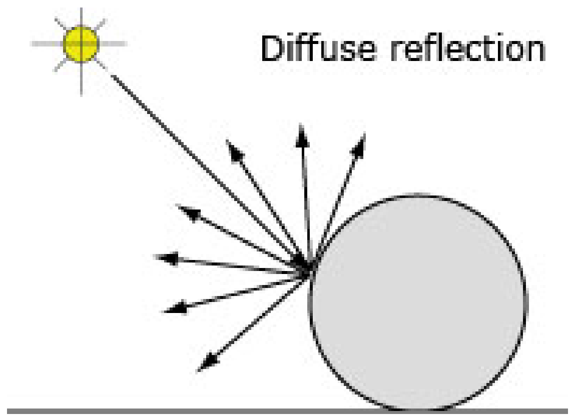
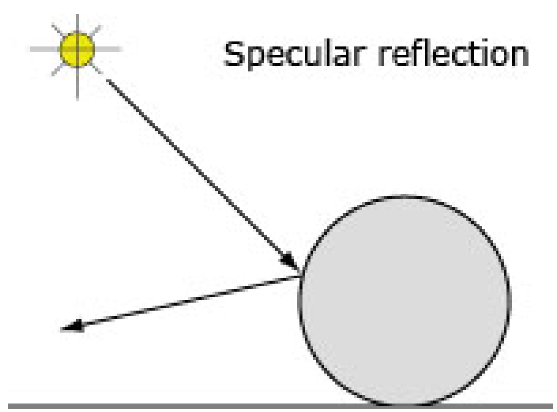
Surface Lighting

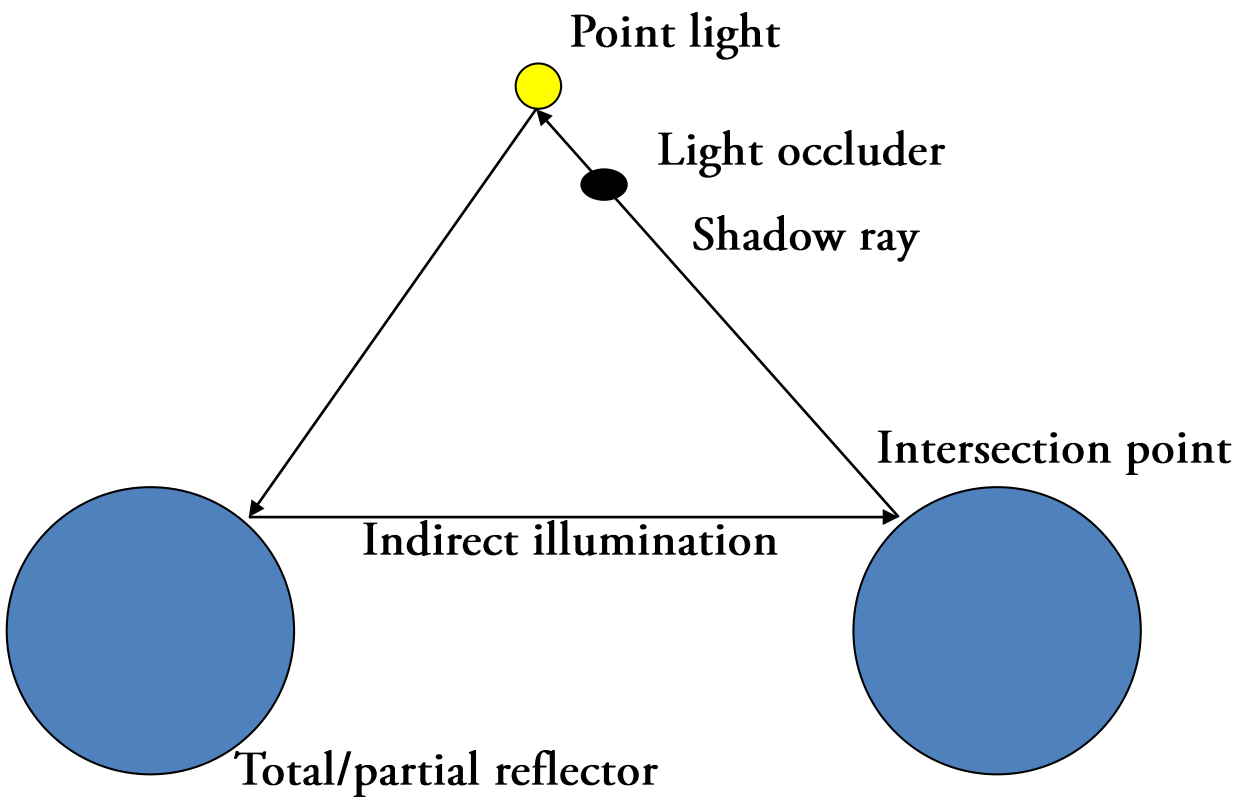
- Ambient
- Diffuse



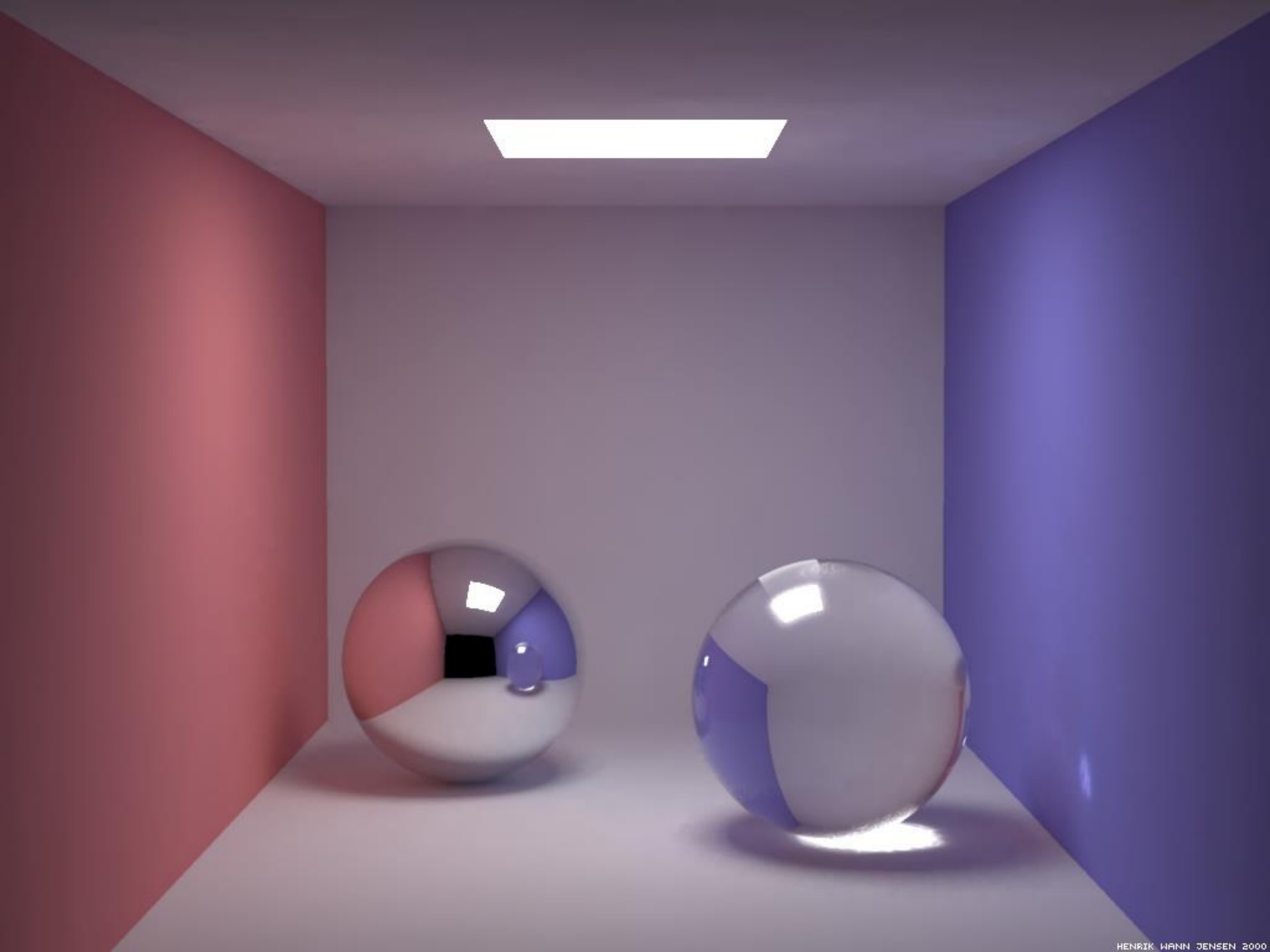
- Specular



Indirect Illumination



We've seen ray tracing using DIRECT ILLUMINATION
INDIRECT illumination is VERY expensive to calculate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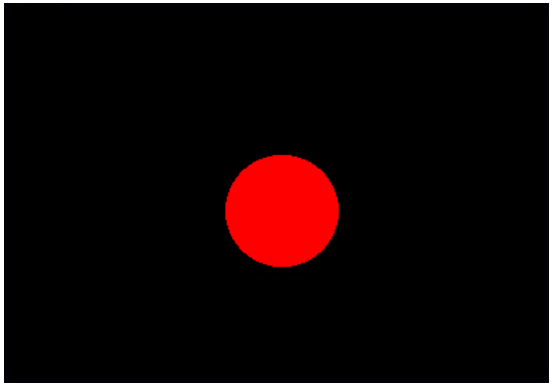
Ambient Reflection

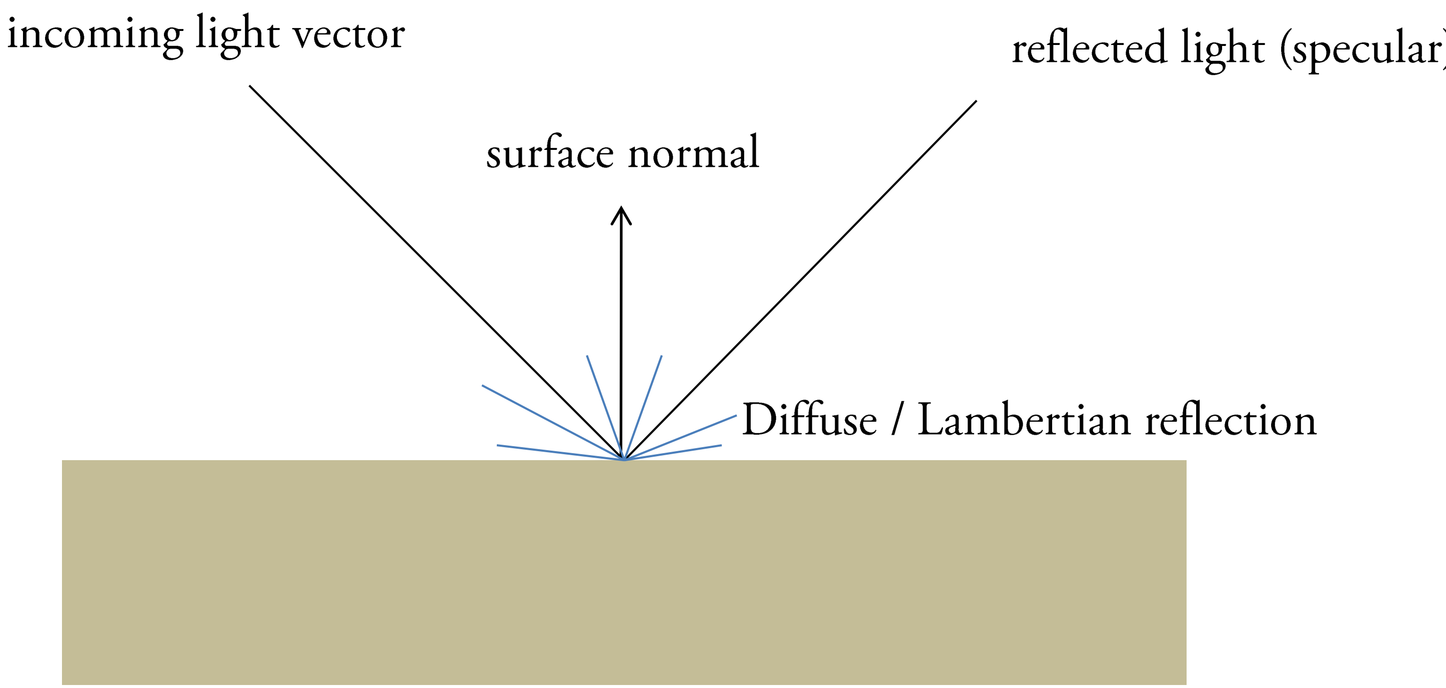


- Ambient reflection
- Pixel intensity, $I=I_aK_a$
- I_a=ambient light intensity
- K_a=ambient reflection coefficient of the surface – how much light it reflects (0-1)
- Usually r,g,b triples
- e.g. White light (1,1,1) x red object (1,0,0)=(1,0,0) (red)

Light Sources

- To create a realistic rendering (during rasterization or ray tracing), we need to calculate the light incident upon the object
- A point (x,y,z) can be the spatial location of a **point light source**
- A vector (dx, dy, dz) can be the direction of a **directional light source**
- As we shall see, many of the following calculations require a vector
- Either a directional light source is used, or the direction can be calculated by subtracting the intersection point from the point light

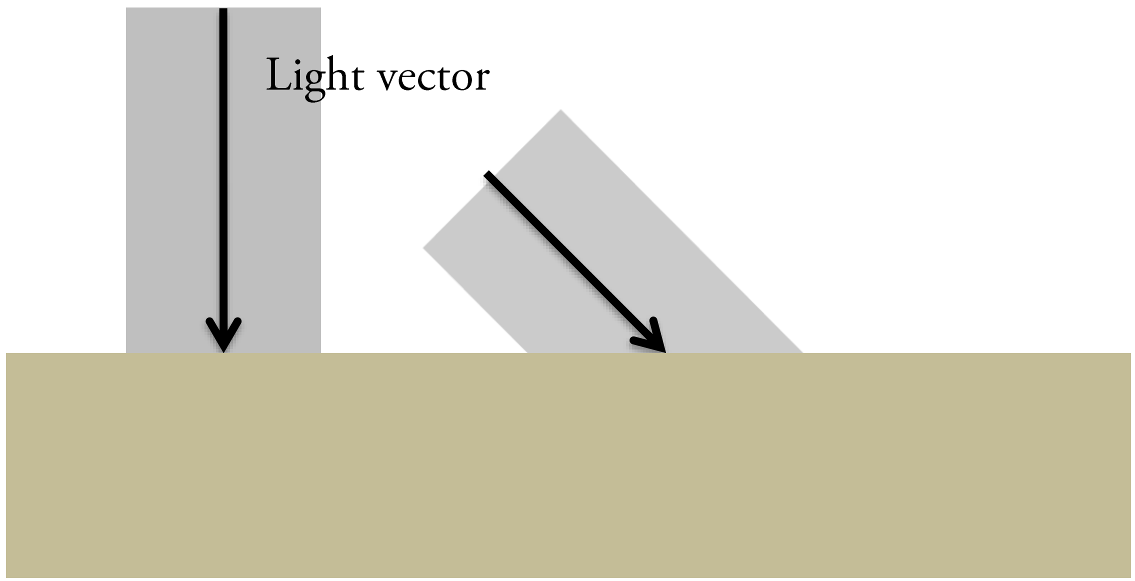
Reflection of light



Light can be perfectly reflected. This is known as specular reflection and is often rendered using Phong's method. Reflected light can be evenly spread. This is known as diffuse or Lambertian reflection.

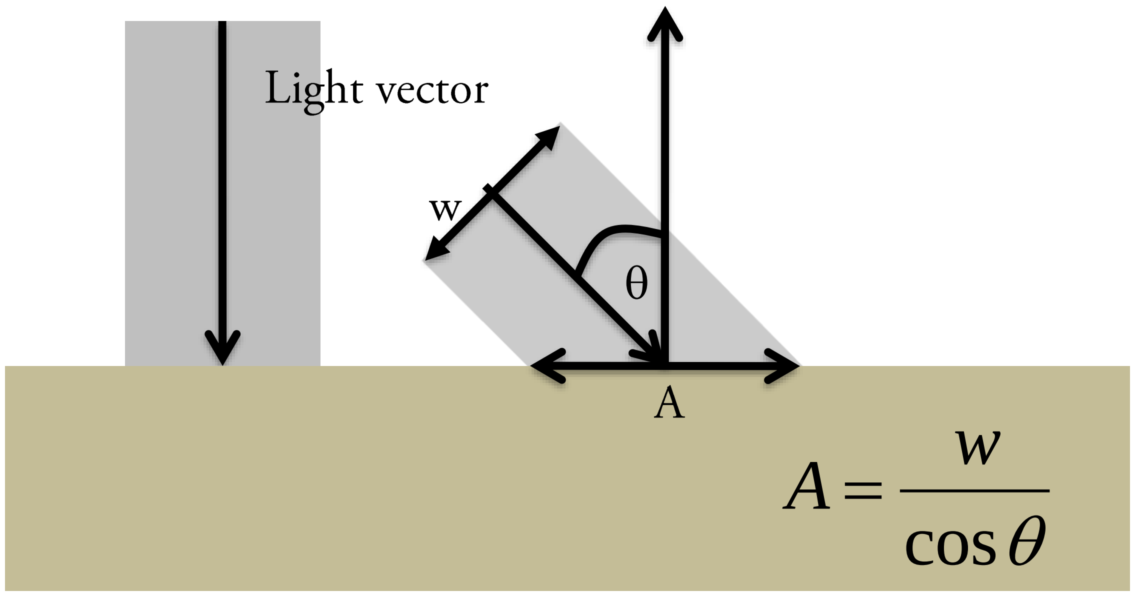
Incident Light

Same shape at 90 and 45 degrees to the surface



Light energy per unit area is higher when at 90^o, compared to 45^o.
Example: The sun striking at the equator compared to higher latitudes.

Incident Light



Light energy per unit area is higher when at 90°, compared to 45°.
Light Energy in box is I/w. Energy hitting the ground is $\frac{I}{A} = \frac{I\cos\theta}{w}$

Lambertian / Diffuse reflection

The incoming light at an intersection point (ray tracing) is $I_{Light} \cos\theta$

The outgoing light at an intersection point, that is, what we see at the pixel is $I_{out} = I_{Light} \cos\theta$, although, if cosθ<0, use 0* see lecture

cos θ is the angle between the surface normal **n** and the direction to the light **l**.
Both **n** and **l** are vectors.
If we assume the vectors are normalised, cos θ is the dot product of the two vectors

$$I_{out} = I_{Light}\mathbf{n.l}$$

Remember, a vector (dx, dy, dz) can be normalised by finding its length, l:

$$l = \sqrt{dx^2 + dy^2 + dz^2}$$

and dividing each component by the length to get a new vector (dx/l, dy/l, dz/l)

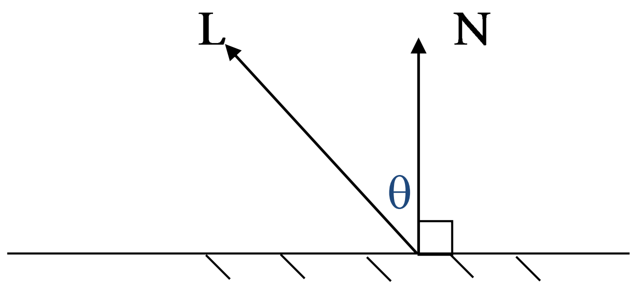
Lambertian relection in colour

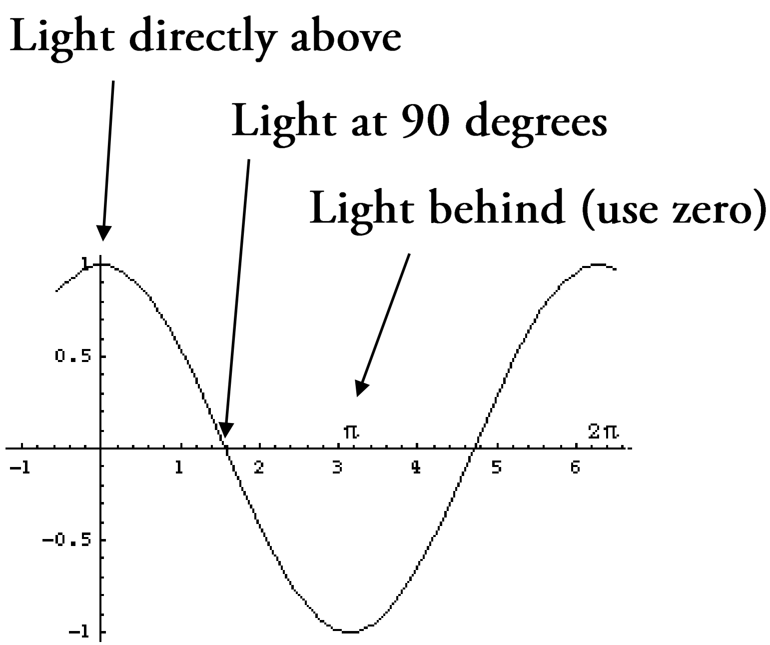
- Assign each object a diffuse reflection coefficient k_d in each colour channel ($k_{d,r}$, $k_{d,g}$, $k_{d,b}$) where each is a value between 0 (absorb all light) and 1 (reflect all light)
- Example, a red object will be (1,0,0) – absorbs blue and green light, but reflects all red light
- The colour of a pixel I_{out} is

$$I_{out,r} = K_{d,r} I_{Light,r} \mathbf{n.l}$$
$$I_{out,g} = K_{d,g} I_{Light,g} \mathbf{n.l}$$
$$I_{out,b} = K_{d,b} I_{Light,b} \mathbf{n.l}$$

- Note, we apply the equation in each colour channel (r,g,b)

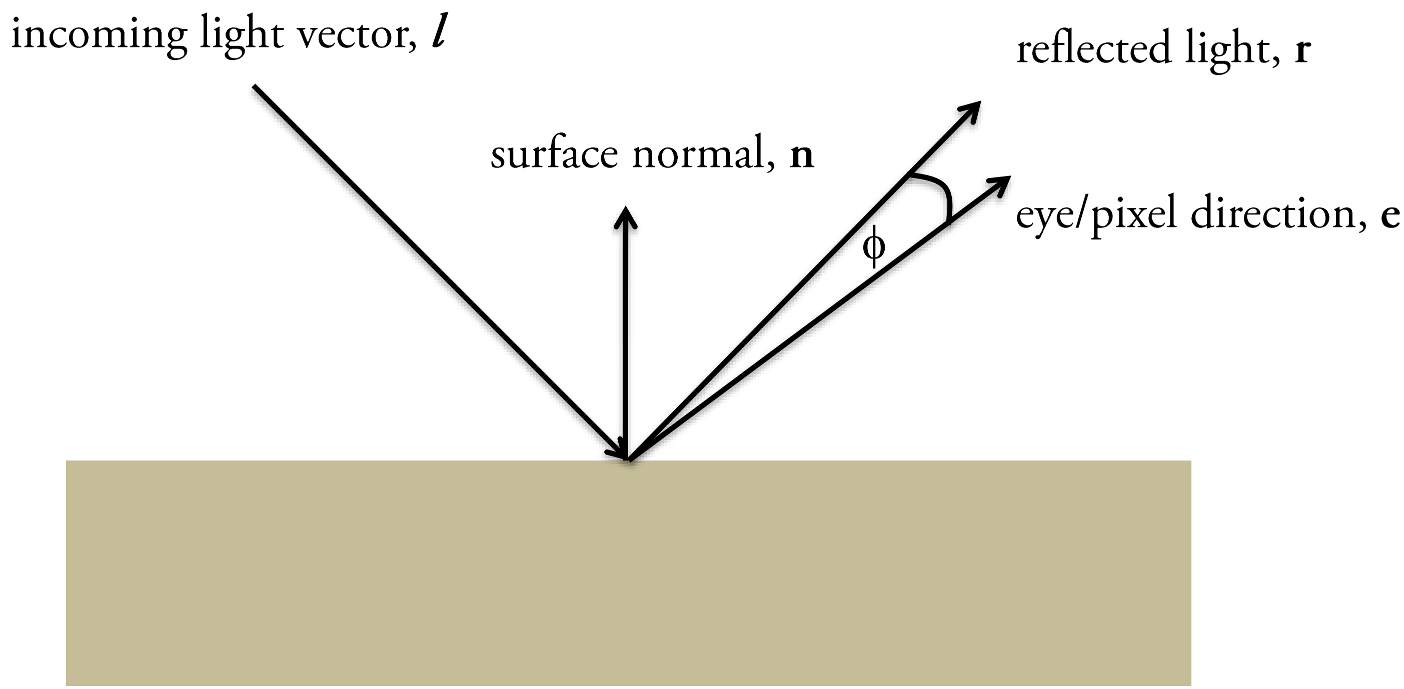
cosθ





- N = surface normal
- L = direction to light source
- $\cos\theta = N.L/|N||L|$
- N and L are usually normalised during calculation, so
- $\cos\theta = N.L$
- if $\cos\theta < 0$, use 0

Specular Reflection

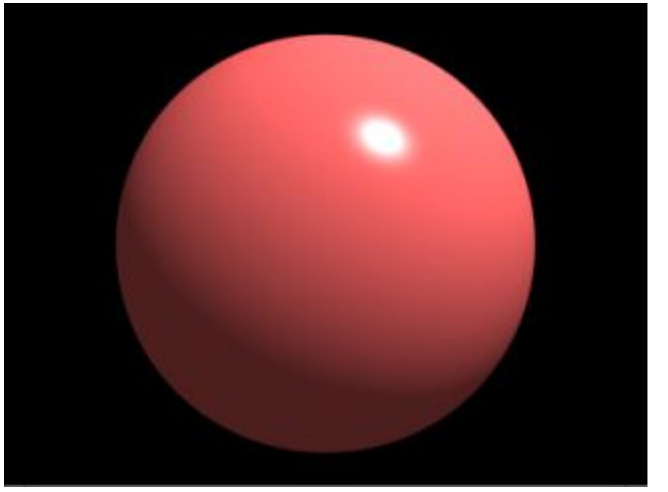


If the object is a perfect mirror, then the light will only be seen if $\phi=0$

Less perfect mirrors will reflect light in a cone

Phong proposed that the reflected light is approximately $\cos \phi^n$, where n is chosen to be a shininess coefficient for the object

Phong Reflection



Phong's equation for specular reflection

$$I_{out,r} = K_{s,r} I_{Light,r} (\mathbf{r.e})^n$$
$$I_{out,g} = K_{s,g} I_{Light,g} (\mathbf{r.e})^n$$
$$I_{out,b} = K_{s,b} I_{Light,b} (\mathbf{r.e})^n$$

cosϕ is calculated using the dot product of **r** and **e**
K_s is the specular reflection coeffiecient for the surface.

Simple Reflection Model

$$I_{out,c} = K_{a,c} I_{Light,c} + K_{d,c} I_{Light,c} \mathbf{n.l} + K_{s,c} I_{Light,c} (\mathbf{r.e})^n$$

where c takes on the values of the colour channels: r, g, and b
Note the equation adds together the **Ambient**, **Diffuse** and **Specular** terms