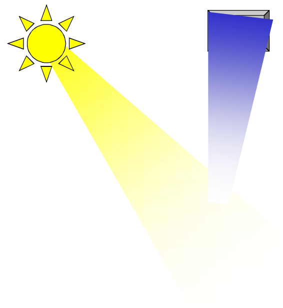
Illumination and shading (1)

Adding “reality” to images
Light sources and lighting models
Surface properties

Rendering: setting up the scene

- Given
  - Object surfaces
  - Light sources
  - Camera
- Compute
  - Colour of each pixel on the screen
  - This is colour that bounces off the surface point and goes in the direction of the camera (viewer)

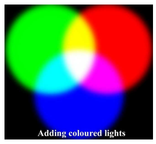


Light

- Sources
  - Ambient
  - Directional: diffuse
  - Directional: point source
  - Divergence
- Location
  - w.r.t object
  - w.r.t. camera
- Colour

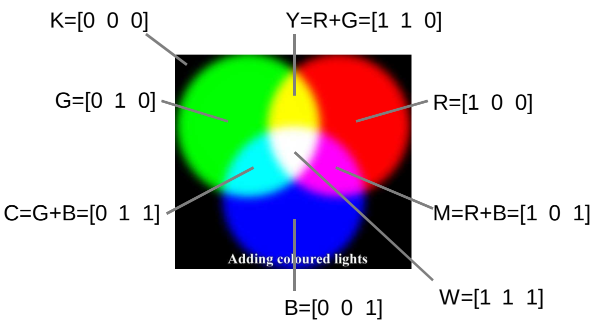
Colour: the basics

- Colour can be represented by a three-dimensional vector [R G B] of three primary colours (“primaries”):
  - Red (R)
  - Green (G)
  - Blue (B)



- Other colours can be represented by a mixture of the three primaries

RGB – an additive system

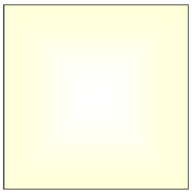


Inputs to computation

- Light sources (emitters)
  - Colour (emission spectrum)
  - Geometry (position and direction)
  - Directional attenuation
- Surfaces (reflectors)
  - Colour (reflectance and absorption spectrum of the material)
  - Geometry (position, orientation of each surface patch)
  - Micro-structure

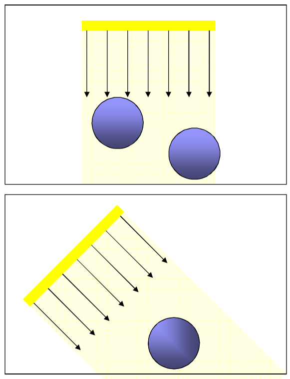
Light sources

- Ambient light
  - Global, background light
  - No spatial of directional characteristics - seems to come from all directions
  - Makes objects visible
  - Does not depend on the orientation or position of a surface
  - Does not depend on the orientation or position of a camera
  - Does not have diffuse or specular reflection components



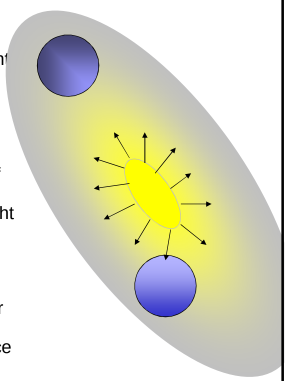
Light sources

- Diffuse Light – parallel
  - Has parallel light rays that travel in one direction along the specified vector (e.g. sunlight)
  - Contributes to diffuse and specular reflections, which depend on the orientation of an object's surface (with respect to light direction vector) but not its position



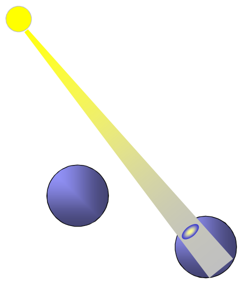
Light sources

- Diffuse Light – point source
  - Light source located at a fixed point in space (e.g. light bulb)
  - Radiates light equally in all directions away from the light source
  - Light is attenuated as a function of distance, i.e. its brightness decreases as distance from the light source increases
  - The rate of decrease is defined by an attenuation factor
  - Contributes to diffuse and specular reflections, which depend on the orientation and position of a surface



Light sources

- Spot Light
  - Light source located at a fixed point in space (e.g. light bulb)
  - Light radiating from the source forms a cone defined by a vector in a particular direction and by the angle determining its spread
  - Light is attenuated as a function of distance, i.e. its brightness decreases as distance from the light source increases (defined by an attenuation factor)
  - Contributes to diffuse and specular reflections, which depend on the orientation and position of a surface



Surfaces

Reminder

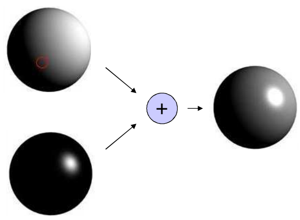
- Properties
  - Geometry (position, orientation of each surface patch)
  - Colour (reflectance and absorption spectrum of the material)
  - Micro-structure

Surfaces

Reminder

Micro-structure
- Defines reflectance properties

Reflectance
- Diffuse: Matte surfaces
- Specular: Shiny surfaces



Computing reflectance: shading model

- Requires
  - Surface geometry, microstructure and colour
  - Positions and type of light sources
  - Position of the viewer (camera)
- Combines the three contributions:
  - Ambient light
  - Diffuse reflectance
  - Specular reflectance

Pixel colour: Ambient + Diffuse + Specular

Shading model

Ambient term: colour

- Colour / intensity of ambient light: I_a
  - Colour is normally assumed white, i.e. I_a =[1.0, 1.0, 1.0];
- Object colour: ambient coefficient K_a
  - Represents the reflectivity of ambient light
  - $0 < K_a < 1$; 0: no reflectivity; 1: full reflectivity
- Complete ambient term: $\boxed{A = K_a I_a}$

Shading model

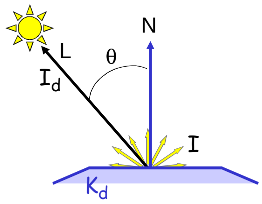
Ambient term: reflectance

- No physical interpretation
- Does not depend on light position
- Looks the same seen from anywhere

Increasing K_a

Shading model

Diffuse term: Reflectance



- Object surface: Lambertian (matte)
  - Light reflected equally in every direction
  - The amount of light reflected depends on the angle between the direction of light and a surface normal at each point
  - Defined by the “Cosine Law”

$$I = I_d \cos(\theta)$$

$$-\pi/2 < \theta < \pi/2$$

Shading model

Diffuse term: colour and reflectance

- Colour / intensity of diffuse light: I_d
  - Colour must be defined, $I_d = [r_d, g_d, b_d]$;
- Object colour: material diffuse reflectivity coefficient K_d
- Complete diffuse term: $\boxed{D = K_d I_d \cos \theta_d}$

Shading model

Diffuse term

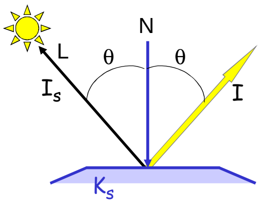
- Shading varies along surface
- A given point looks the same irrespective of the position of the viewer

Increasing K_d

Shading model

Specular term: Reflectance

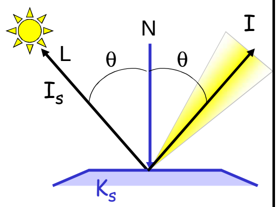
- Object surface: Mirror (ideal case)
  - Light reflected in accordance with the Snell's Law:
    The angle of reflection equals to the angle of incidence (with respect to the surface normal)
  - The amount of light reflected towards the viewer / camera varies, depending on the relative position of the light source, position of the viewer and surface orientation



Shading model

Specular term: Reflectance

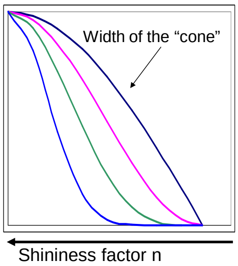
- Object surface: glossy
  - Extends the ideal (mirror) case
  - The reflected light forms a "cone" around the ideal (Snell-law) reflectance vector



Shading model

Specular term: Reflectance

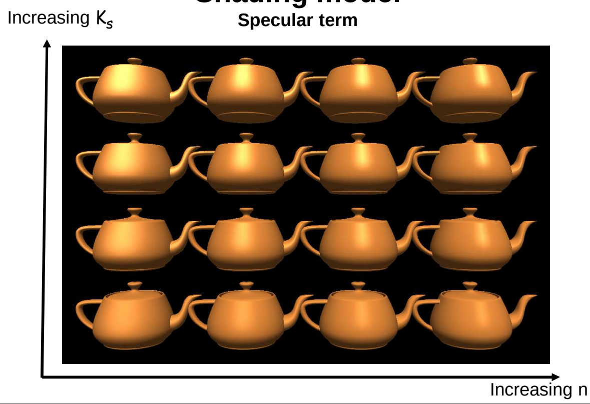
- The amount of light reflected within the cone decreases from the centre outwards (as a function of exponential decay)
- The rate of decay n is a "shininess factor"
- Object colour: material specular reflectivity coefficient K_s
- Colour / intensity of specular light: I_s
  - Colour must be defined, $I_s = [r_s, g_s, b_s]$;
  - Common assumption: $I_s = I_d$



Complete specular term: $\boxed{S = K_s I_s (\cos \theta_s)^n}$

Shading model

Specular term



A complete shading model

Combines all the terms:

Pixel colour: Ambient + Diffuse + Specular

$$I = A + D + S$$

$$\boxed{I = K_a I_a + K_d I_d \cos \theta_d + K_s I_s (\cos \theta_s)^n}$$

where $\cos \theta_s = \underline{N \cdot L_s}$ and $\cos \theta_d = \underline{N \cdot L_d}$

dot product
(N and L normalised)

Next lecture

Shading algorithms