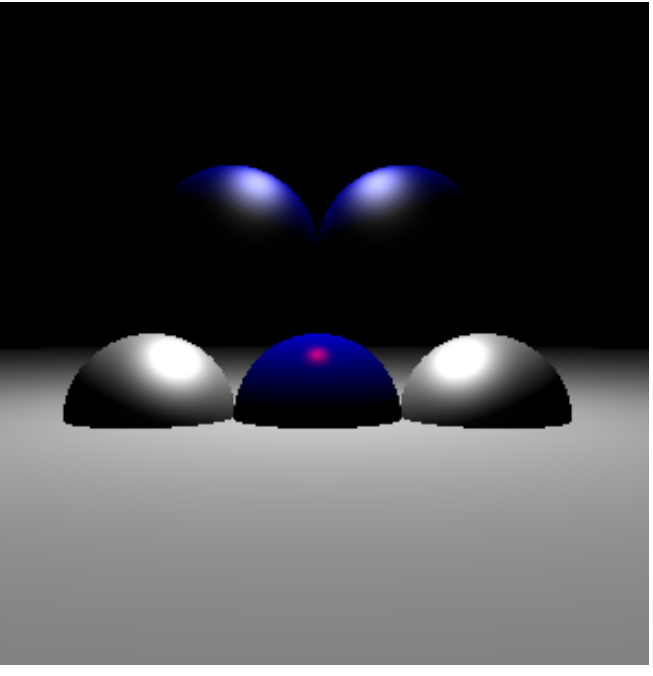
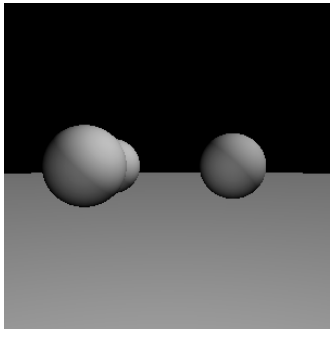
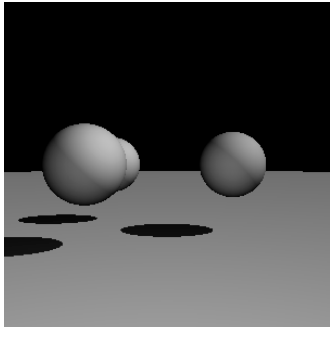
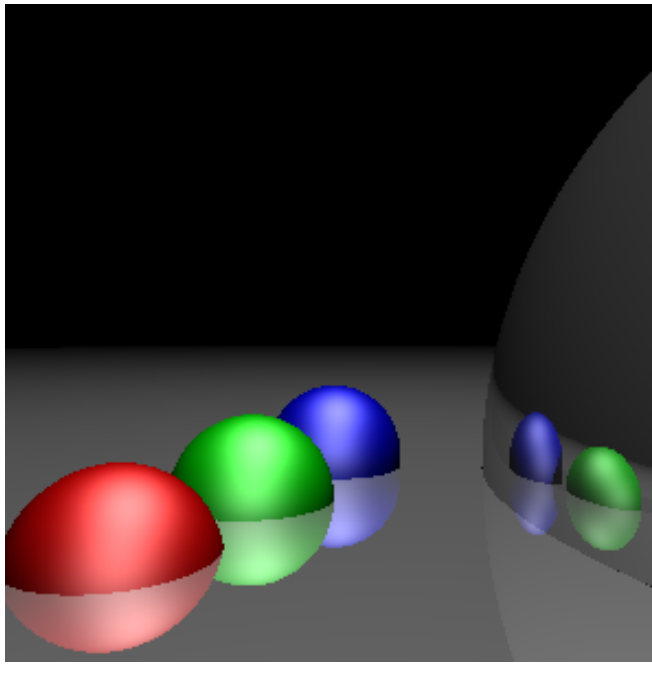





Computer Graphics

Lecture 8

Diffuse Shading

Mirror Reflection

Shadows

Announcements

- Some A1 stats:
  - Time since release: one week
  - Time to deadline: 5 days
  - Office hours remaining before deadline: 2
  - Questions in office hours so far: 1
  - Groups that hadn't created their github repo as of this morning: 8

A0 Artifact results are in...

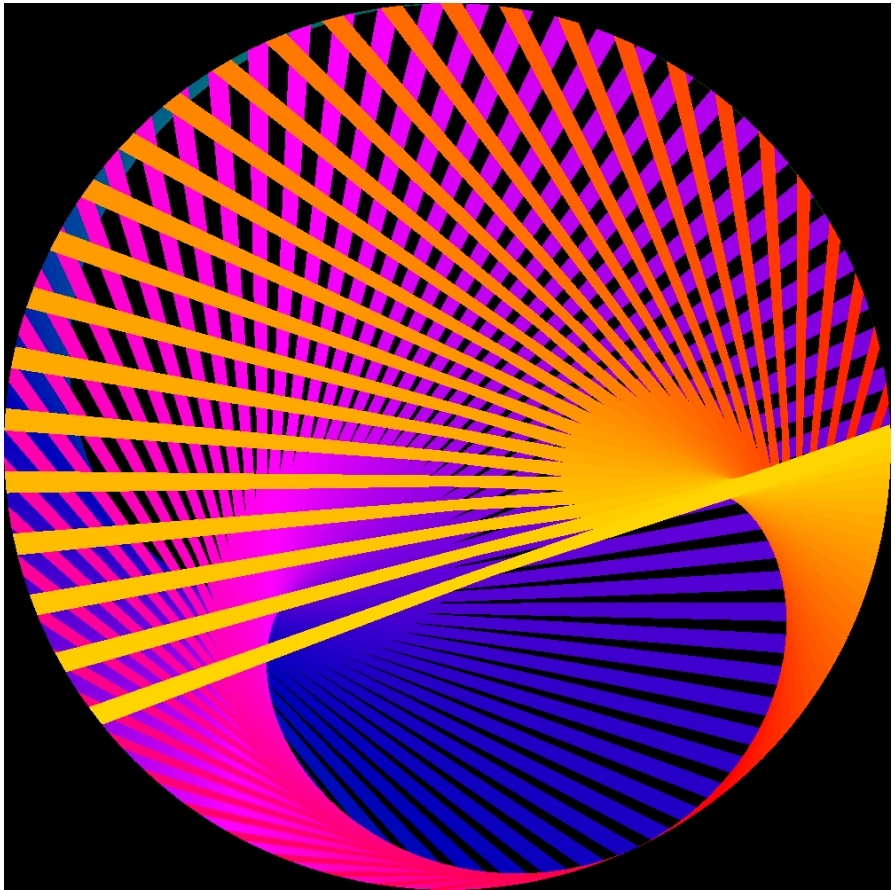
- A 2-way tie for first place!

First Place

Alex Ayala!

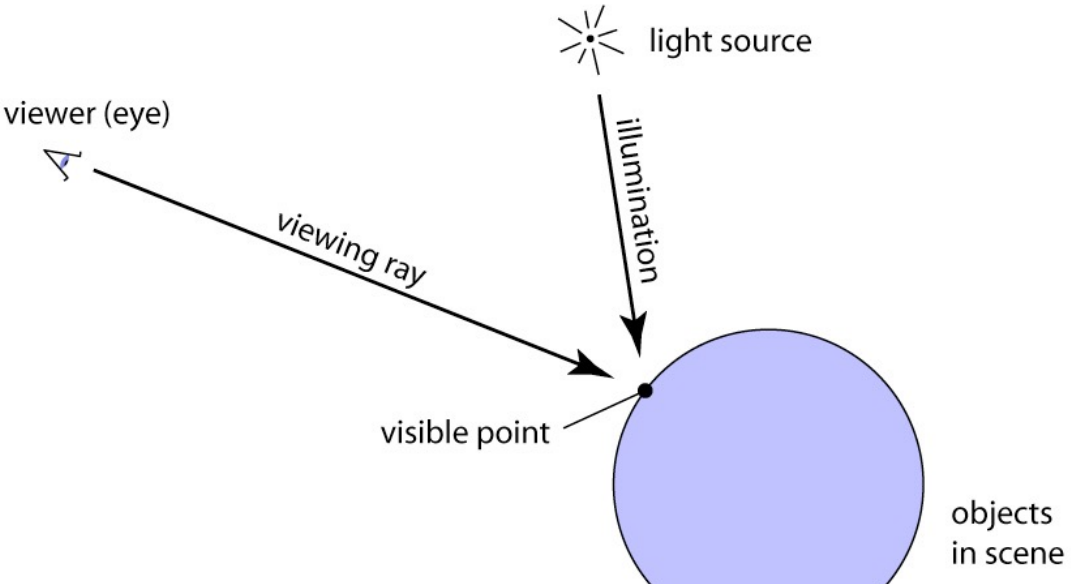
Also First Place

Raiden Van Bronkhorst!



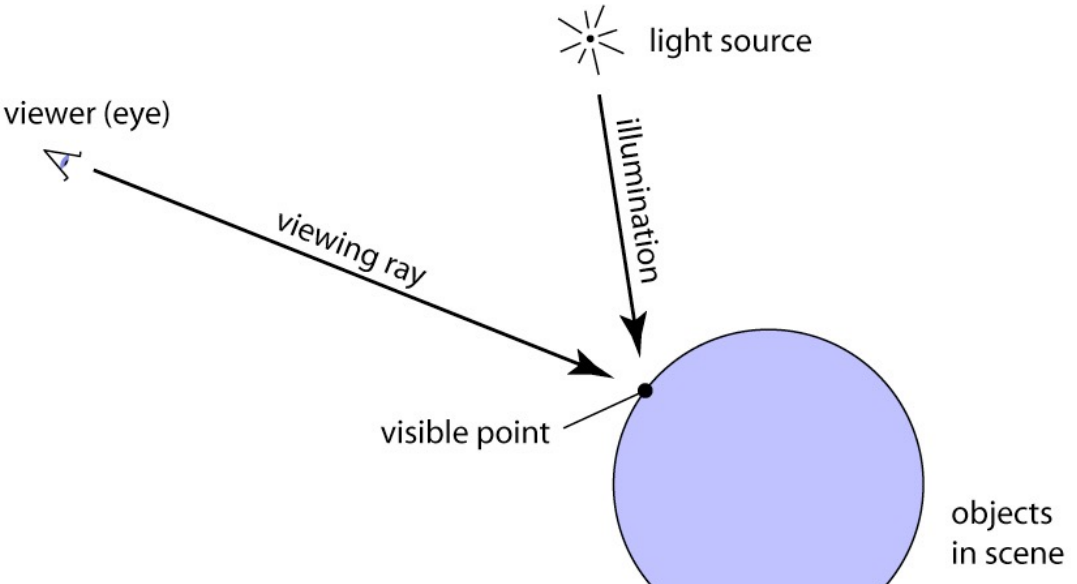
Ray Tracing: Pseudocode

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

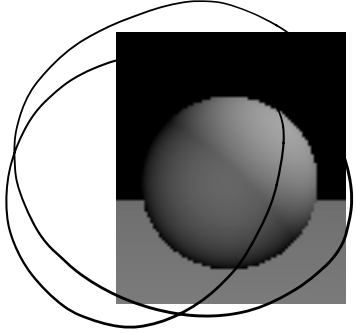


Ray Tracing: Pseudocode

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



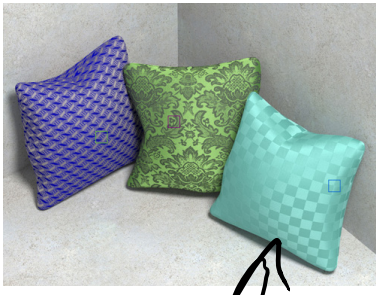
Shading



What does the color of a pixel depend on?

material
color of object
light
intensity of
direction to light from surface
occlusions between surface and light?
surface normal
transparency / translucency → stuff shining thru?

Shading



What does the color of a pixel depend on?

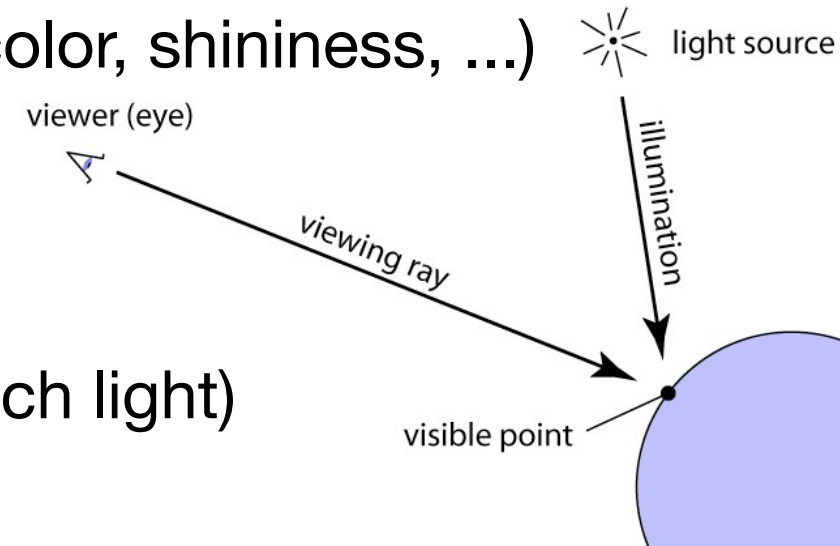
Hint: think beyond matte gray spheres.

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*

Ray-Sphere: Code Sketch

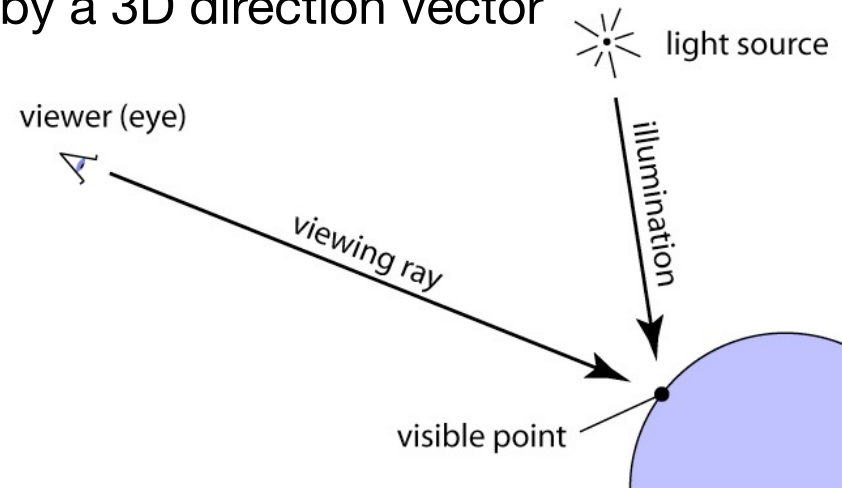
```
function ray_intersect(ray, sphere, tmin, tmax):
```

- Use last lecture's math to find +/- *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.

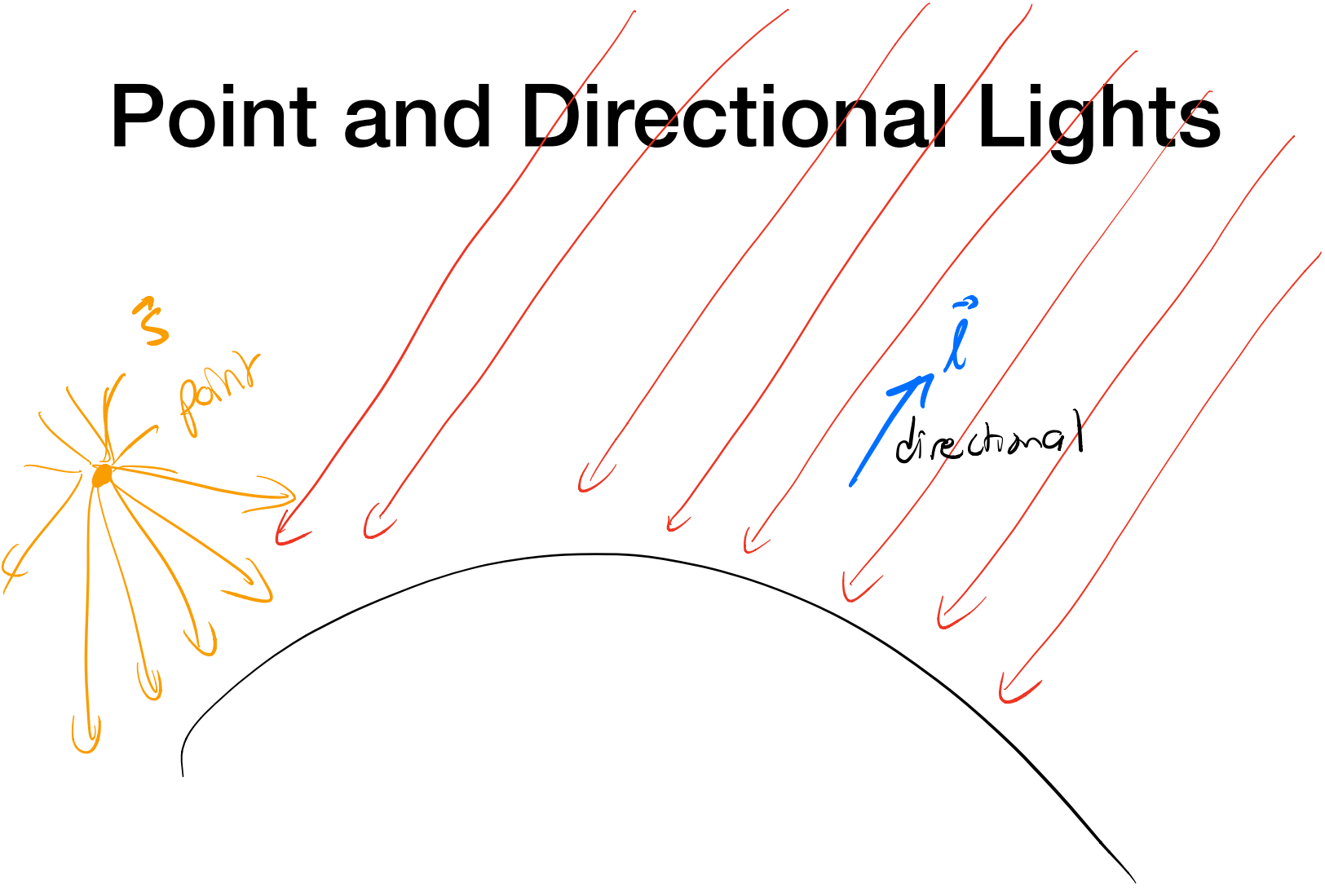
In A2: t, intersection point, normal, texture coordinate, object

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!

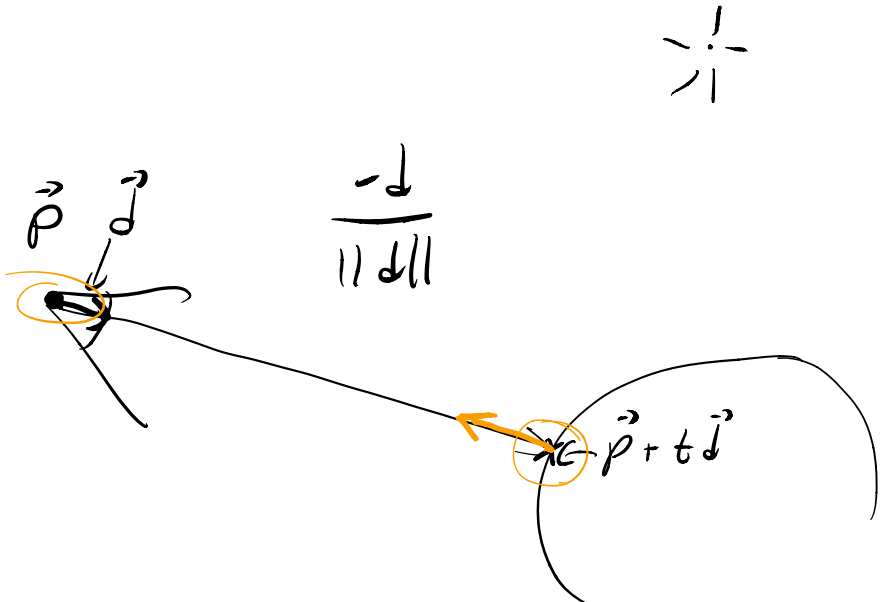


Point and Directional Lights



Problems 1-2:
Eye Direction and Light Direction

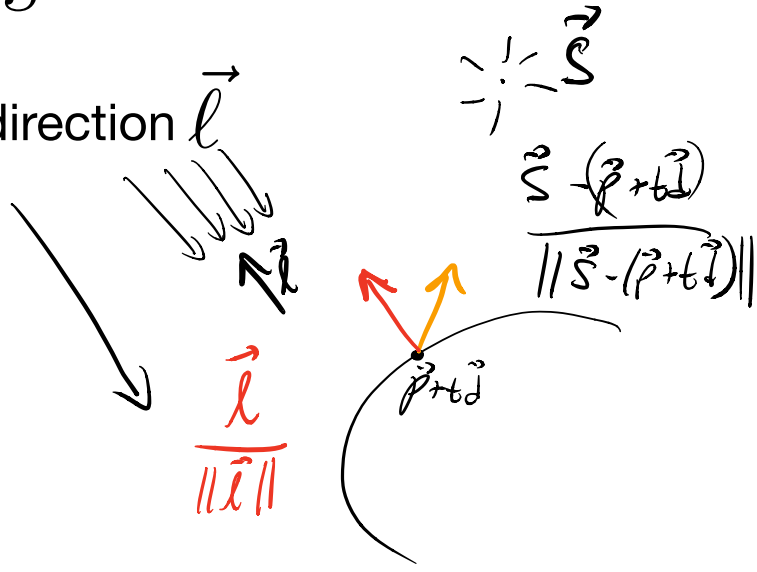
Given a viewing ray (**p** + *t***d**) and the *t* at which it intersects a surface, find a unit vector giving the direction from the surface towards the viewer.



Light Sources: Exercise

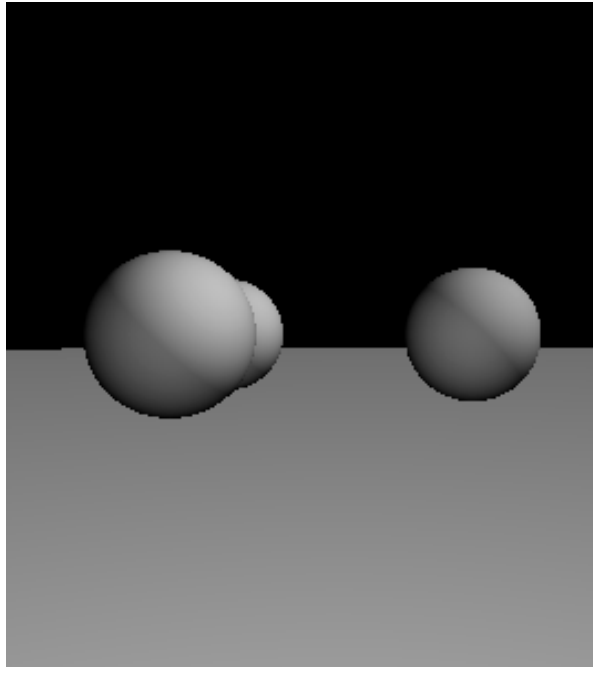
Given a ray (**p** + *t***d**) and the *t* at which it intersects a surface, calculate a unit vector giving the direction from the surface towards:

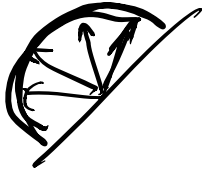
- a point light source at position $\vec{s}$
- a directional light source with direction $\vec{\ell}$



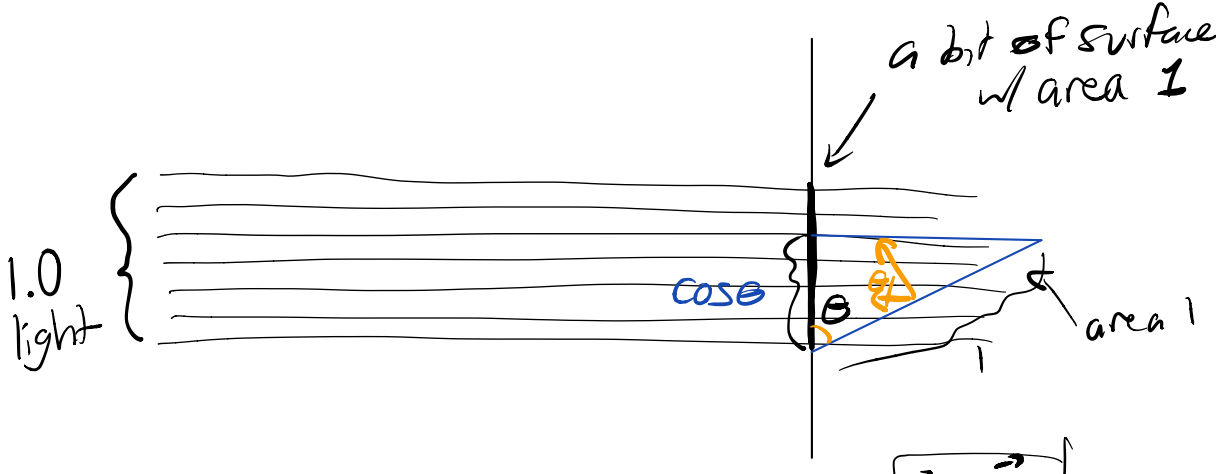
Diffuse (Lambertian) Reflection

- 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"



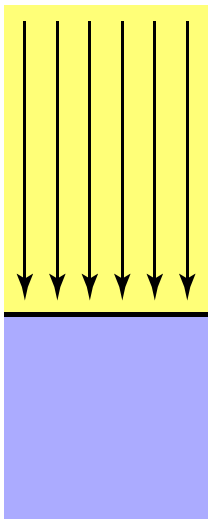


Diffuse (Lambertian) Reflection

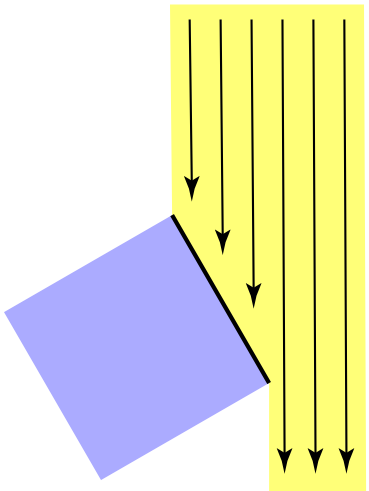


$$L_d \propto \cos\theta = \boxed{\vec{n} \cdot \vec{l}}$$

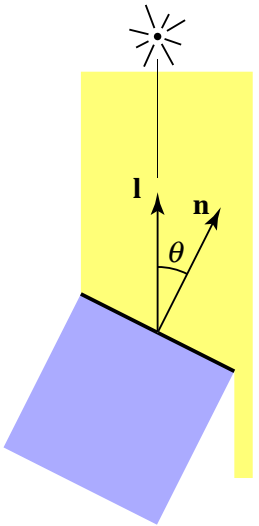
Diffuse (Lambertian) Reflection



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:

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

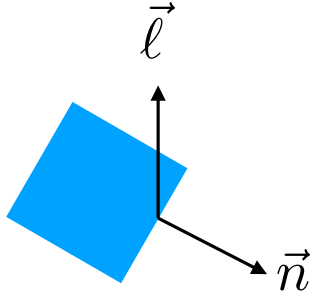
diffusely reflected light

diffuse coefficient

surface color

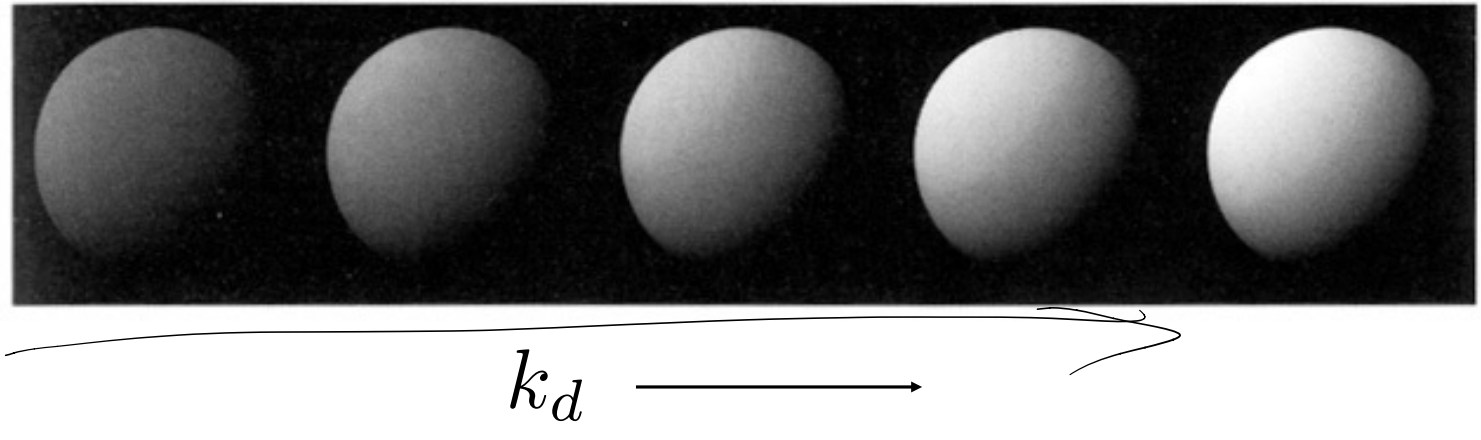
light intensity

why max?



Diffuse (Lambertian) Shading

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



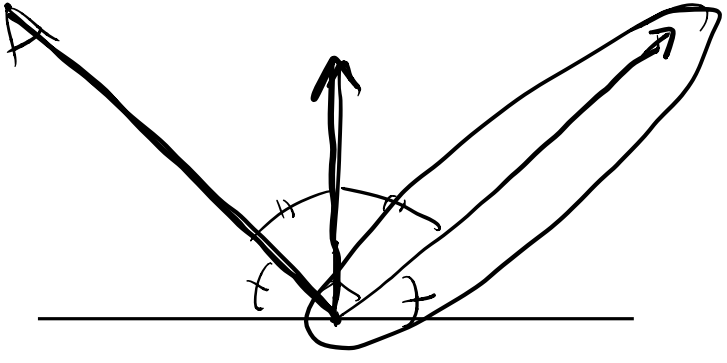
[Foley et al.]

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

Let's talk shinies.

Let's talk shinies.

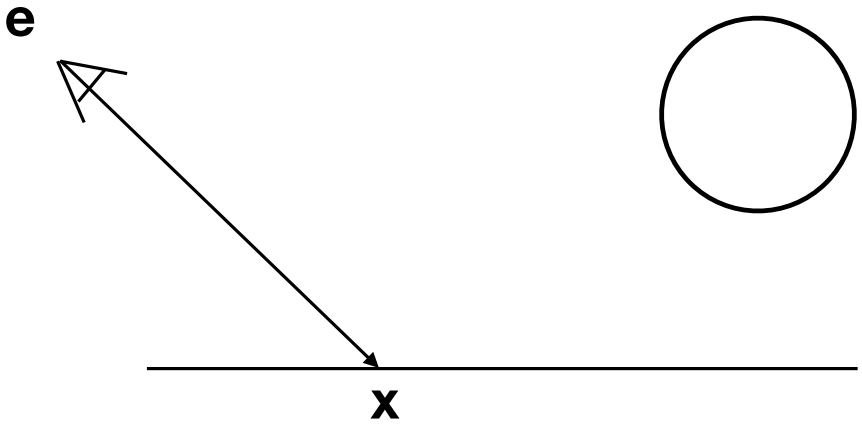
How does a mirror interact with light?



Problems 3-4:
Diffuse and Mirror Reflection

Mirror Reflection

What does a camera see when it looks at a mirror?

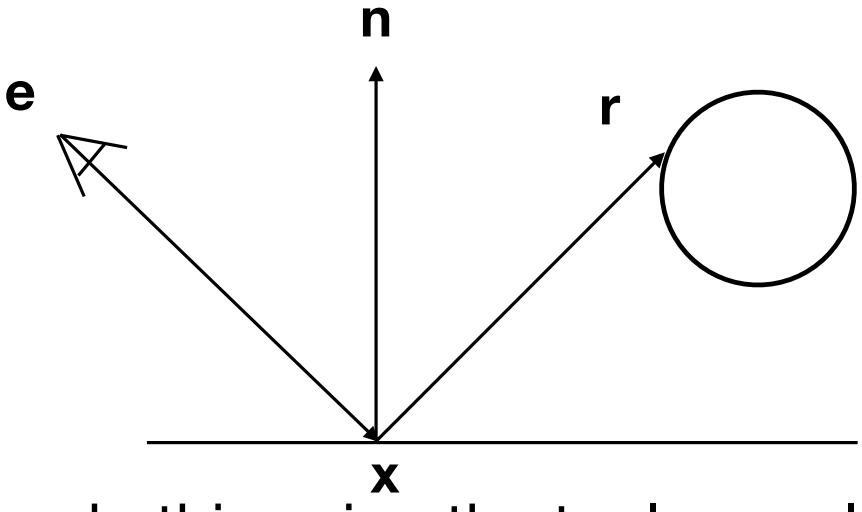


Can we do this using the tools we already have?

(Problem 4)

Mirror Reflection

What does a camera see when it looks at a mirror?

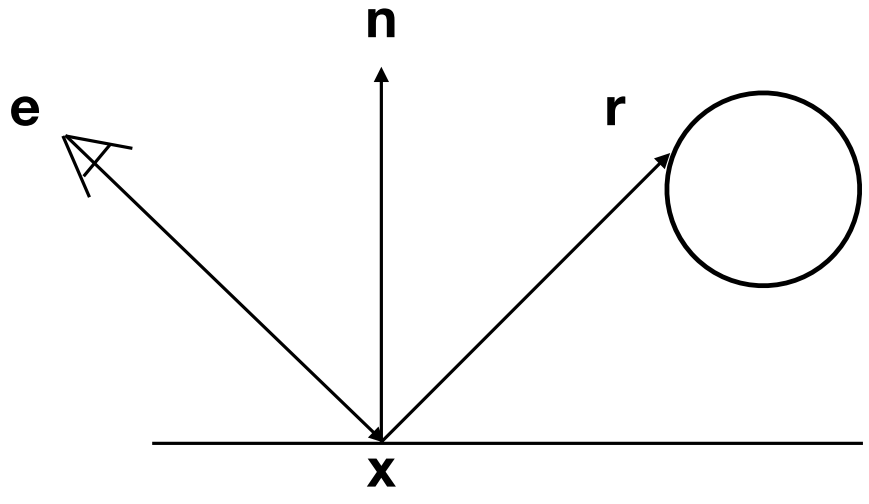


Can we do this using the tools we already have?

```
find_intersection(ray, scene)
```

Mirror Reflection

What does a camera see when it looks at a mirror?




```
compute r
ray = Ray(x, r)
find_intersection(ray, scene)
```

Recursion!?

```
traceray(ray, scene):
    t, rec = find_intersection(ray, scene)
    if rec.obj is a mirror:
      compute r, the reflection direction
      mirror_ray = Ray(rec.x, r)
      return traceray(mirror_ray, scene)
    # other cases, ...
```