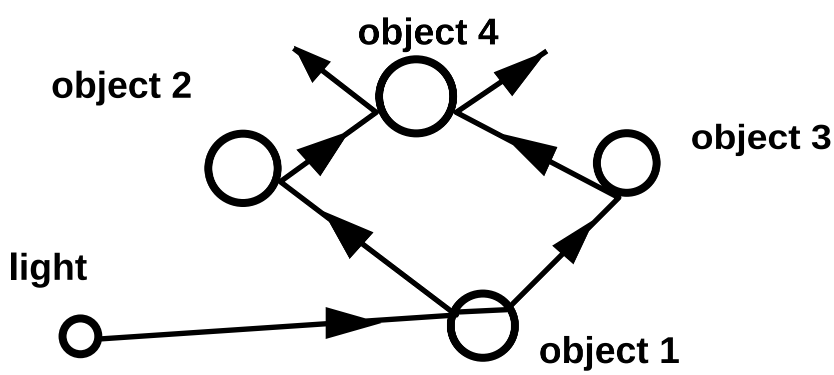
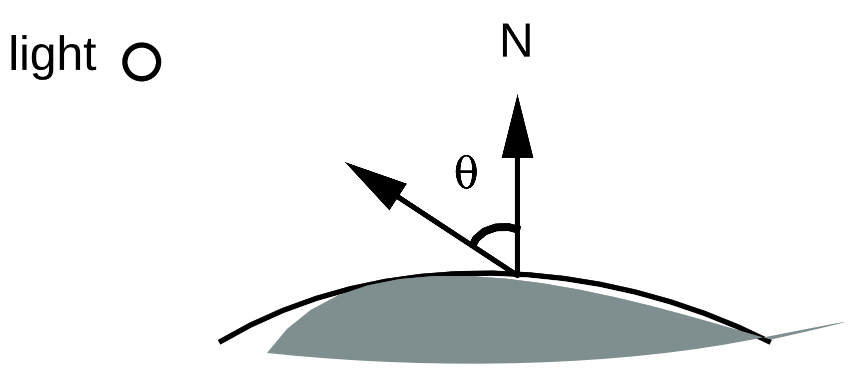
# Lighting (Illumination) Model

- To model the interaction of light with surfaces to determine the final color & brightness of the surface

  - Global Illumination models: take into account the interaction of light from all the surfaces in the scene.




  - Local illumination: only consider the light, the observer position, and the object material properties




We will only discuss local illumination model this quarter

– Basic Illumination Model:

simple and fast method for calculating surface intensity at a given point

Lighting calculating are based on:

- The background lighting conditions
- The light–source specification: color and position
- Optical Properties of surfaces: glossy, matte, opaque, transparent (control refection and absorption)

## (1) Ambient light: (background light):

– The light that is the result from the light reflecting off other surfaces in the environment

– A general level of brightness for a scene that is independent of the light positions or surface directions –> ambient light has no direction

– Each light source has a ambient light contribution = $I_a$

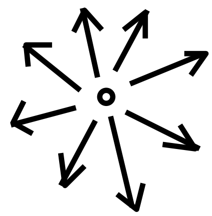
– For a given surface, we can specify how much ambient light the surface can reflect using a

ambient–reflection coefficient : $K_a$ $(0 < K_a < 1)$

=> So the amount of light that the surface reflect is therefore

$$I_{amb} = K_a * I_a$$

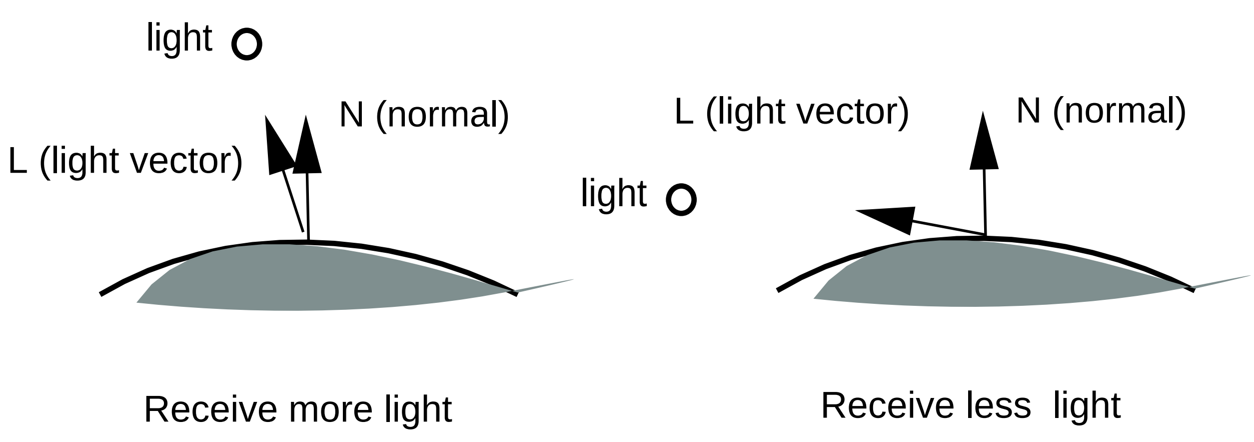
In our basic lighting model, we use point light source



Now let's look at the interaction between a point light source with a surface

(2) Diffuse Light:

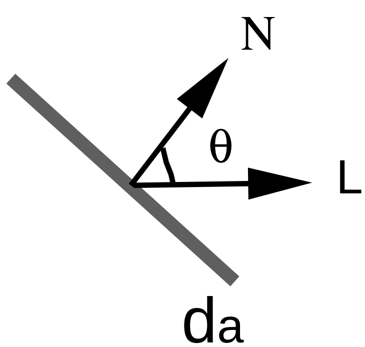
- The illumination that a surface receives from a light source and reflects equally in all directions
- This type of reflection is called <u>Lambertian Reflection</u>
- The brightness of the surface is indepenent of the observer position (since the light is refelected in all direction equally)
- However, how much light the surface receives from a light source depends on the angle between its angle and the light vector (the vector from the surface point to the light)



- Lambert's law: the radiant energy '$I_d$' from a samll surface $d_a$ for a given light source is:

$$I_d = I_L * \cos(\theta)$$

where $I_L$ is the intensity of the light source, and $\theta$ is the angle between the surface normal (N) and light vector (L)




- Now let's take the surface's material property into account. Assuming that the surface can reflect Kd (0<Kd<1) amount of diffuse light, then we have

$$I_{diff} = Kd * I_L * \cos(\theta)$$

If N and L are normalized vectors, then $\cos(\theta)$ = N.L , so

$$I_{diff\_} = Kd * I_L * (N.L)$$

inner product !

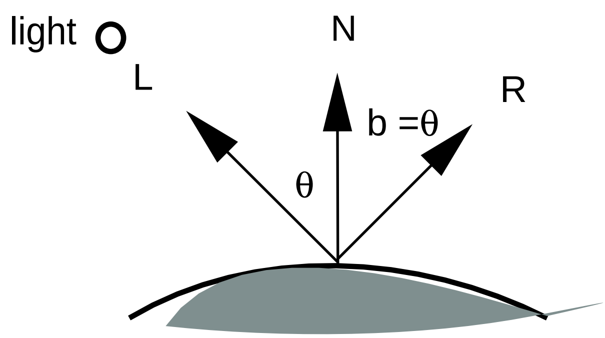
where Kd is called <u>diffuse−reflection coefficient</u>

- The total diffuse reflection = (1) + (2) =

$$I_{diff} = Ka * I_a + Kd * I_L * (N.L)$$

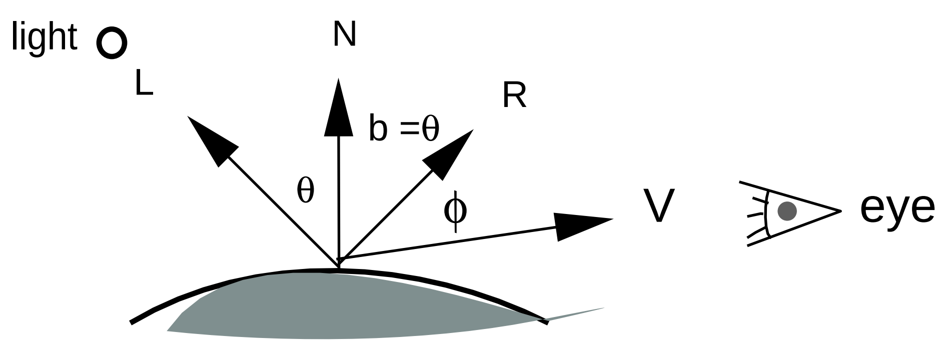
# (3) Specular Light

- These are the bright spots on objects (such as polished metal, apple, or your forehead...)
- The result of near total reflection of the incident light in a concentrated region around the specular reflection angle

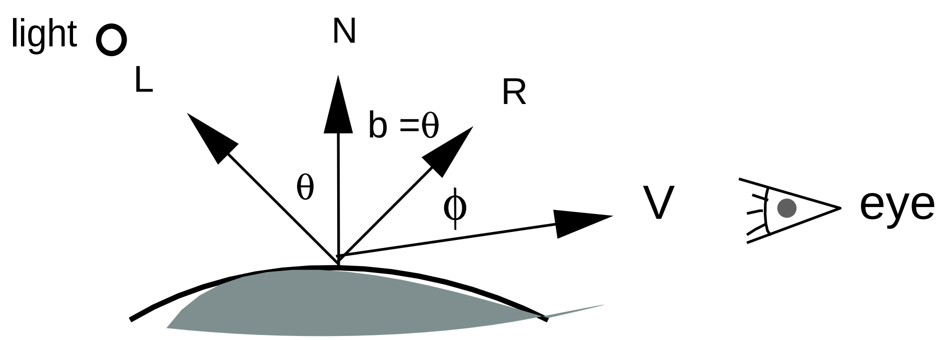



specular reflection angle b equals angle of incident light θ

- How much reflection light you can see depends on where you are




When ϕ is small, you will see more specular light




Specular light :

specular reflection coefficient

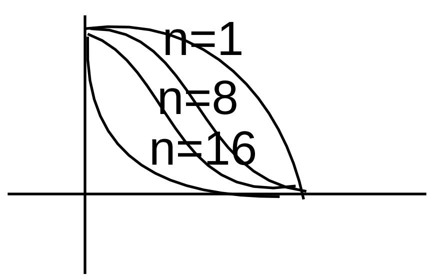
specular light

Phong's model $\quad I_s = K_s * I_s * \cos^n(\phi)$

$\phi$ is between 0 and 90 degree

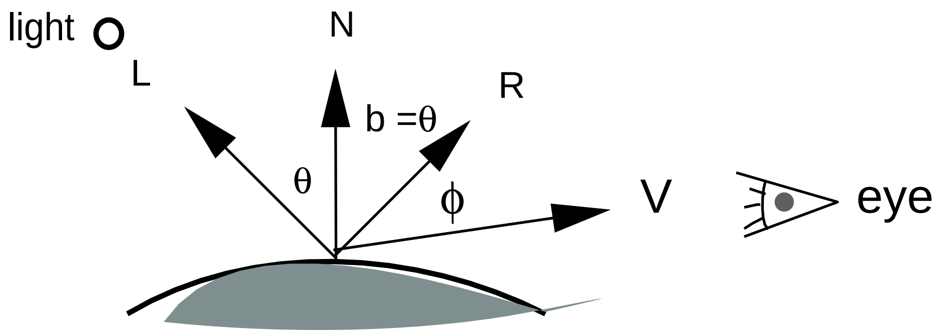
This is the famous <u>Phong Shading</u>

$\cos^n(\phi)$ : the larger is n, the quicker the cosine function drops




when n = $\infty$ , we have a perfect reflector (mirror!)

– In other words, when n is large, we have a very shiny object




Phong's model $I_s = K_s * I_s * \cos^n(\phi)$

− To calculate COS(Φ) : If R and V are normalized vector

$\cos(\Phi) : R.V$

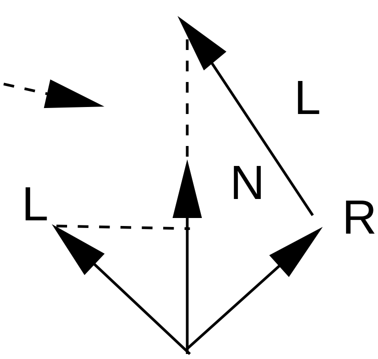
So

$$I_s = K_s * I_s * (R.V)^n$$

− How to calculate R? (we know N, L, but not readily R)

$R + L = (2N.L)N$

$R = (2N.L)N - L$




− An alternative way of computing phone lighting is

$I_s = k_s * I_s * (N.H)^n$ where H (halfway vector) = $\frac{L+V}{|L+V|}$

halfway between V and L

## Put it all together

I = Ambient + Diffuse + Specular =

$$K_a * I_a + K_d * I_L * (N.L) + K_s * I_s * (R.V)^n$$

If there are multiple light sources

$$I = \sum^{i} \left( K_a * I_a + K_d * I_L * (N.L) + K_s * I_s * (R.V)^n \right)$$

Typically, for nice high light

Ka = 0.2 Kd = 0.8 Ks = 1.0 n = 50