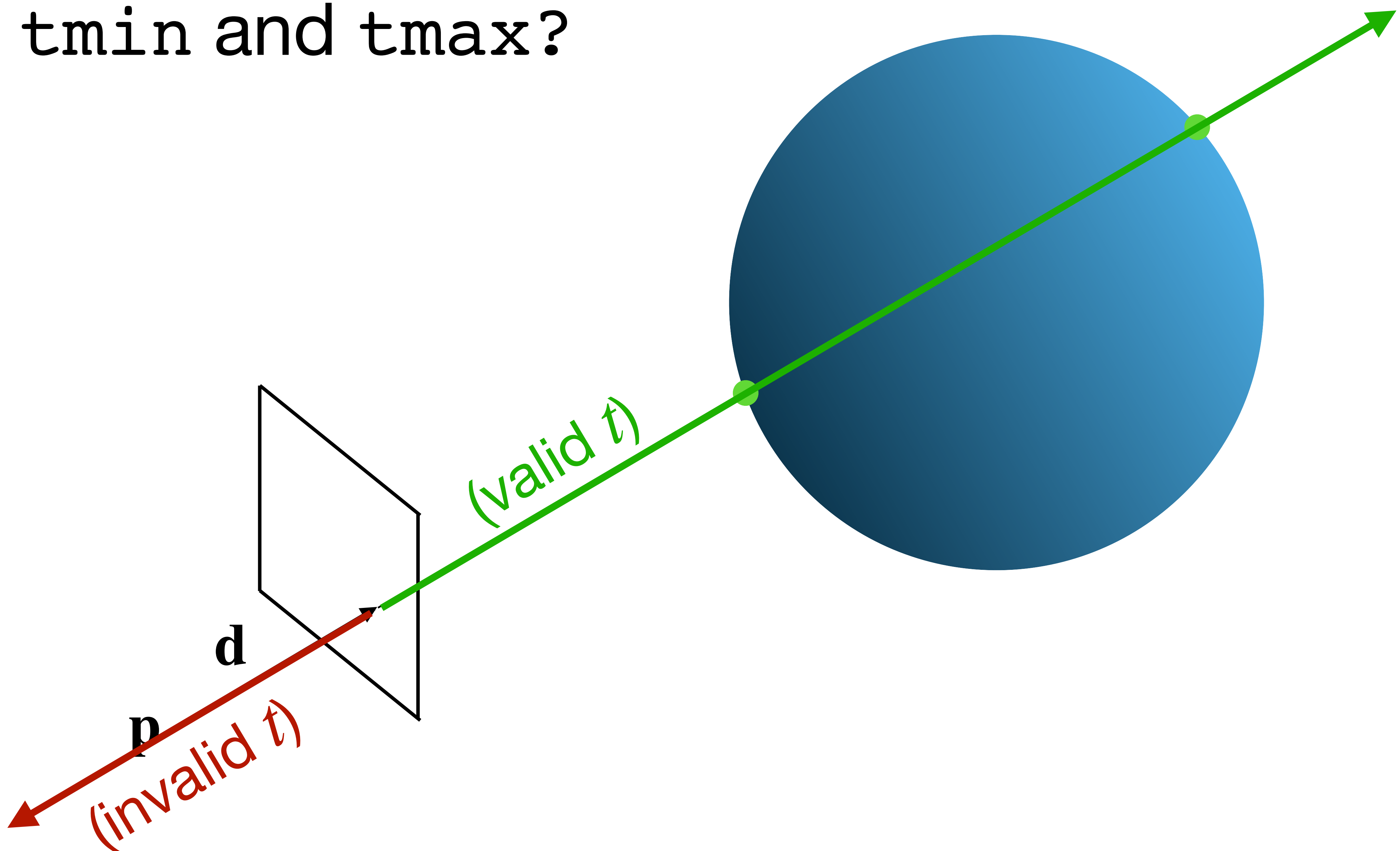
- Use last lecture's math to find $\pm t$
- If no real solutions, return `nothing`
- Otherwise, return closest *t* that lies between `tmin` and `tmax`
- Also return info needed for shading - store in a `HitRecord` struct.

In A2: t, intersection point, normal, texture coordinate, object

Ray-Sphere: Code Sketch

```
function ray_intersect(ray, sphere, tmin, tmax):
```

Why `tmin` and `tmax`?



Ray Tracing: Code Sketch

```
scene = model_scene()
for each pixel (i,j):
   ray = get_view_ray(i, j)
   canvas[i,j] = traceray(scene, ray, tmin, tmax)
```

Ray Tracing: Code Sketch

```
scene = model_scene()
for each pixel (i,j):
    ray = get_view_ray(i, j)
    canvas[i,j] = traceray(scene, ray, tmin, tmax)

function traceray(scene, ray, tmin, tmax):
    t, rec = ray_intersect(ray, scene, tmin, tmax)
    if rec != nothing:
        canvas[i,j] = rec.obj.color
    else:
        canvas[i,j] = scene.bgcolor
```

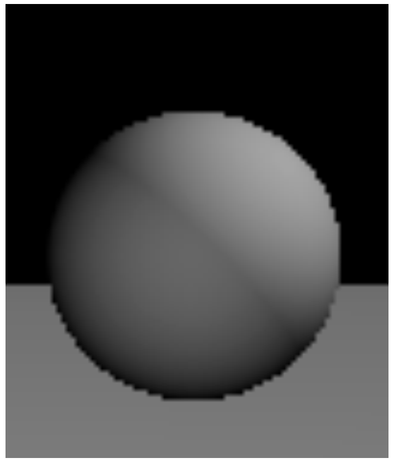
Ray Tracing: Code Sketch

```
scene = model_scene()
for each pixel (i,j):
    ray = get_view_ray(i, j)
    canvas[i,j] = traceray(scene, ray, tmin, tmax)

function traceray(scene, ray, tmin, tmax):
    t, rec = ray_intersect(ray, scene, tmin, tmax)
    if rec != nothing:
        canvas[i,j] = rec.obj.color
    else:
        canvas[i,j] = scene.bgcolor
```

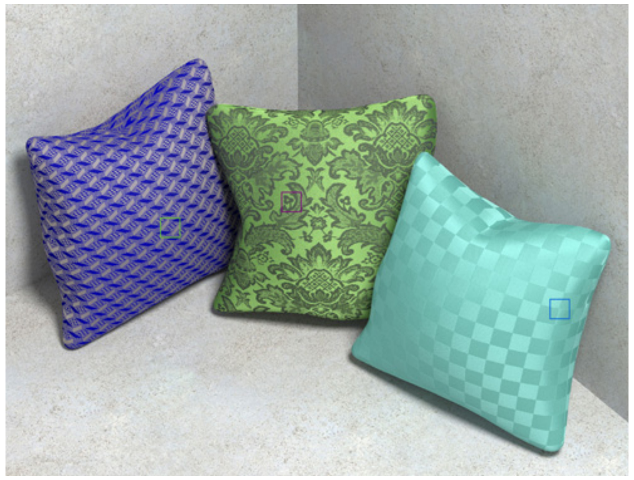
Let's work on this.

Shading



What does the color of a pixel depend on?

Shading



What does the color of a pixel depend on?

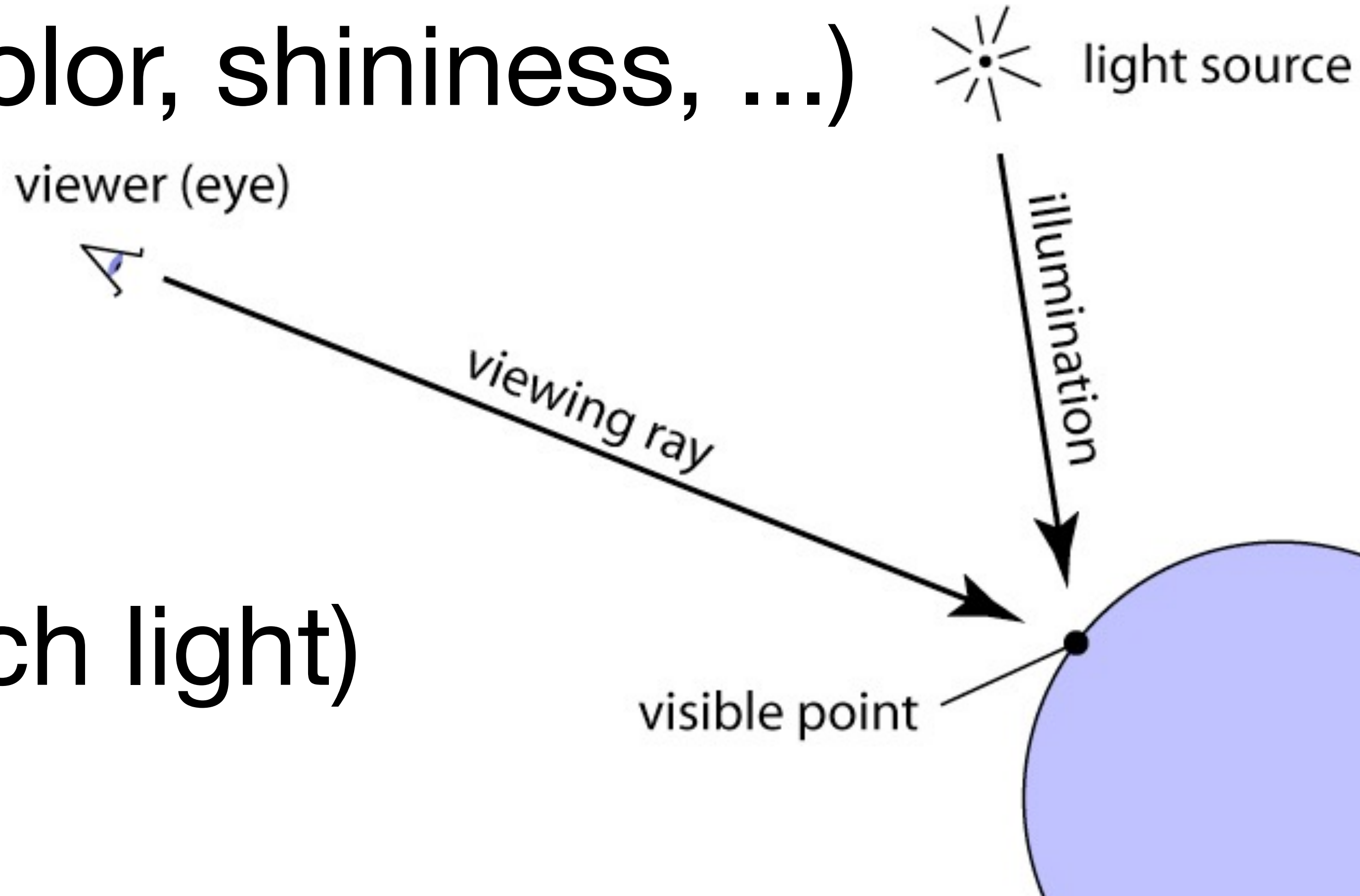
Try to think beyond matte gray spheres.

Wood? Velvet? Hair? Brushed stainless steel? Glass? Wax?

Shading

What does the color of a pixel depend on?

- surface normal
- surface properties (color, shininess, ...)
- eye direction
- light direction (for each light)



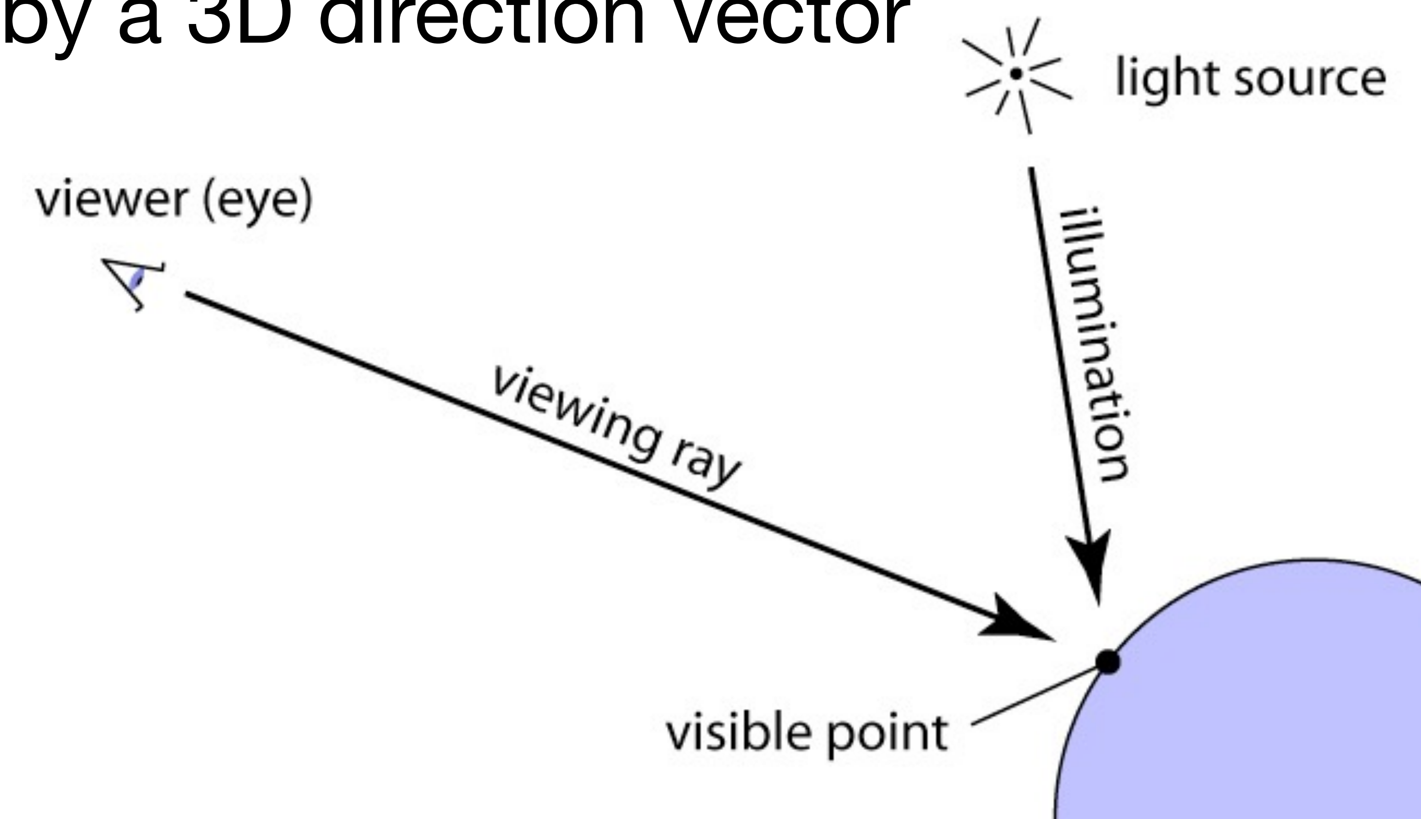
Shading

What does the color of a pixel depend on?

- surface normal *stored in or calculated from object*
- surface properties (color, shininess, ...) *stored in object*
- eye direction *calculated from viewing ray and intersection point*
- light direction (for each light) *calculated from light and intersection point*

Light Sources

- Where does light come from?
- Two simple kinds of sources:
  - point source: defined by a 3D position
  - directional source: defined by a 3D direction vector
  - ...many other possibilities!



Point and Directional Lights

- (whiteboard)

Shading

What does the color of a pixel depend on?

- surface normal *stored in or calculated from object*
- surface properties (color, shininess, ...) *stored in object*
- eye direction ***calculated** from viewing ray and intersection point*
- light direction (for each light) ***calculated** from light and intersection point*

Problems 1-2: calculated how?

Problems 1-2: Eye Direction and Light Direction

Given a viewing ray ($\mathbf{p} + t\mathbf{d}$) and the t at which it intersects a surface,

1. Find a unit vector giving the direction from the surface towards the viewer.

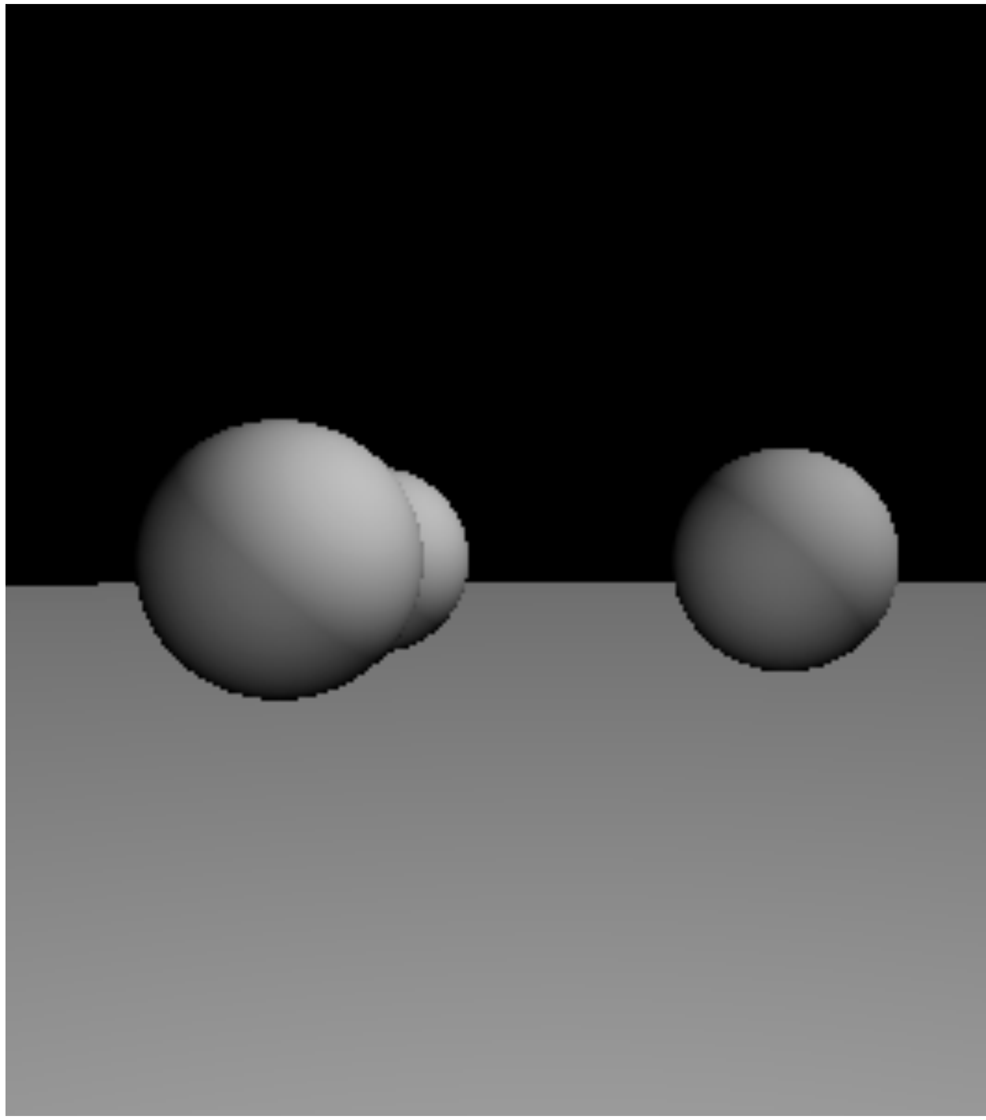
2. Find a unit vector giving the direction from the surface towards:

    - a point light source at position $\vec{s}$

    - a directional light source with direction $\overrightarrow{\ell}$

Diffuse (Lambertian) Reflection

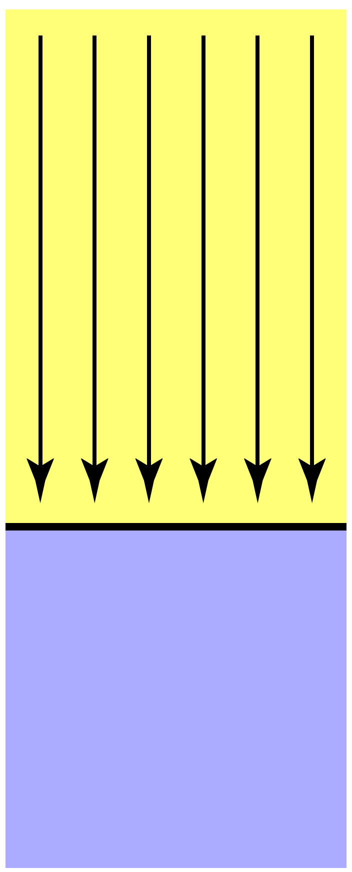
- On a *diffuse* surface, light scatters uniformly in all directions.
- No dependence on view direction.
- Many surfaces are approximately diffuse:
  - matte painted surfaces, projector screens,
  - anything that doesn't look "shiny"



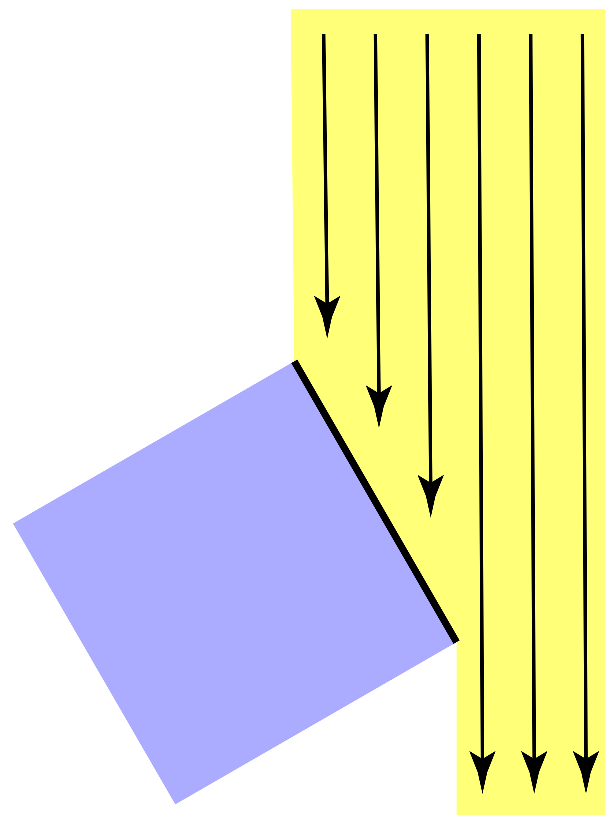
Diffuse (Lambertian) Reflection

whiteboard

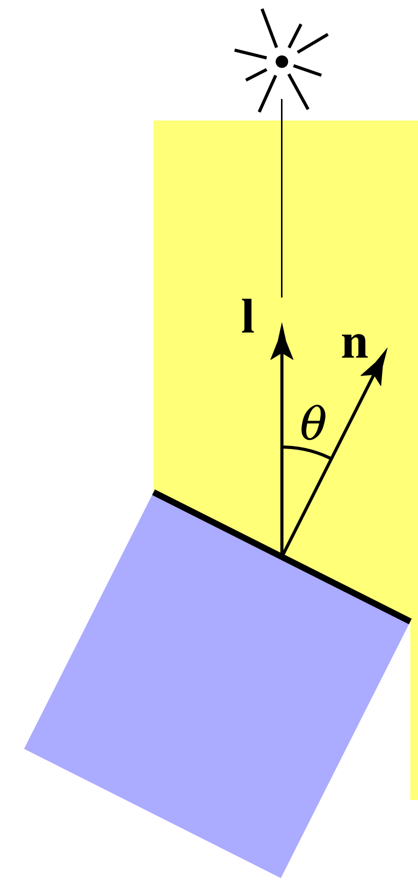
Diffuse (Lambertian) Reflection



The top face of a cube receives some amount of light.



Rotated 60°, the same face receives half the light.



Light per unit area is proportional to $\cos\theta = \vec{n} \cdot \vec{\ell}$

Highly recommended reading:
https://ciechanow.ski/lights-and-shadows/

Diffuse (Lambertian) Shading

- The full model:

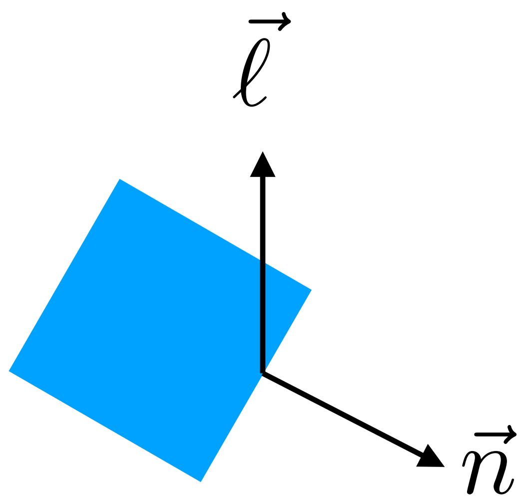
$$L_d = k_d I \max(0, \vec{n} \cdot \vec{\ell})$$

why max with 0?

diffuse coefficient

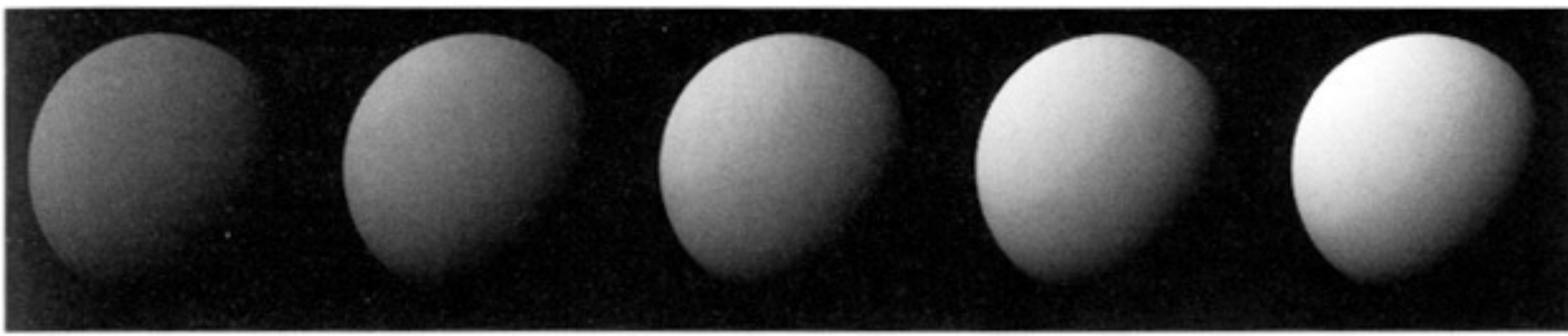
diffusely reflected light

light intensity



Diffuse (Lambertian) Shading

$$L_d = k_d I \max(\vec{n} \cdot \vec{\ell})$$



[Foley et al.]

$k_d \longrightarrow$

For colored objects, k_d is a 3-vector of R, G, and B reflectances.

Problem 3:
Diffuse Reflection