Illumination and Shading

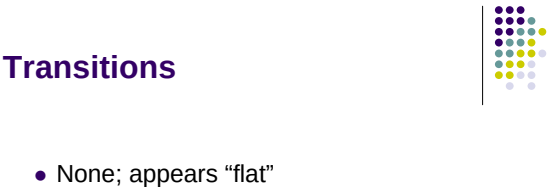
Z-buffer shaders

- Four shaders
- Two cues

Cues

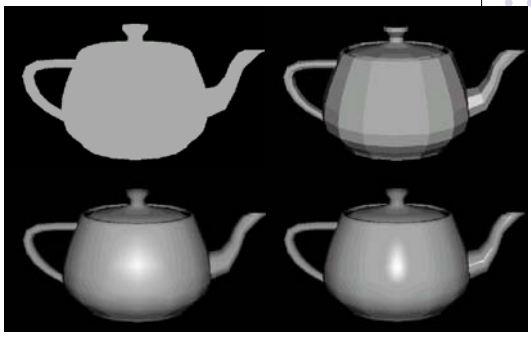
- Transitions from light to dark
- Highlights

Transitions



- None; appears “flat”
- Each polygon has only one color
- Smooth transition

Transitions

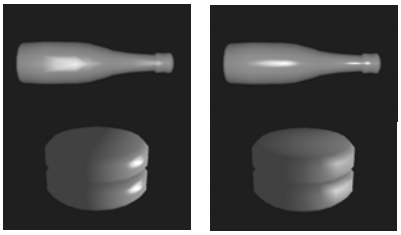


Highlights

- Smeary, star-shaped, polygon-shaped
- Compact, elliptical, “shiny plastic”

Highlights

What do you think?



Simple Illumination Models

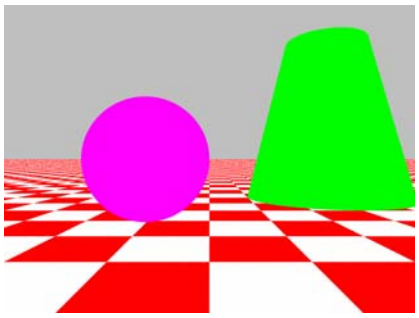
Ambient Light

Intensity — Intensity of ambient light

$$I = I_a k_a$$

Ambient-reflection coefficient (property of material)

Ambient Light



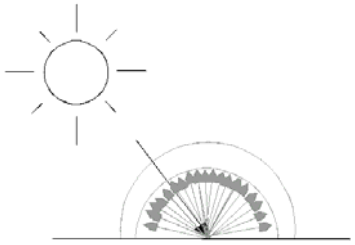
Reflection

- What we see is reflected light
- Some light is absorbed, radiated as heat.
- Some light is reflected.

Two types of reflection

- Diffuse (Lambertian)
- Specular

Diffuse Reflection

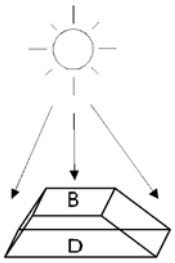


Our sun

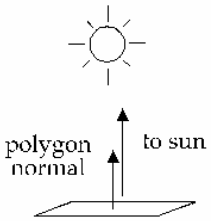
•Position of a direct light also affects an object's reflectance

Polygon orientation

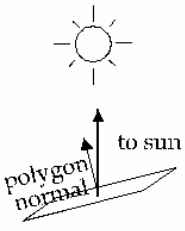
Directional lights' orientation relative to a surface affects the intensity of the light that strikes the surface



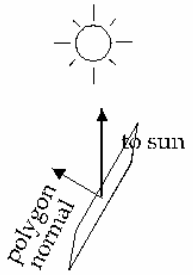
Light intensity



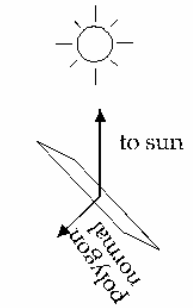
Light intensity



Light intensity



Light intensity



Diffuse reflection

- Matte or dull surfaces
- Produces what the eye perceives as color
- Depends on
  - components of white light it reflects
  - strength of ambient light striking surface
  - strength of direct light striking surface
  - position of the direct light
  - orientation of surface

Lambert's Law

The reflected intensity of matte or dull surfaces

- is proportional to the cosine between the normal of the surface and the direction of light
- is independent of the viewing angle

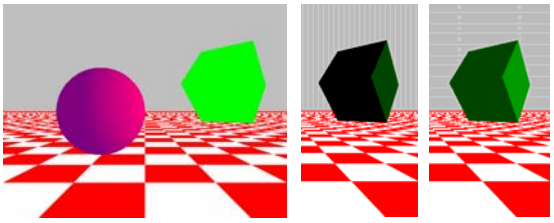
Intensity — Direction of light (normalized)

$$I = I_p\,(N \,.\, L)$$

Intensity of point-light source — Surface normal (normalized)

Ambient and Diffuse Light

$$I = I_a k_a + I_p\,(N \,.\, L)$$



Phong lighting model

- Approximates physics
- Interaction of light and surfaces

Light

- Point light
- Ambient

Reflection

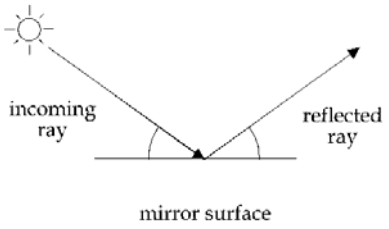
Phong lighting model supports both types of reflection:

- Diffuse (Lambertian)
- Specular

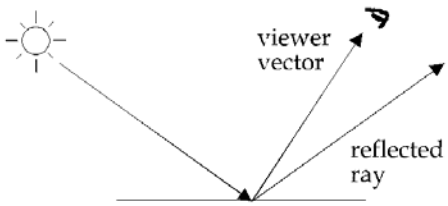
Specular Reflection

- Doesn't absorb light -- reflects it.
- Highlights
- Influences
  - Strength of directional light
  - Position of directional light
  - Orientation of the surface
  - Position of viewer
  - Surface roughness

Perfect specular reflector

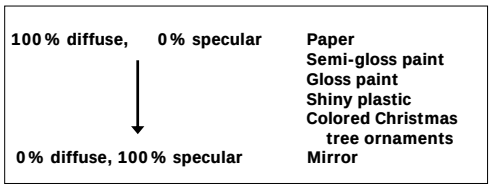


Viewer



Roughness

A range of materials



Phong Illumination (simplified)

roughness

$$I = I_a k_a + I_p [(N \cdot L) + k_s (N \cdot L)^n]$$

Specular reflection coefficient (material dependent)

Missing:

- Light-Source Attenuation
- Atmospheric Attenuation (depth cueing)
- Colored diffusion

Z-Buffer Shading

Z-buffer shaders

- Constant
- Faceted
- Gouraud
- Phong

Constant shading

- One color calculation per object

Faceted shading

- One color calculation per polygon
- Called constant shading in Foley, van Dam, Feiner, Hughes

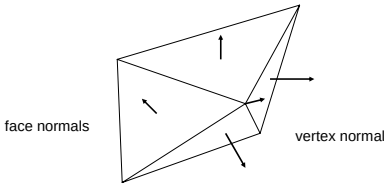
Gouraud shading

aka color interpolation shading

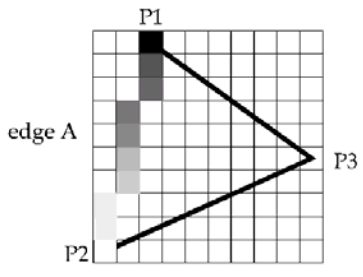
- One color calculation per *vertex*
- Blend color within each face

Vertex Normals

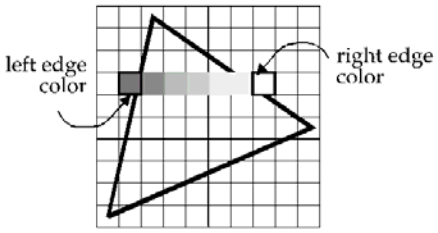
•Can be given, or
•Can be computed, or
•Can be approximated by face normals



Blending, part 1



Blending, part 2

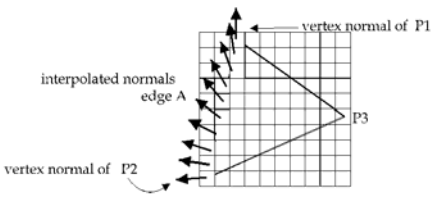


Phong shading

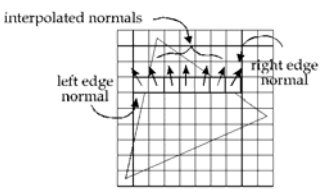
aka normal vector interpolation shading

- One color calculation per pixel
- Blend normals!

Phong, part 1



Phong, part 2



Gouraud versus Phong

•Speed?
•What if: highlight falls on a vertex?
•What if: highlight lies entirely within face?
•Mach-bands?

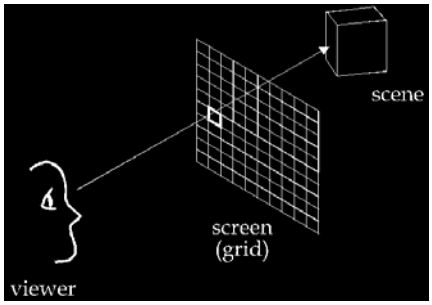
Interpolation Shading

General Problems (FvDFH):
•Polygonal silhouette
•Perspective distortion
•Lack of robustness under transformations

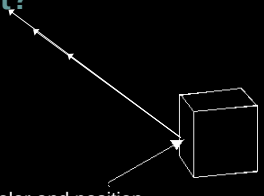
Basic Raytracing Shaders

More on POV-Ray

Basic idea, revisited



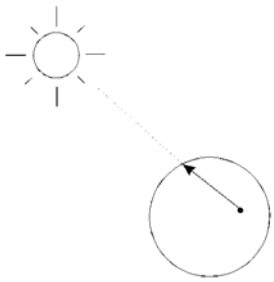
Where next?



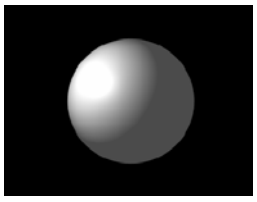
- Light source color and position
- Surface properties and shape
- The rest of the scene

But First ……

Shadows



The dark side

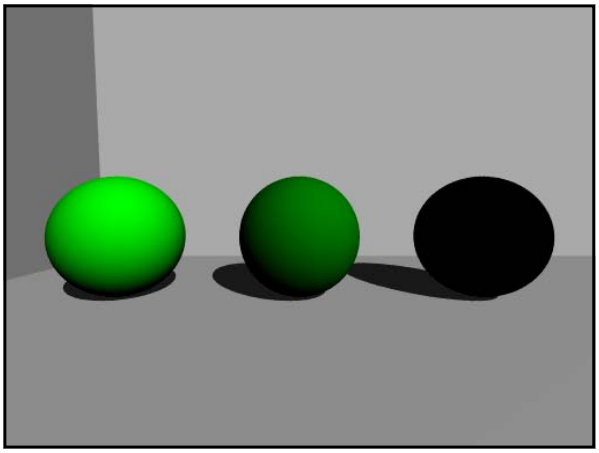


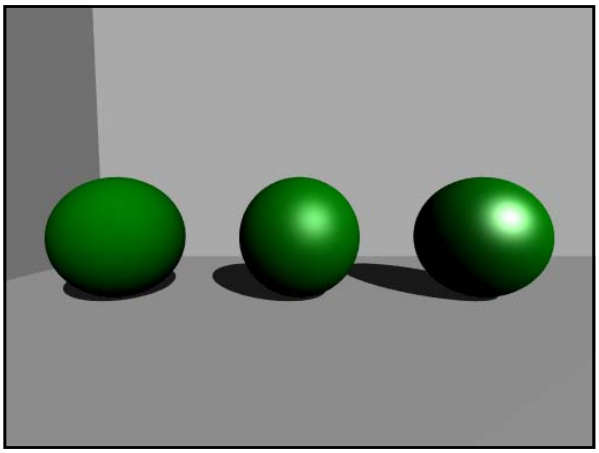
Basic Shaders for raytracing

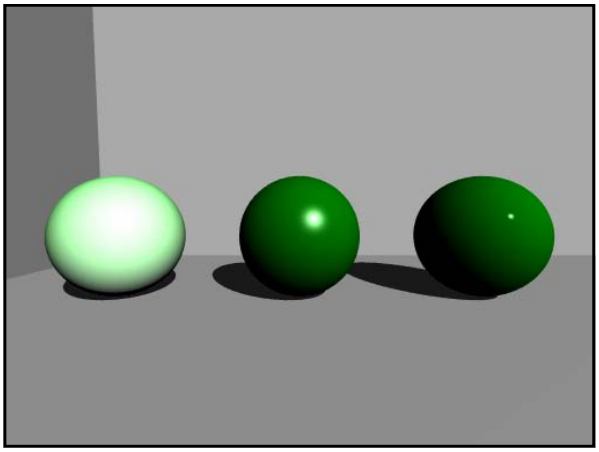
- Diffuse
- Specular
- Reflective
- Transparent

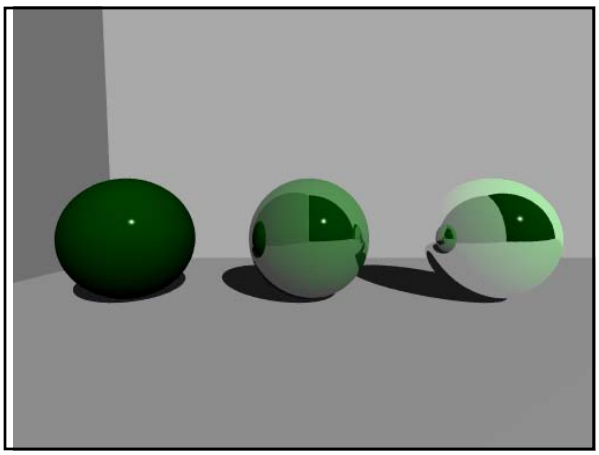
POV-Ray

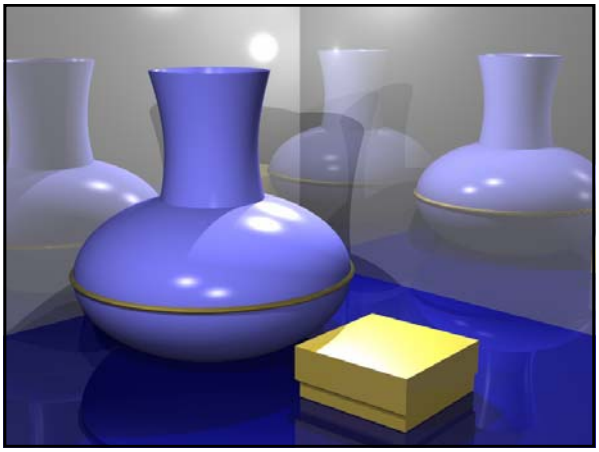
- phong, phong_size
- specular, roughness
- reflection

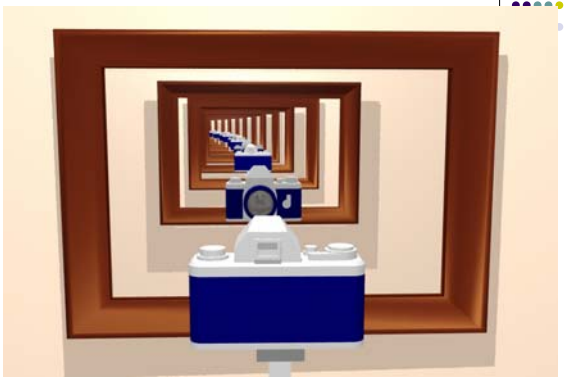




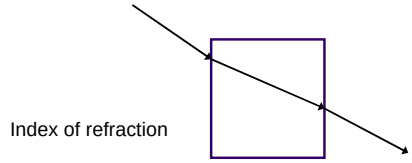


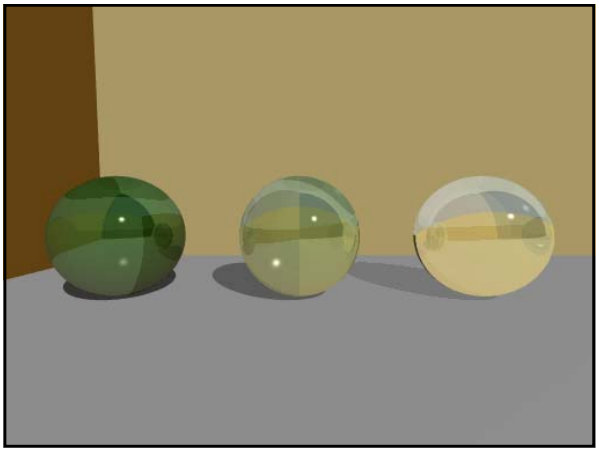


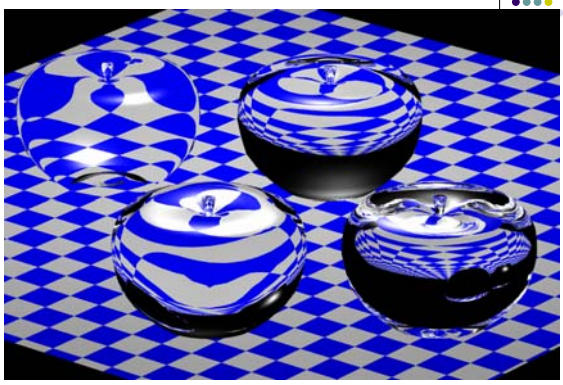


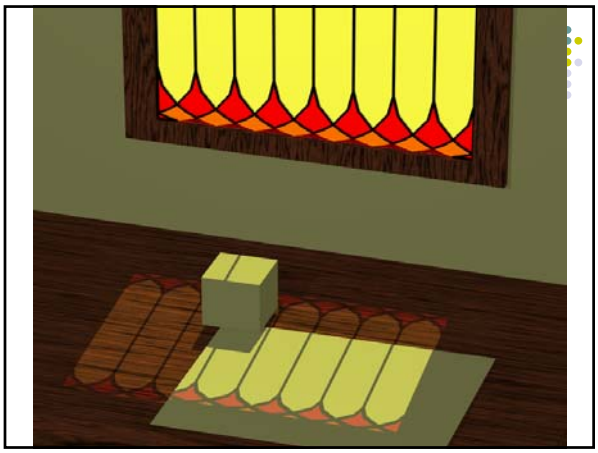


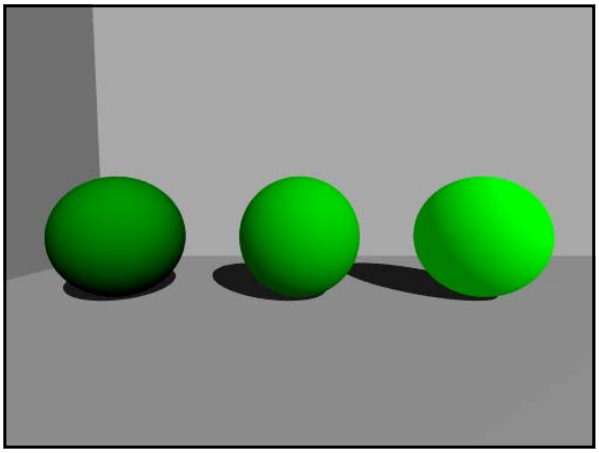
Transparency











Exercise