What color do we make these solid objects? Depends on object and light!

How does lighting work?

In the real world......
Light bounces off everything
All objects influence all others

Global illumination
Hard to do - must consider all objects, interactions, .... interdependence (1 depends on 2 depends...)
good for getting complex lighting effects
an advanced topic

In the CG world......
Local lighting -
Decision of how to light a point on an object depends on:
- surface AT that point
- eye position
- lights
LOCAL LIGHTING

Consider only 1 point on 1 object

- No shadows
- No self shadows
- No color spill
- No inter-reflection
- No area light sources - point sources only

If you want these, add with a hack

3 parts (per light)

- Specular (direct reflection)
- Diffuse (scattering)
- Ambient (back for indirect)

Lighting is a hack.

Real lighting is complex.
Microstructure of materials.

Get "biggest" features of lighting correct.

Your models are still hacks, just get more features right.
Lighting & Shading

What color is a point?

Physics: depends on how light interacts with all objects in scene
- some of the objects reflected light
go off towards eye ⇒

CG: do some computation to determine color  Shader

color = Shader ( info )

⇒ what info do we give the shader?

Simple Shading:
- reflectance
- object properties (color)
- light info (position, color, intensity)
- eye position
- local geometry (position, normal)
Diffuse Shading

matte objects
rough surfaces
"micro surface texture" scatters light in all directions

chalk, paper, unpolished wood or stone, ...

Lambertian reflects
scatters light in all directions equally

eye position doesn't matter

light position DOES matter (relative to surface orientation)

consider fixed sized object:

\[
\begin{align*}
\text{amount of light that hits is } & \propto \\
\cos \theta & \text{ where } \theta = \angle \text{ between light and normal} \\
D_i & \propto \hat{n} \cdot \hat{l}
\end{align*}
\]
One last problem—

What about inter-reflected light—
room isn't totally black

☐ ← this side of object should have some light

"Ambient" light = indirect light that is just bouncing around

Hach 8 add in a light source that affects all objects equally - Ambient lighting
Specular (direct reflection)
Perfect mirror

\[ \begin{align*}
\theta_i & \quad \theta_r \\
N & \quad \vec{E} \\
\end{align*} \]

ping-pong ball model
\[ \theta_i = \theta_r \]

light gets to eye only if things line up exactly

\textbf{HACK} \rightarrow if it's close to the eye, that's good enough

distance as it gets further away

\[ L \approx \hat{E} \cdot \hat{R} \]

\[ L \text{ need a falloff function} \]

Phong Model
\[ L \approx (\hat{E} \cdot \hat{R}) \cdot \hat{C}_L \]

Easier Way
\[ H = \text{half-way angle} \]
\[ L = (\hat{N} \cdot \hat{H}) \cdot \hat{C}_L \]
Hack Lighting Model (GL)

1. Eye Position
2. Object Local Geometry (NORMALS)

3. Each light source has a position (may be at infinity) and a brightness (color) $I_i$

4. Ambient light has a brightness (color) $A$

5. Surface has a diffuse reflector color $C_D$, specular color $C_S$, shininess $s$, an ambient color (reflectance) $C_A$

\[
\text{color} = A \times C_A + \sum_{i \in \text{lights}} \left( I_i \times (C_D \cdot (\hat{n} \cdot \hat{i}) + C_S (\hat{N} \cdot \hat{n})^s) \right)
\]
Some improvements:

1. Falloff (brightness depends on distance)
2. More sophisticated ways of finding $C_0, C_5$ based on position
3. More complex reflectance function
   $BRDF \left( \text{bi-directional} \right)$
   reflectance
   distribution function

given -
   input direction $\rightarrow$ output direction $\rightarrow$
   reflectance
How to use this?

Polygons are all the same color (one normal)

- FLAT shading
  - approximation \( \hat{\mathbf{L}} \) and \( \hat{\mathbf{E}} \) do change, only a little

Problem:

- polygons are an approximation to a smooth surface
- normal per vertex

1. Compute color at vertices
   - linearly interpolate color
   - GOURAUD Shading

2. Linearly interpolate normals
   - compute lighting per-pixel
   - PHONG SHADING

(do not confuse with Phong LIGHTING)