IMPORTANT NOTE: ASSIGNMENT 2 DEADLINE

Due to the bank holiday next Monday (meaning one lost lecture relevant to the POV-ray assignment), the deadline is postponed until 20th November, 2016.
MATERIALS AND ILLUMINATION
How do artists choose colours across an object to depict shape?
ILLUMINATION MODELS

Try to represent what the eye sees as light is reflected from objects in the scene
In Computer Images, we're always concerned with how this relates to individual pixels.
ILLUMINATION DEPENDS ON...

- Position of objects
- Position of light
- Position of viewer

Colour of objects?
How light bounces off objects
LOCAL VS. GLOBAL ILLUMINATION

**Local**
Illumination depends on local object & light sources only

**Global**
Illumination at a point can depend on any other point in the scene
Phong Illumination Model: A means of calculating the colour of points in a scene
DIFFUSE REFLECTION

The appearance of matte/rough surfaces.

Random scattering by microfacets

Light from a point is invariant to changes in viewing direction

(no matter from where you view it, it looks like the same colour and brightness)
DIFFUSE REFLECTION

However the intensity of light reflected **is** dependent on light direction.
Intensity (brightness) of reflected light at a point depends on:

- The **angle ($\theta$) the light rays make** with the surface of the object at that point
  [this varies across scene]

- The **reflectivity of the object** surface ($k_d$): percentage of incoming light reflected out
  [this is constant for the object]

- The **colour and brightness of the lightsource** ($R$)
  [this is constant for the scene]

$$I = R \cdot k_d \cdot \cos \theta$$
ASIDE: THE NORMAL VECTOR

Used in 3D Graphics to represent surface orientation at a point
Vector that is 90 degrees (right angle) to the object at that point

\[
\text{plane} \\
\{ \\
\quad <0, 1, 0>, 0 \\
\quad \text{pigment \{rgb<.5,.5,.5>\}} \\
\}
\]

\[
\text{plane} \\
\{ \\
\quad <1, 1, 0>, 0 \\
\quad \text{pigment \{rgb<.5,.5,.5>\}} \\
\}
\]
The variation of normal across an object is what primarily causes the illumination of the object to vary at different points.
DIFFUSE REFLECTION IN POV-RAY

Material properties of an object are specified in the `finish` sub-object.

For instance the key-word `diffuse` allows you to specify the diffuse reflectance, what percentage of incoming light is reflected back out by the object.

```
sphere
{
    <0,0,0>, 1
    pigment { rgb <1, 1, 1> }
    finish { diffuse 0.5 }
}
```

The spheres above are have diffuse values of 0.0, 0.25, 0.5, 0.75, 1 respectively.
SPECULAR REFLECTION

Bright highlights observed in polished or shiny objects

For a very shiny object (perfect reflector) all incoming light is bounced back out in direction of reflection ($\theta_r = \theta_i$)

Many objects are not so perfect — they reflect light in a small range of angles around the direction of perfect reflection
PHONG MODEL OF SPECULAR REFLECTION

Intensity of reflected light depends on:

- Angle ($\phi$) between the viewer direction and the reflected direction (the latter is based on incoming light direction)
- Light colour + brightness ($R$)
- Shininess/polish of material ($\alpha$)
- Reflectivity of material ($k_s$)

$$I = R \cdot k_s \cdot \cos\alpha \cdot \phi$$
sphere
{
  <0, 0, 0>, 1
  pigment { rgb <1, 0, 0> }
}

finish
{
  phong 1
  phong_size 225
}

phong (typically between 0 and 1.0) controls the brightness of the highlight.
[a.k.a. specular reflectivity, \( k_s \), percentage of incoming light reflected back out]

phong_size (typically between 1 to 250) controls the size/focus of the highlight. Bigger means more polished objects (i.e. smaller highlights)
[a.k.a. the shininess or phong exponent, \( \alpha \) ]
specular/phong \( (k_s) \) values of 0, 0.25, 0.5, 0.75, 1

shininess/phong_size \( (\alpha) \) values of 5, 25, 75, 125, 225
Combined with a constant diffuse red component
Light scattered in the scene is modelled using an ambient component – a small level of colour added to all objects in the scene.

Intensity of reflected light depends on:
- Light colour + brightness \( R \)
- Reflectivity of material \( k_a \)

N.B. Usually we add only very small amounts of ambient illumination.

Ambient values 0, 0.25, 0.5, 0.75, 1. Bottom row: combined with diffuse lighting.
AMBIENT COLOUR IN POV-RAY

Per-Object Ambient reflectance:

```
sphere
{
  <0,0,0>, 1
  finish
  {
    ambient <.1,0,0>  //small red ambient
  }
}
```

Overall Ambient Light in Scene

```
global_settings { ambient_light rgb <.1, .1, .1>}
```
Complete Phong Model (local illumination): The intensity of light from one point is a sum of the diffuse, specular and ambient components:
sphere
{
  <0,0,0>, 1
pigment
{
  rgb <1,0,0> //red
}
finish
{
  diffuse 0.5
  phong 0.5
  phong_size 100 //shininess
  ambient 0.2
}
}
Equivalent to <0.2, 0.2, 0.2>
Local illumination can be combined with texture
SURFACE MODELLING
RECALL: NORMAL AFFECTS ILLUMINATION
BUMP MAPPING

A “real” bump distorts the directions of the normals due to actual change in geometry.

In bump-mapping, “gake” bumps are created by distorting the normals although the geometry is still flat.

A bump-map texture applied to a flat polygon.
PRACTICAL EXAMPLE IN POVRAY

“Marble” bump map

Wood texture map
PROCEDURAL BUMPS
NORMAL MAPS

We can add bumps, dents, wrinkles, ripples and waves to our objects.

Sample Scene (no normal maps)

```pov
define pigment = White;
finish reflection .4;
normal {
    //add normal pattern here ****
}
```
normal
{
    bumps 1
}

BUMPS
normal
{
    dents 1
}

DENTS
normal
{
  wrinkles 1
}

WRINKLES
normal
{
  ripples 1
}

RIPPLES
normal
{
    waves 1
}

WAVES
BUMP MAP

normal

{

    bump_map

    {

        gif "bumpmap.gif"

    }

    rotate 90*<1, 0, 0>

    scale 8

}
RECAP: POVRAY

General Object Declarations are usually in the following order:

```plaintext
Object_name
{
  Object_variables
  texture
  {
    pigment
    {
      colour | image_map | “procedural maps”
    }
    finish
    {
      diffuse | ambient | phong | phong_size
    }
  }
  normal
  {
    bump_map | “procedural maps”
  }
  transforms
}
```