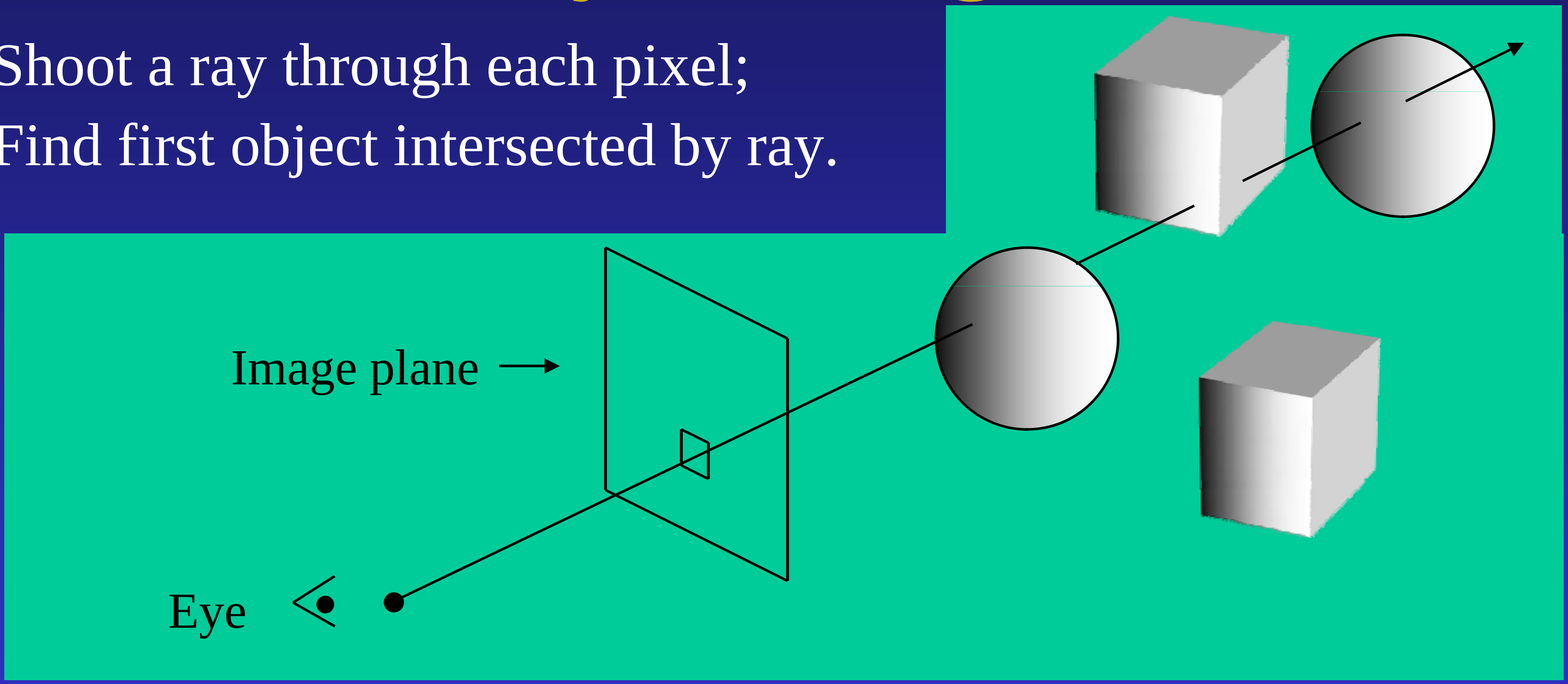
Introduction to Ray Tracing

Ray Tracing

- Shoot a ray through each pixel;
- Find first object intersected by ray.

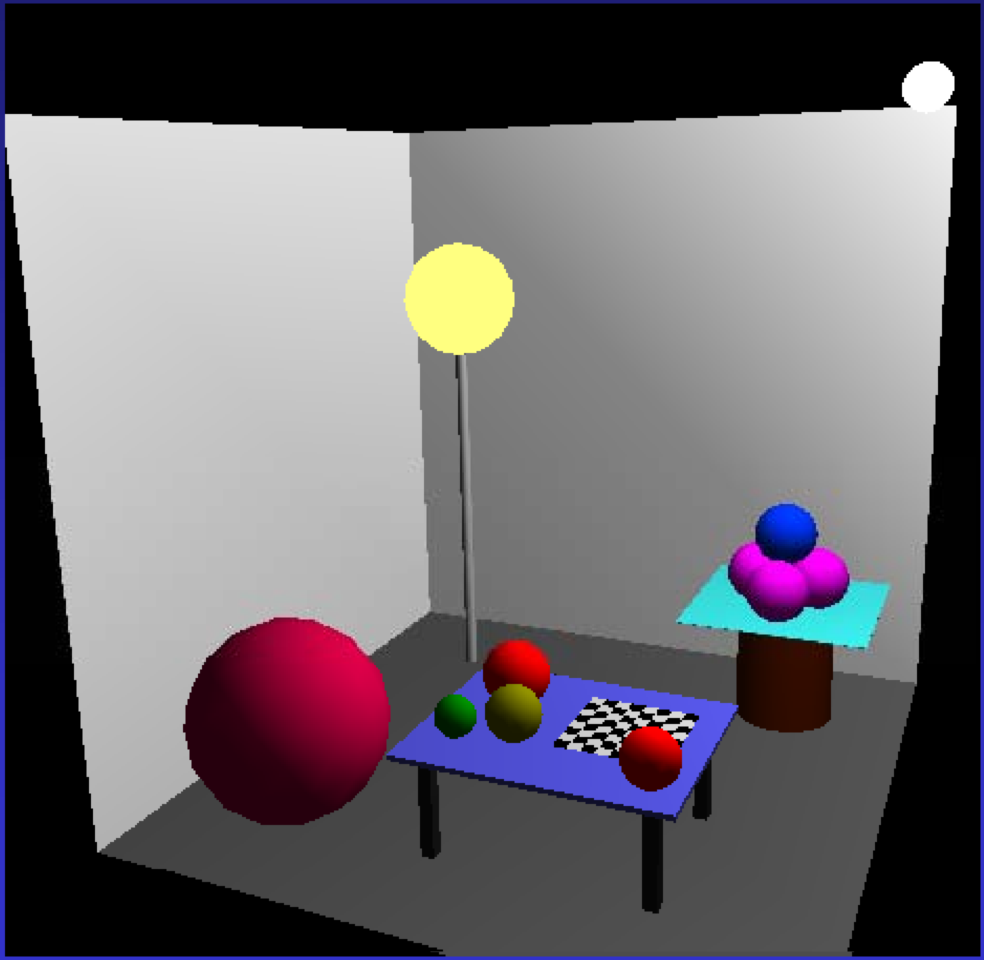


- Compute ray. (More linear algebra.)
- Compute ray-object intersection.

Ray Tracing

- For each pixel
  - Form ray from eye through pixel
  - For each object
    - Intersection ray with object
    - If intersection is closer than any other so far, save it
  - Color pixel with shade of object at point of intersection

Example

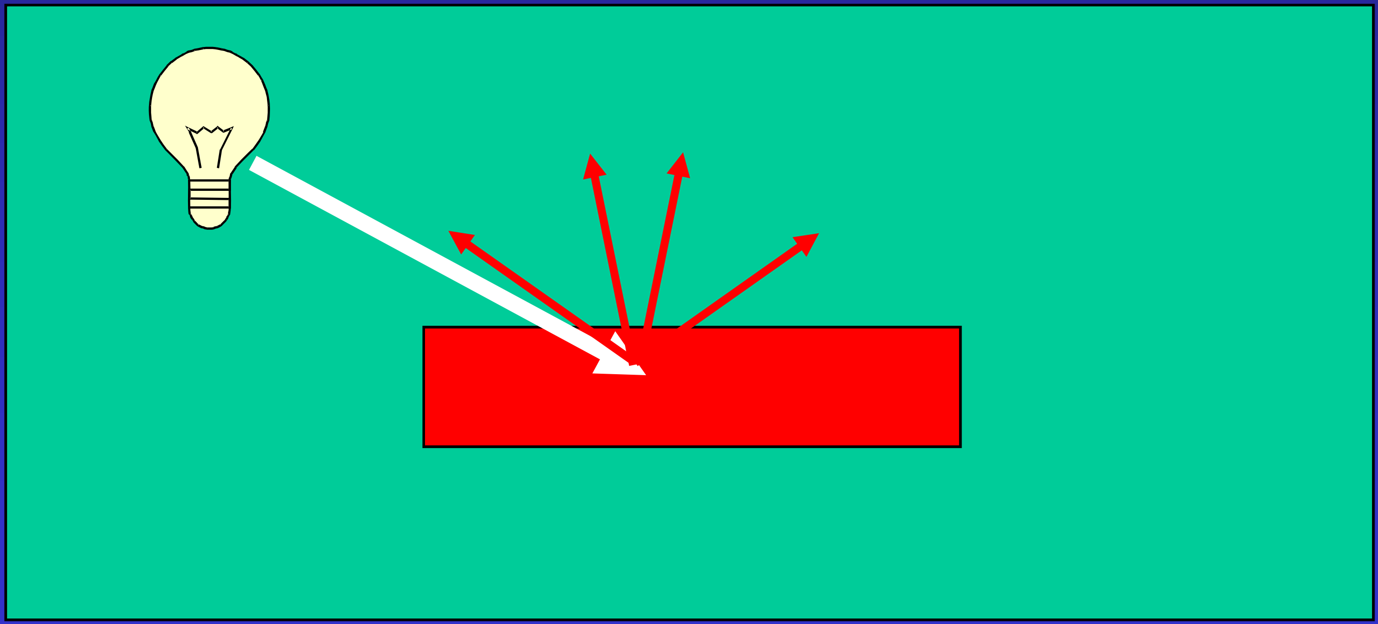


Shade of Object at Point

- Ambient
- Diffuse
- Specular
- Shadows
- Material properties
- Texture
- Reflections
- Transparency (refraction)

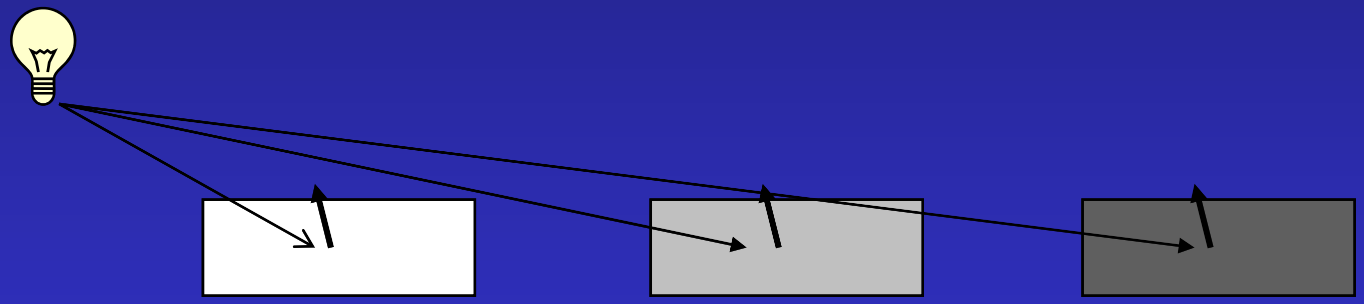
Diffuse Reflection

- Light that gets absorbed into the objects surface
- Gets reflected equally in all directions
- Need to calculate angle of incoming light to surface

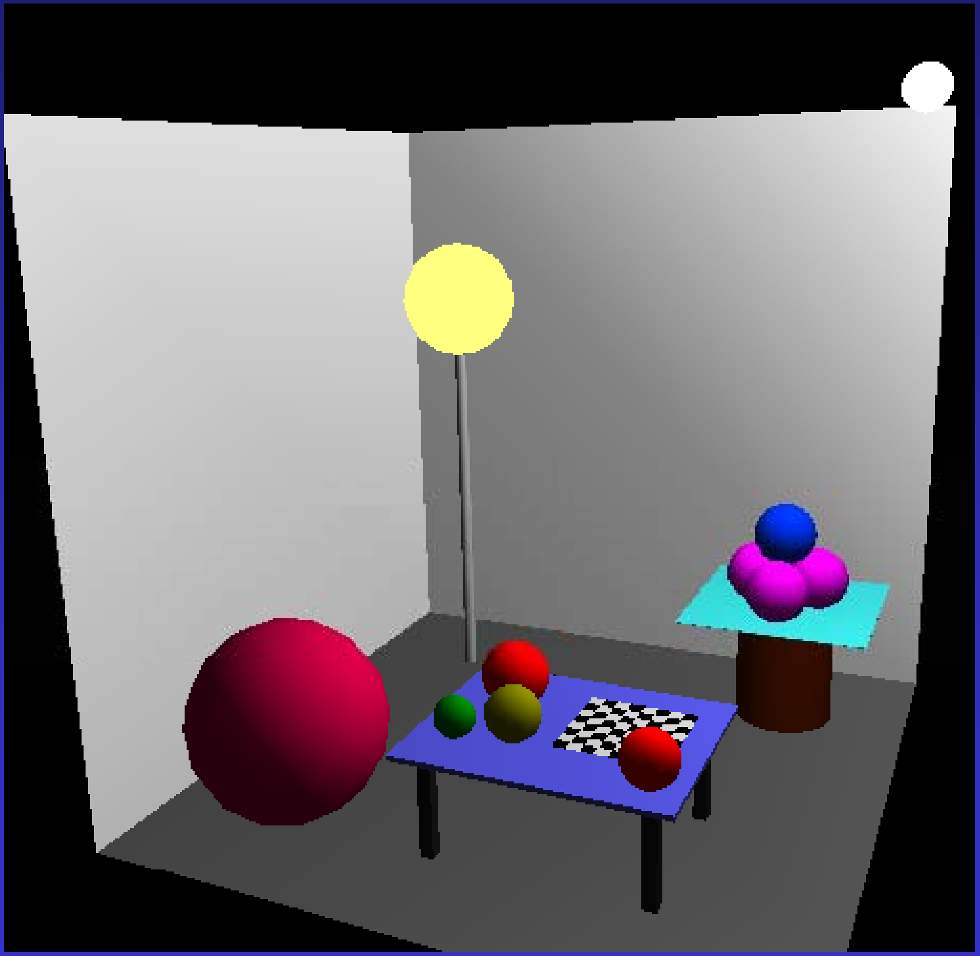


Diffuse Reflection

- Calculate amount/color of light shining on an object.
- Depends on angle between light ray and surface normal.

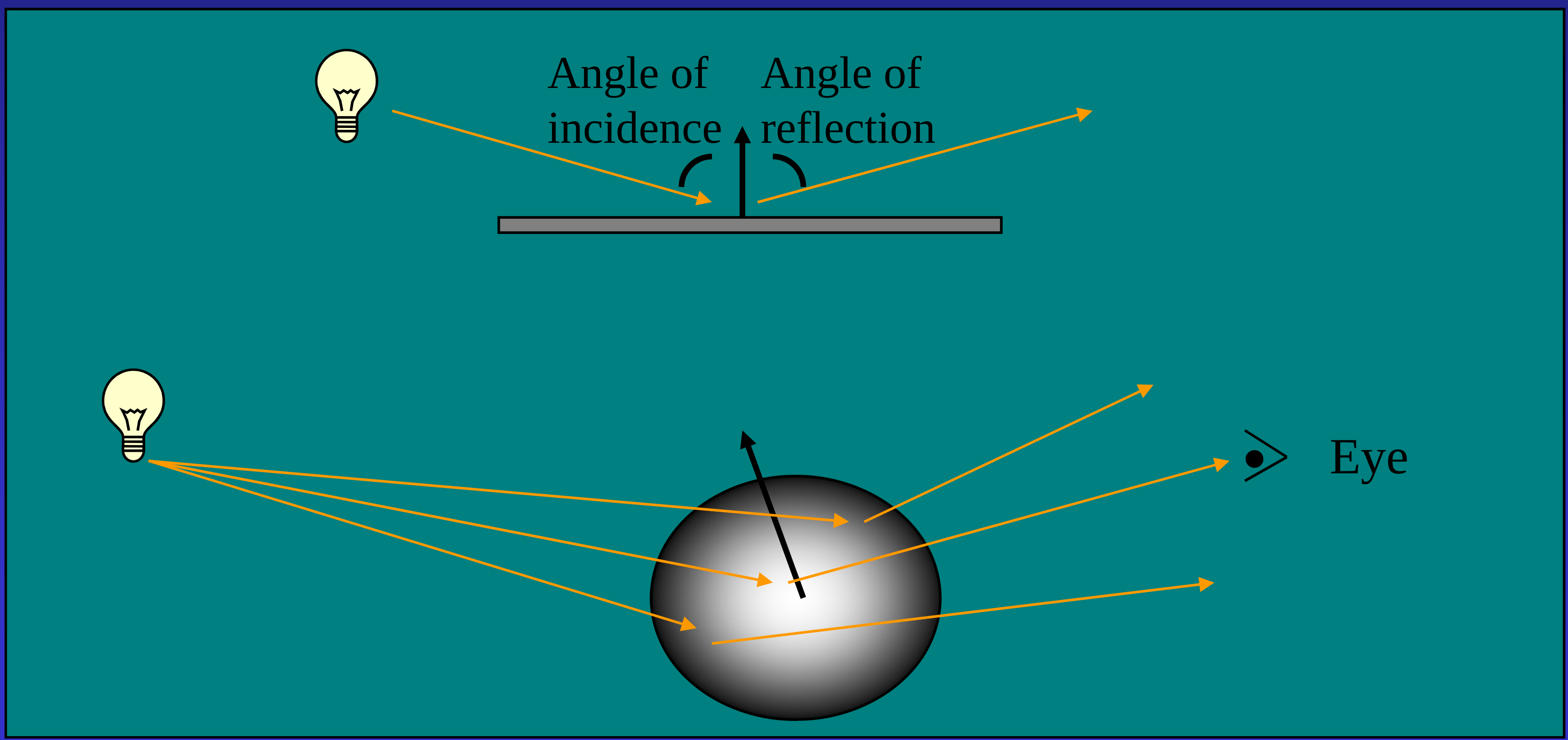


Example: Diffuse reflection

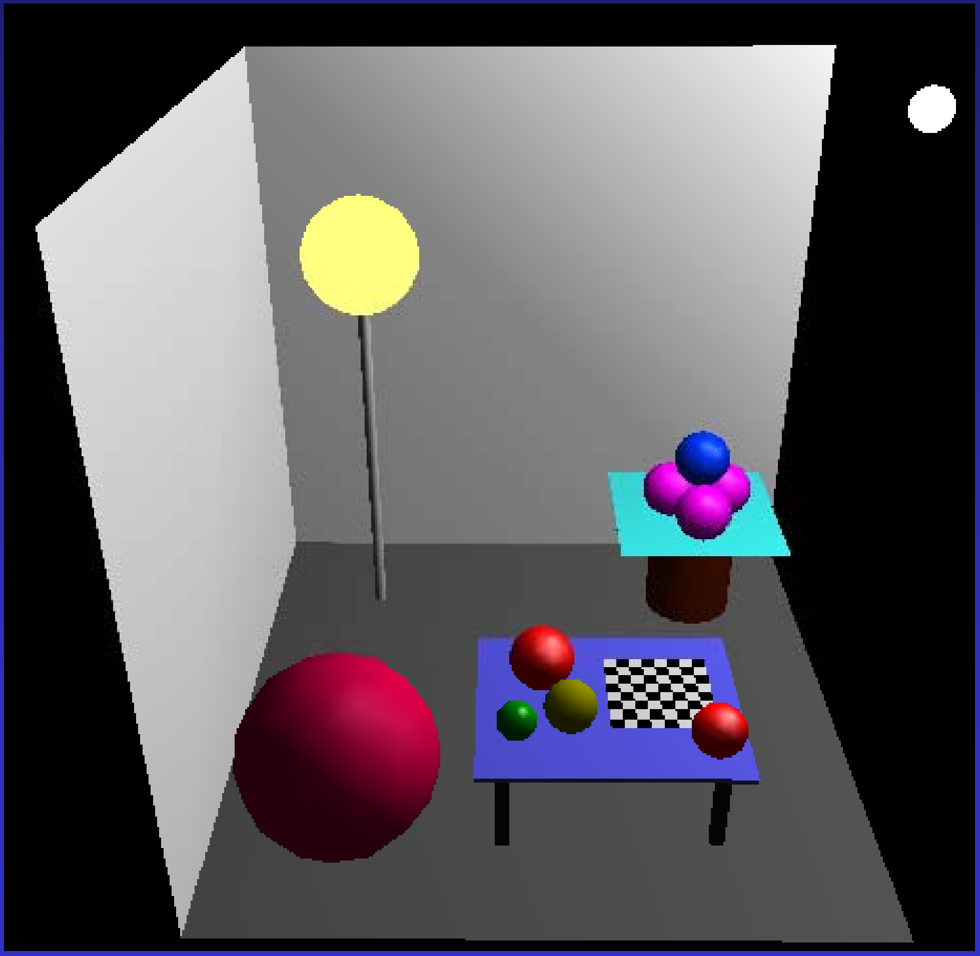


Specular Reflection

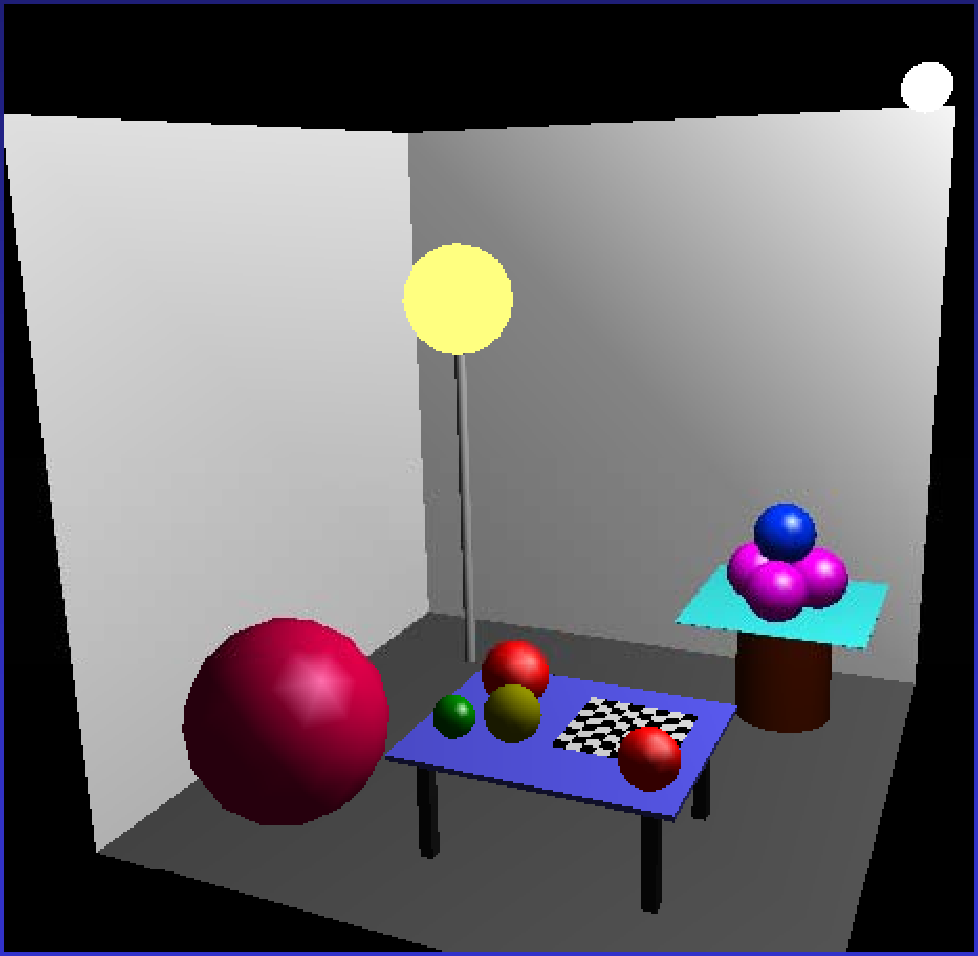
- Calculate light bouncing off object to your eye;
- Angle of incidence = angle of reflection.
- Most intense at angle of reflection; falls off from there



Example: Specular Reflection

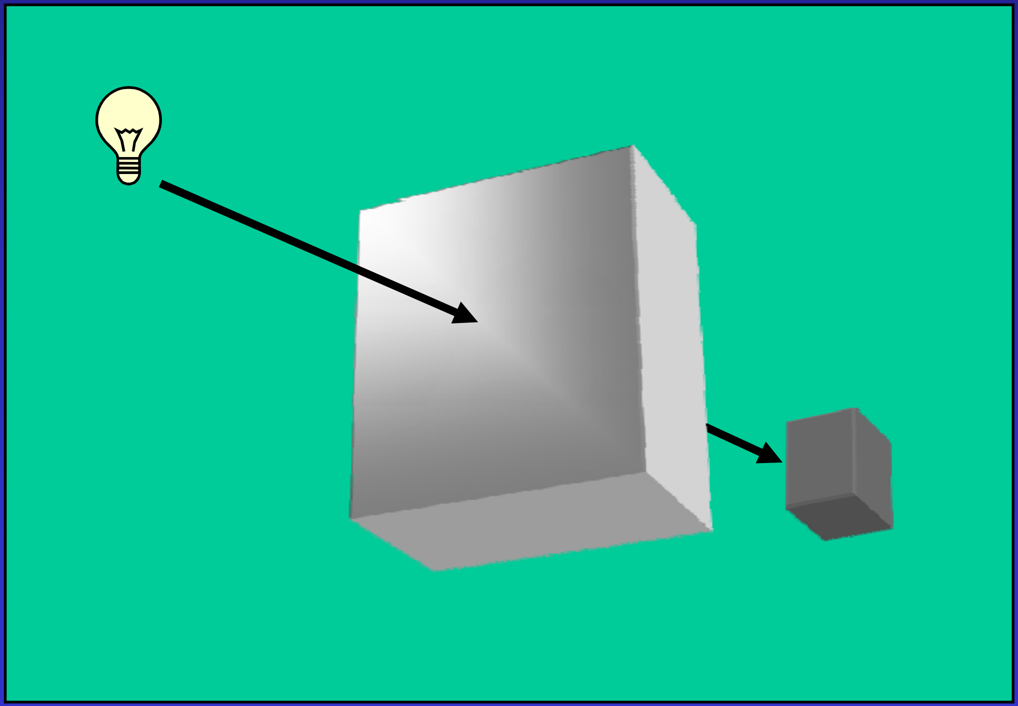


What's wrong with this picture?



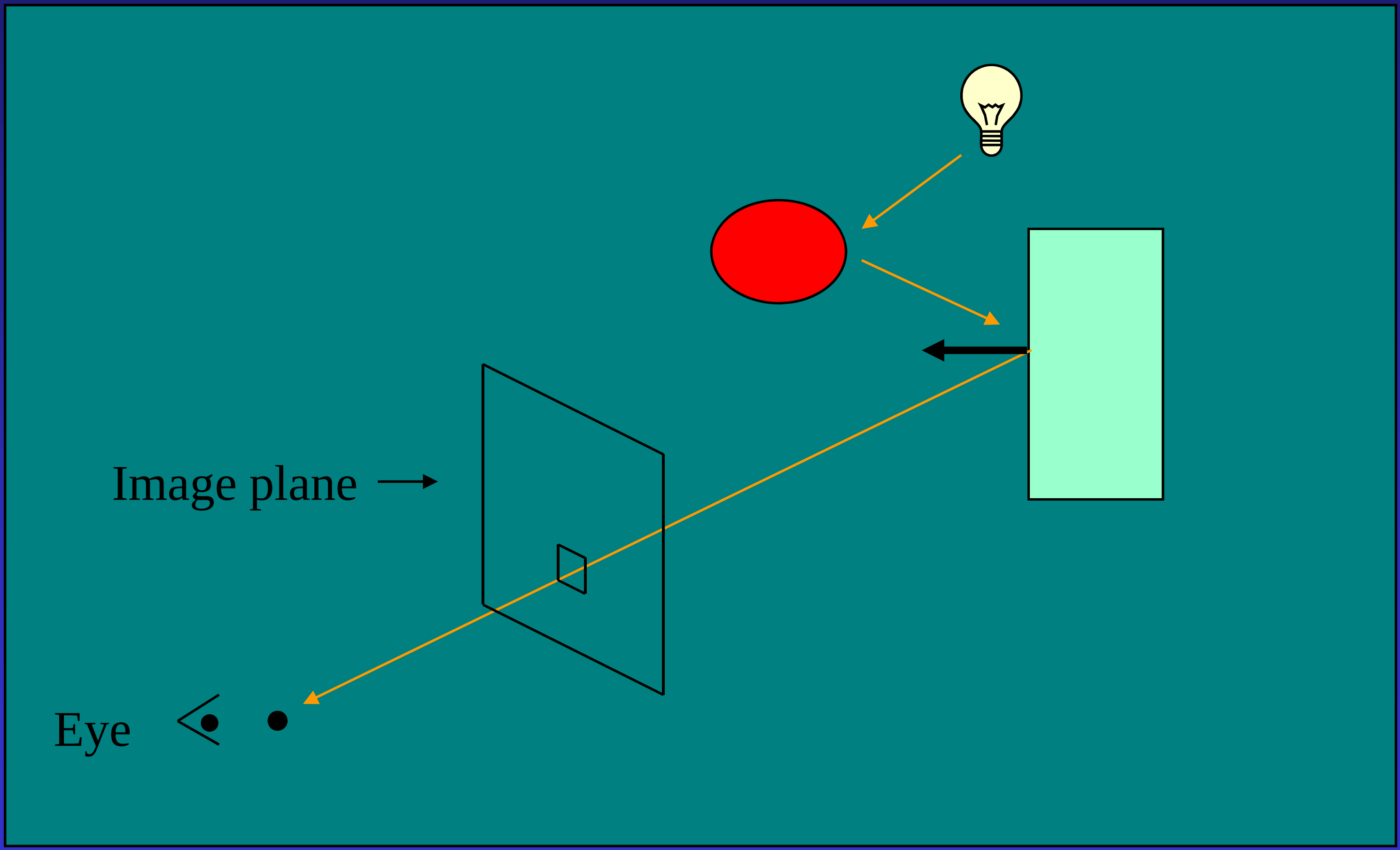
Shadows

- Determine when light ray is blocked from reaching object.
- Ray-object intersection calculation

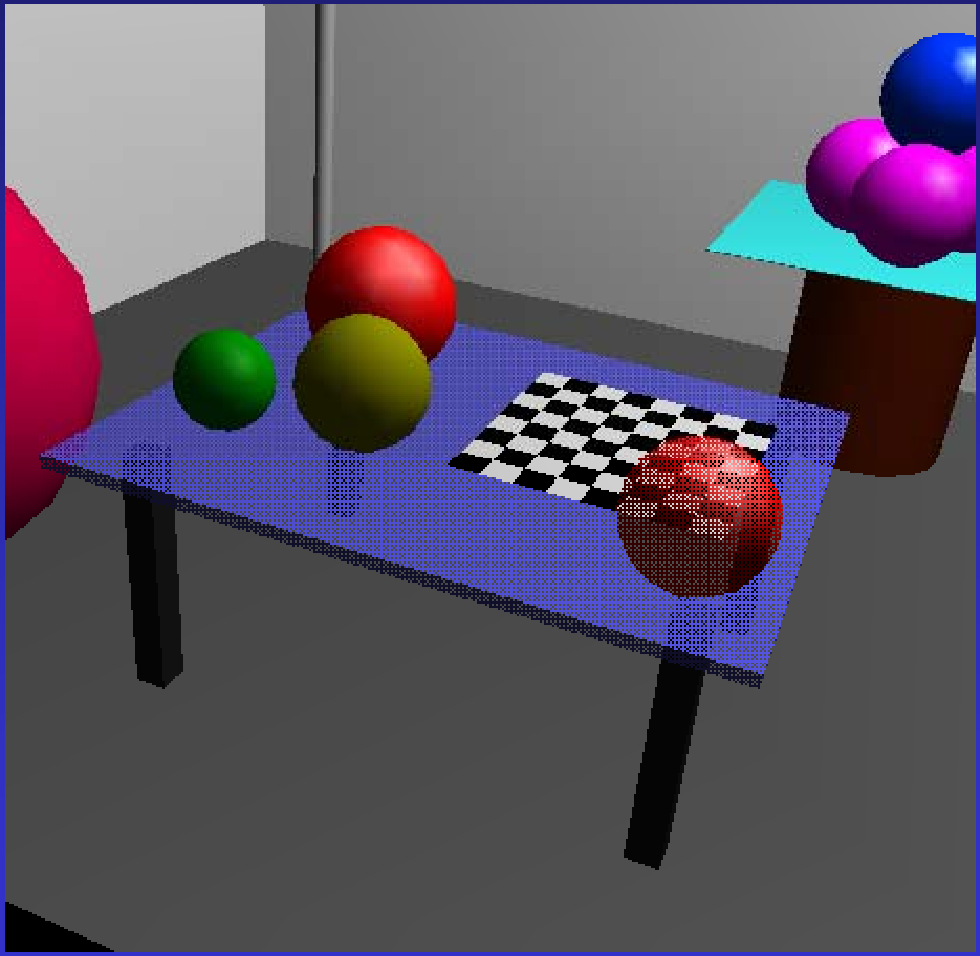


For each pixel
  for each object
  for each light source
    for each object

Reflection

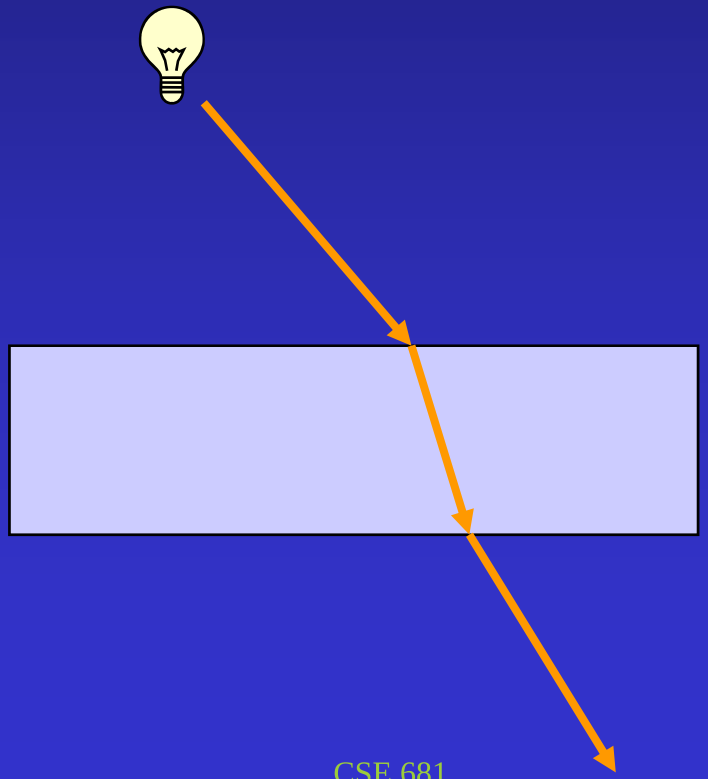


Transparency



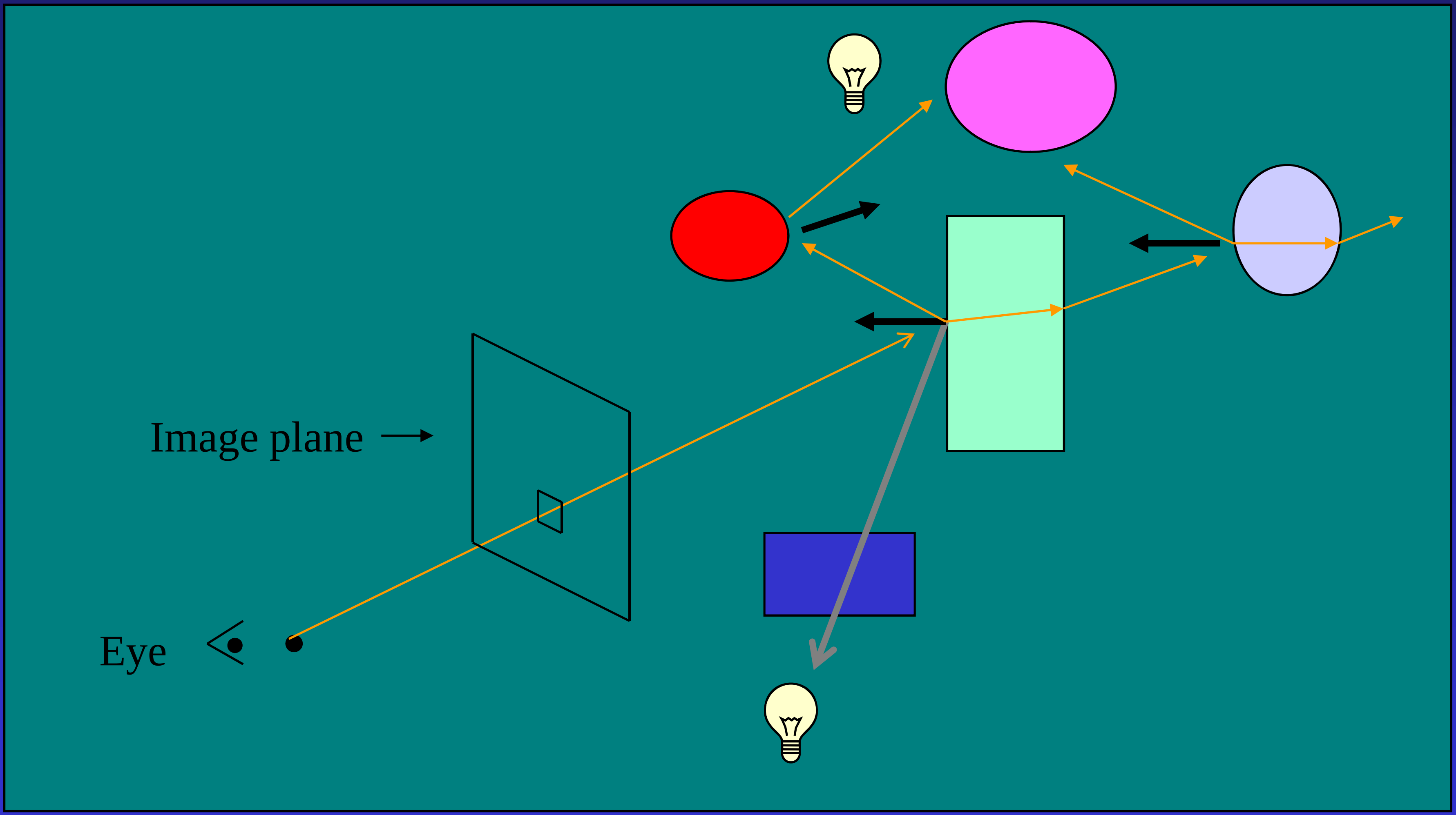
Transparency & Refraction

- Ray changes direction in transition between materials
- Material properties give ratio of in/out angles

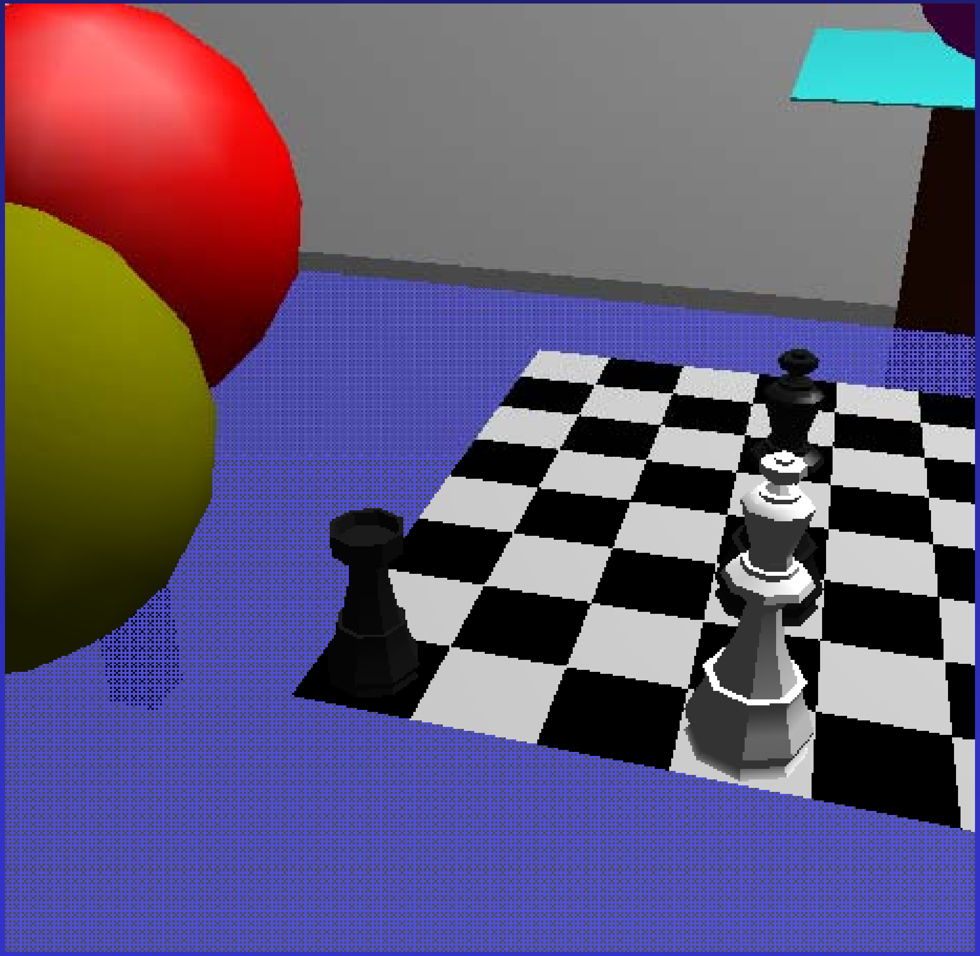


Transparency & Refraction

Recursive Ray Tracing



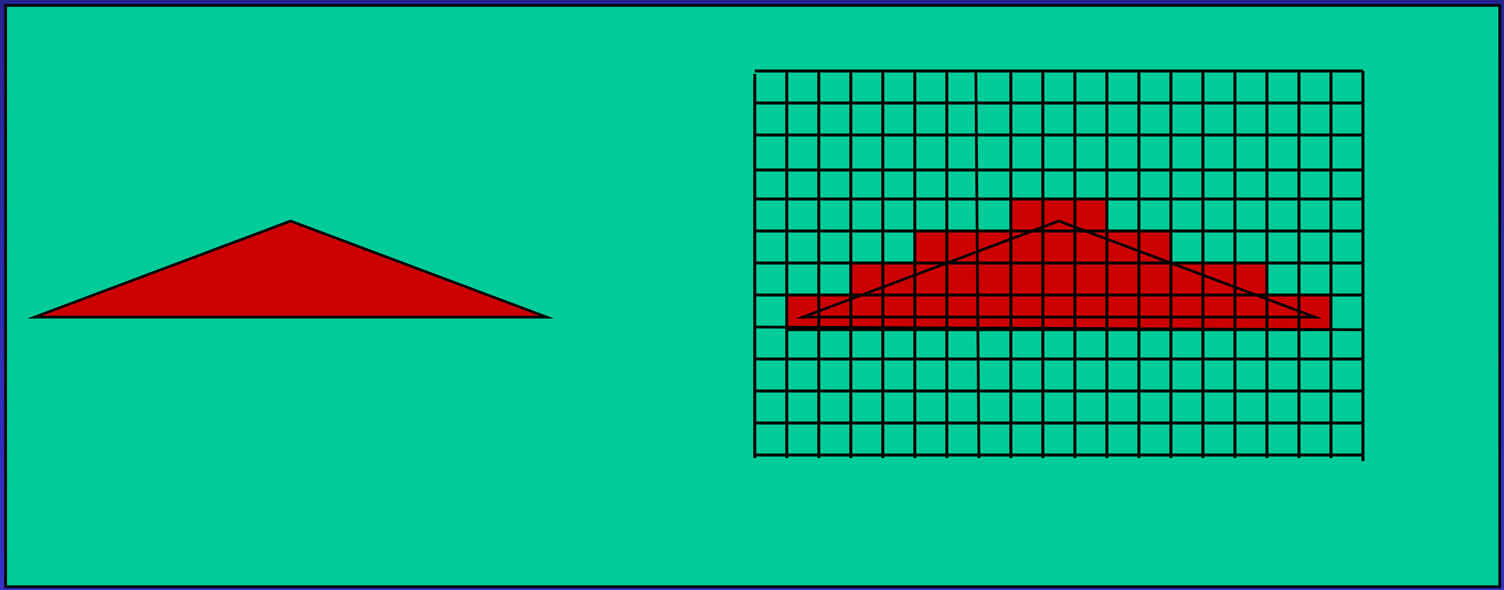
Polyhedral Models



Texture Mapping

Sampling and Aliasing

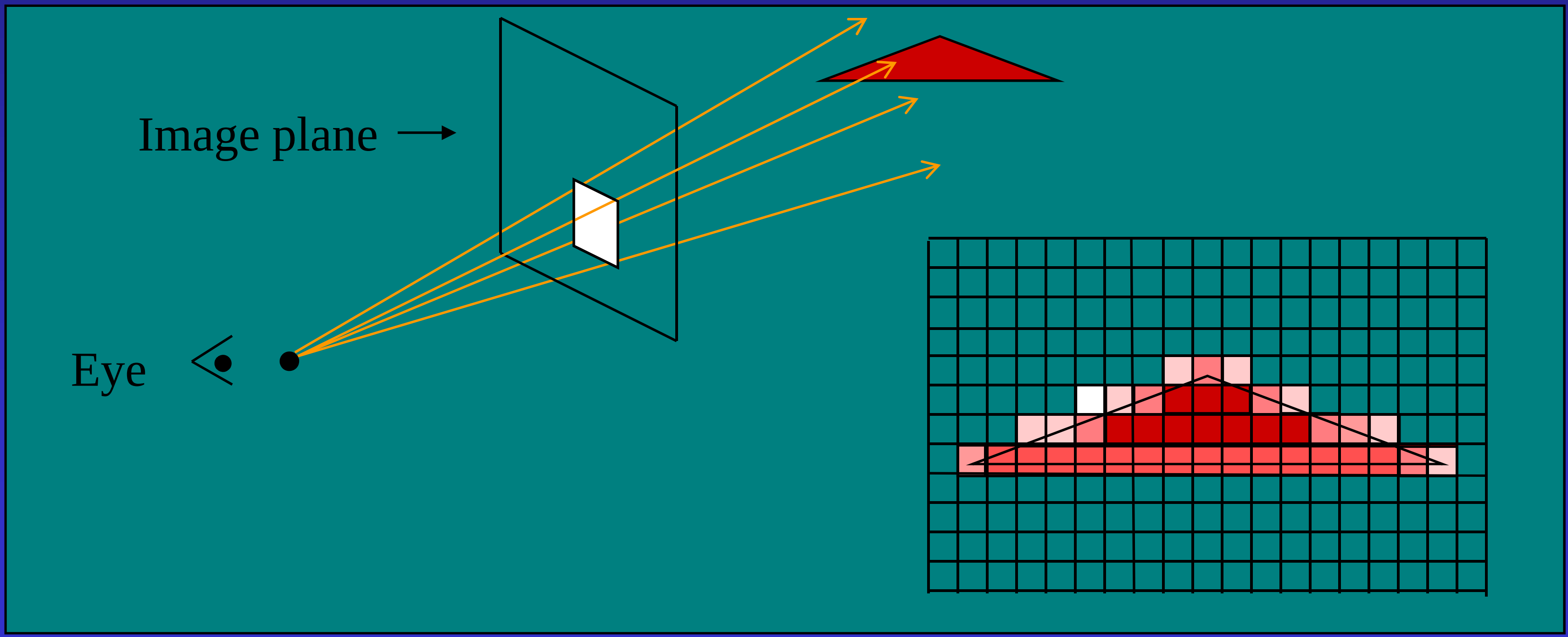
Problem: Representing pixel by a single ray.



Anti-Aliasing

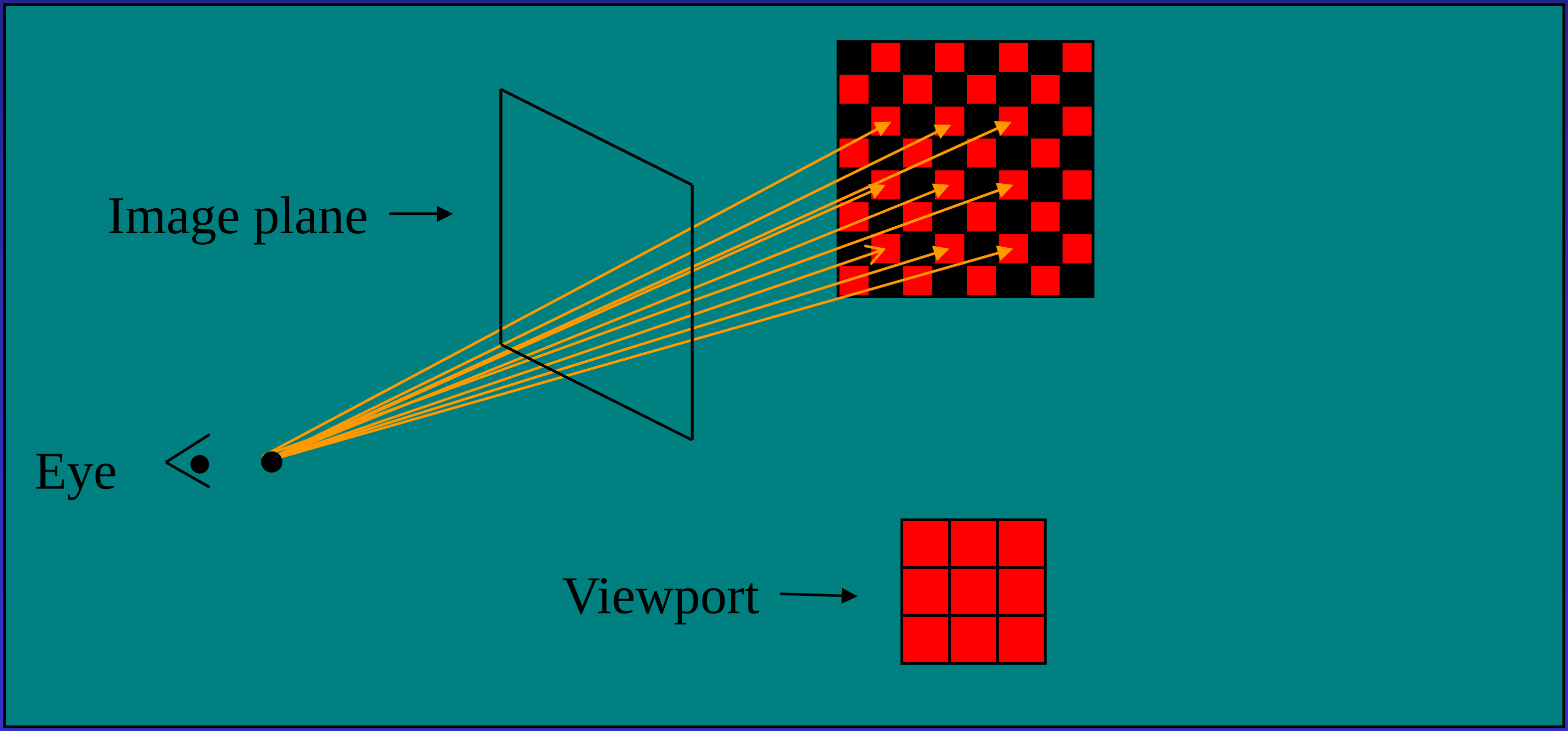
Solution:

- Use multiple rays;
- Average values calculated by rays.



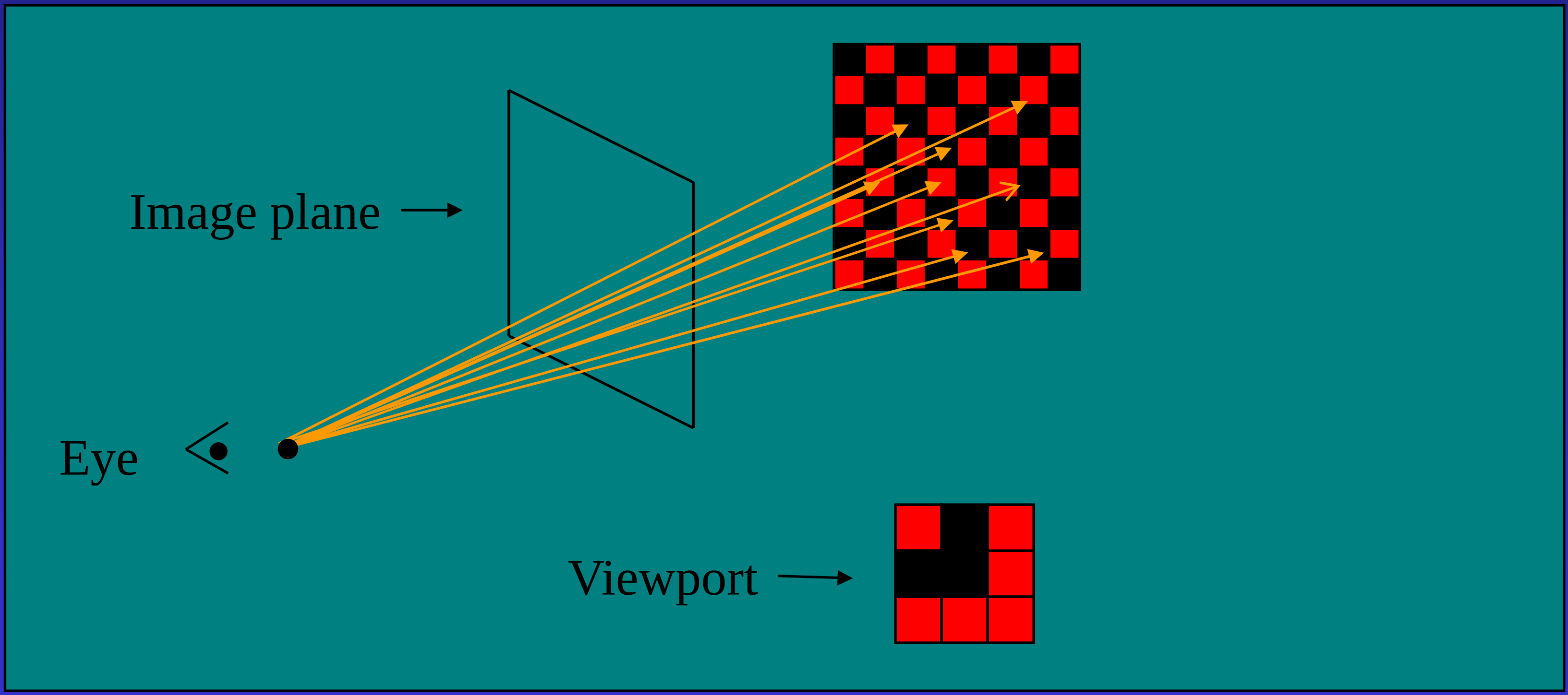
Sampling and Aliasing

Problem: Sampling frequency may match image frequency.



Random/Stochastic Sampling

Randomly sample rays through pixel.



Efficiency

- 1280 x 1024 = 1,310,720 ≈ 10^6 pixels.
- 10^6 initial rays.
- 10^6 reflection rays.
- Potentially 10^6 refraction rays.
- 3 x 10^6 shadow rays (3 lights.)

Next level:

- Potentially 4 x 10^6 refraction/reflection rays.

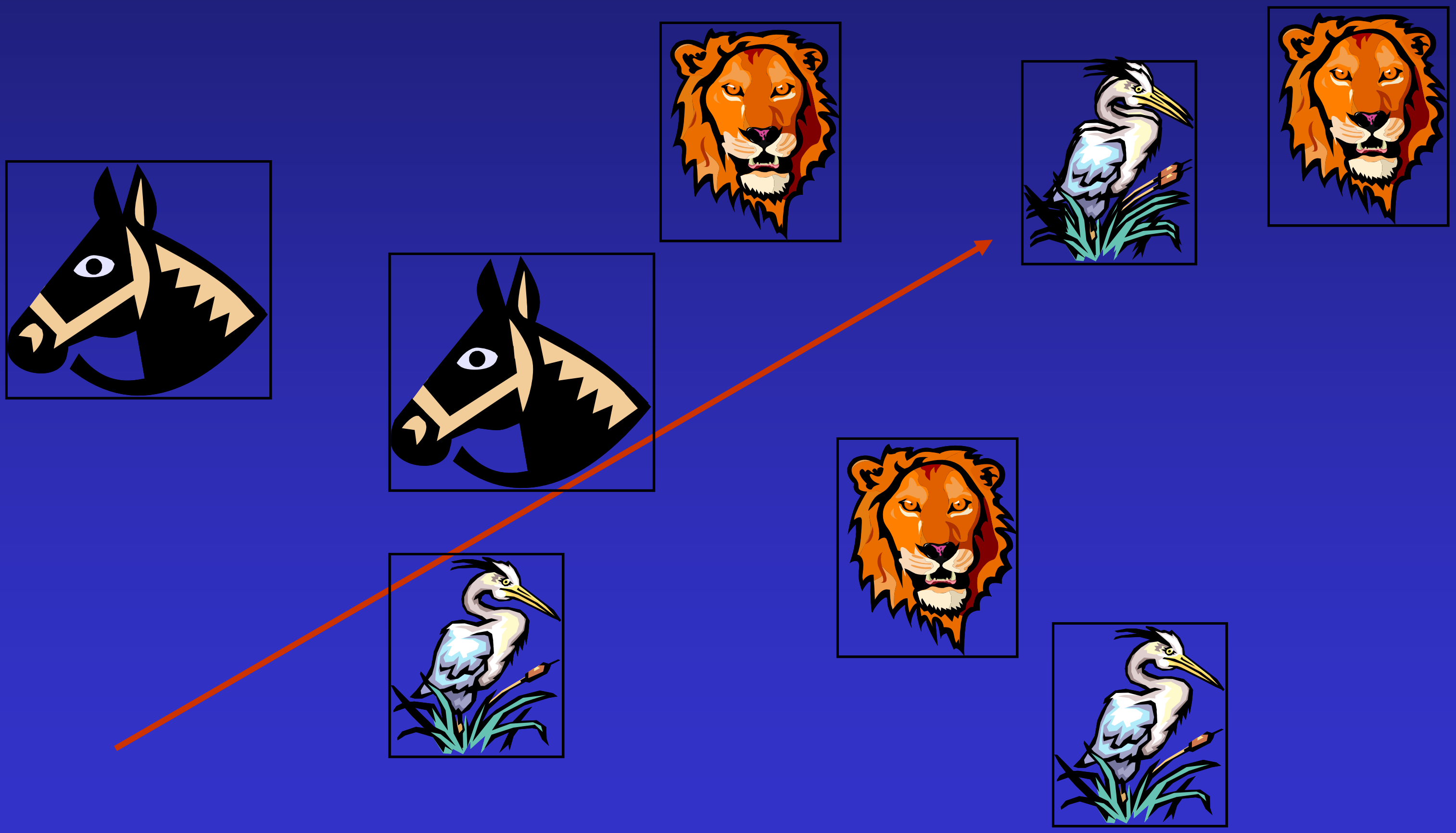
1,000,000 polygons.

10^7 x 10^6 = 10^{13} ray-polygon intersection calculations.

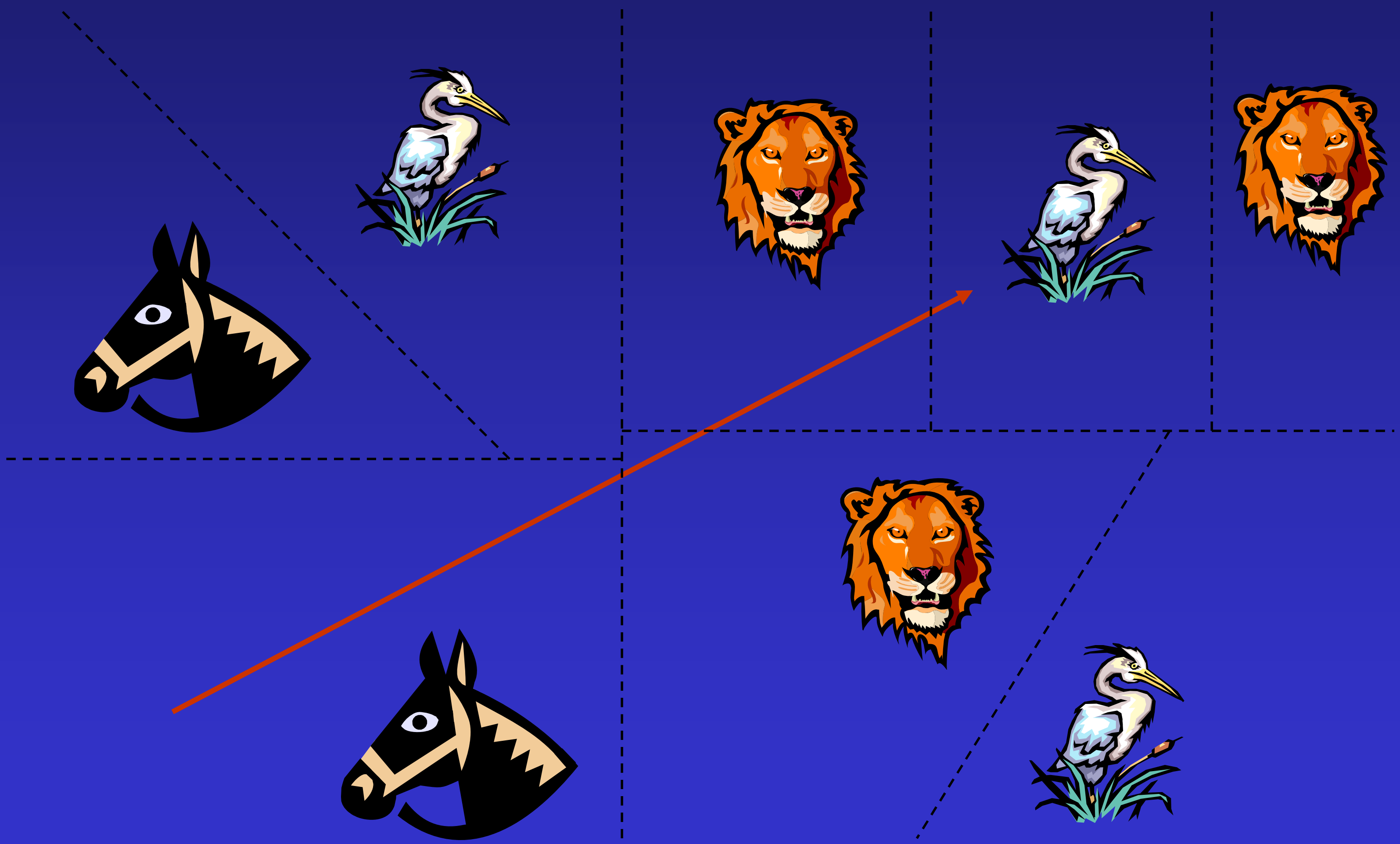
Intersection Data Structures

1. Coarse test to see if ray could *possibly* intersection object
2. Divide space up - sort objects into spatial buckets – trace ray from bucket to bucket

Bounding Boxes



Spatial Subdivision



Theory: sampling the environment

1. Rendering as sampling problem
2. Expected value & variance
3. Techniques to efficiently reduce variance

Major Course Topics

- Object & coordinate transformations.
- Ray-object intersections.
- Diffuse & specular reflection.
- Shadows.
- Opacity & refraction.
- Shadows.
- Recursive ray tracing.
- Polyhedral models.
- Texture mapping.
- Anti-aliasing and sampling.
- Bounding boxes and spatial subdivision.
- Sampling theory.