Lighting Model

→ Mostly used by artists to show detailing or differentiating multiple objects.

→ In computer graphics we compute the lighting to initiate the same effect virtually.

Effects of Lighting

A

Pixels colour only

B

Pixel colours and lighting.

To picturize a 2D shape in 3D we need lighting.

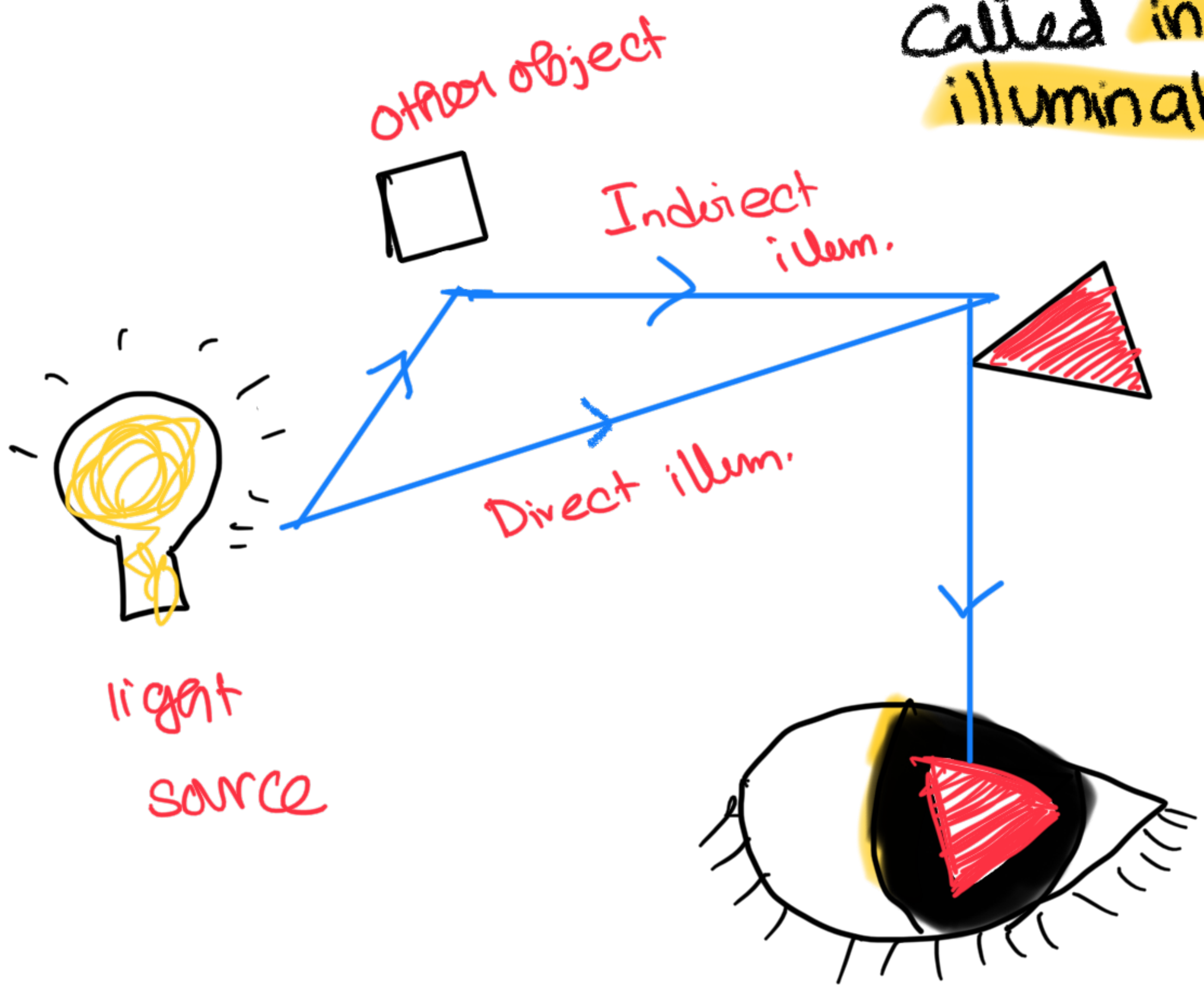
In picture A all the pixels of the shape are given same colour, hence, the structure cannot be recognized.

In pic B we can see the structure clearly. We can see multiple shading and shiny surfaces.

Illumination

Light comes from a source falls on the object. From object light reflects in our eyes. This is direct illumination.

Light falls on other objects and from other objects falls to the target object. Light from the target object reflects in our eyes. This is called indirect illumination.



→ If we want to calculate faster. For ex in games the images change quickly so we cannot apply indirect illumination much.

→ Indirect illumination is used for animated movies to give real life effect. Used for complex modeling.

Phong's Reflection Model

Through reflection lighting is achieved and we are able to see our model.

Starting object

An object with no colour is black & object with all colour is white.

The target of P.R.M is to transform the black structure to 3D coloured object through step by step process.

Step 1: Ambient Reflection

If there's no light in a room yet you will be able to see somewhat of the object because of some external light source existing far away or light reflected from object outside.

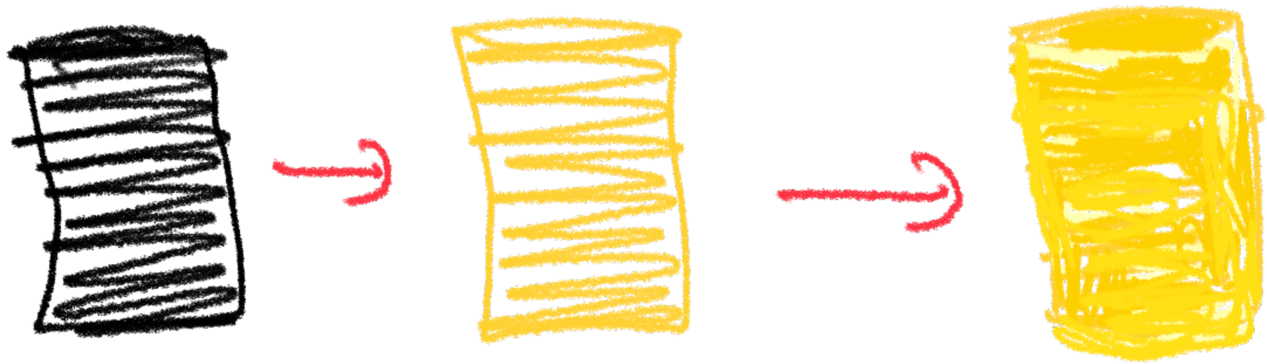
We will not be able to see a clear picture but enough to see the 2D shape.

No colour

All pixels coloured by A.D

Step 2: Diffuse Reflection

Now we assume we have a light source and the object has lighting based on where reflection is more/less/zero.
The places where reflection is greater is light in colour.
The places with 0 reflection is dark.



Step 3: Combining Ambient + Diffuse

This helps to get a 3D image.

Step 4: Shinny effect (Specular reflection)

This is black because Colour & Shinniness are independent factors.

Shinniness depends on the light source. This is called specular reflection.

Ambient Reflection

↳ light is not from the light source.

↳ light from the environment is used to see the shape of the object.

↳ replicates indirect illumination.

↳ Assumption made:

We assume the light intensity on the entire object is same (though in real life it is not true)

$$A = I_a k_a$$

↓ A Ambient light

↓ I_a light intensity

↳ k_a coefficient of ambience.

* The higher the light intensity, the brighter is the object though for Ambient we do not expect high light intensity
* The ambient light is calculated at every pixel of the object

Why do we need ka?

The value of $ka \in [0, 1]$.

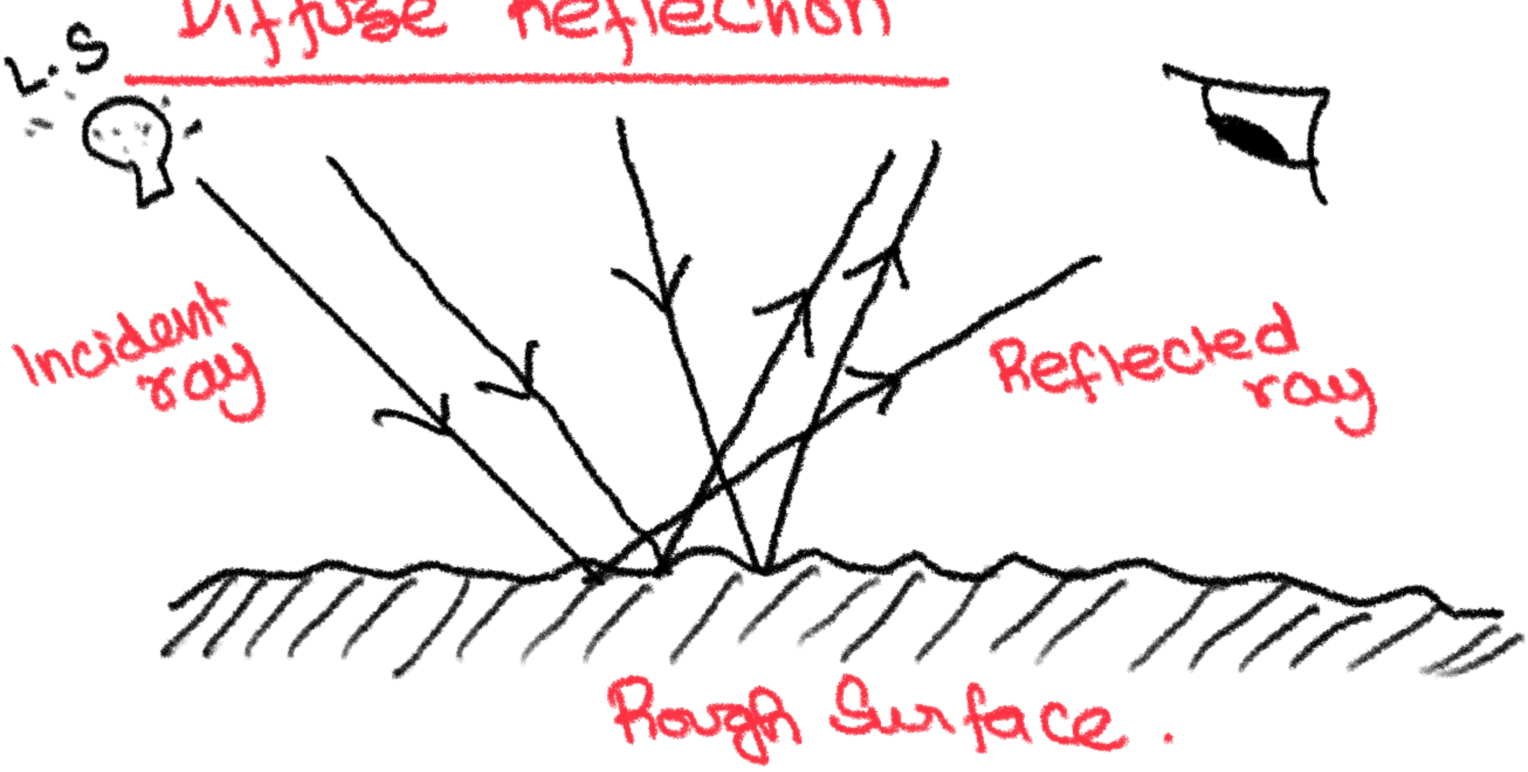
If coeff. is 0, no light

If coeff is 1, full intensity light.

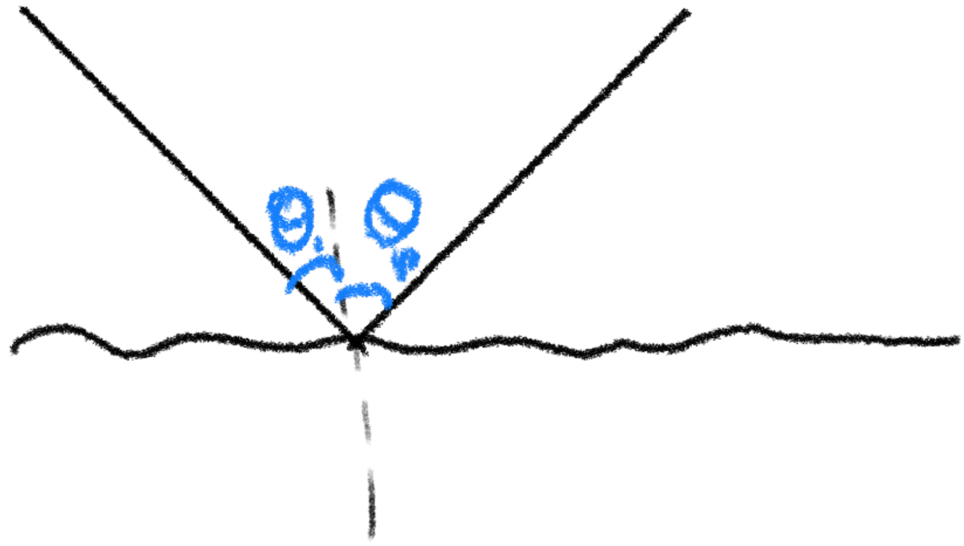
$0 \longrightarrow 1$ light intensity increases.

ka is used to provide the right amount of ambient light for the object.

Diffuse Reflection



From light source incoming rays fall on rough surface so the reflection is distorted / scattered.



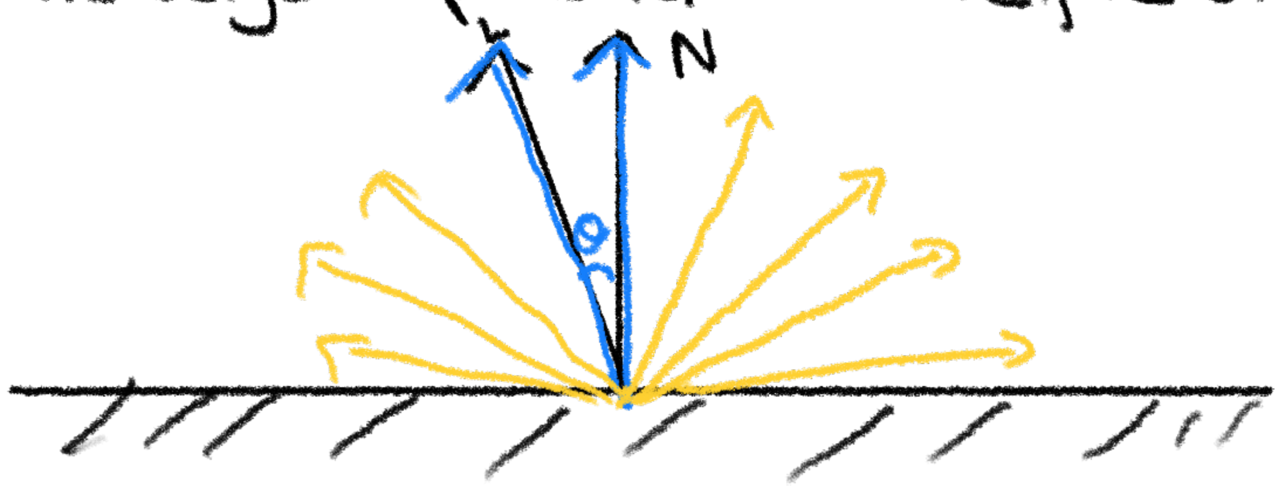
* Using the angle at which ray falls angle of reflection is calculated

* The reflected rays have different intensity
  We can see the light that directly falls on eyes.
  We can partially see light that does not fall on eyes.

* Complex Calculation.

We will see Simplified approach:

We assume we have a point light source. The single ray from light source strikes the surface. We assume the magnitude at which the ray falls, in same magnitude the rays spread and reflect.



In real life different reflected rays have different magnitude but for calculation we assume all ray are of same magnitude.

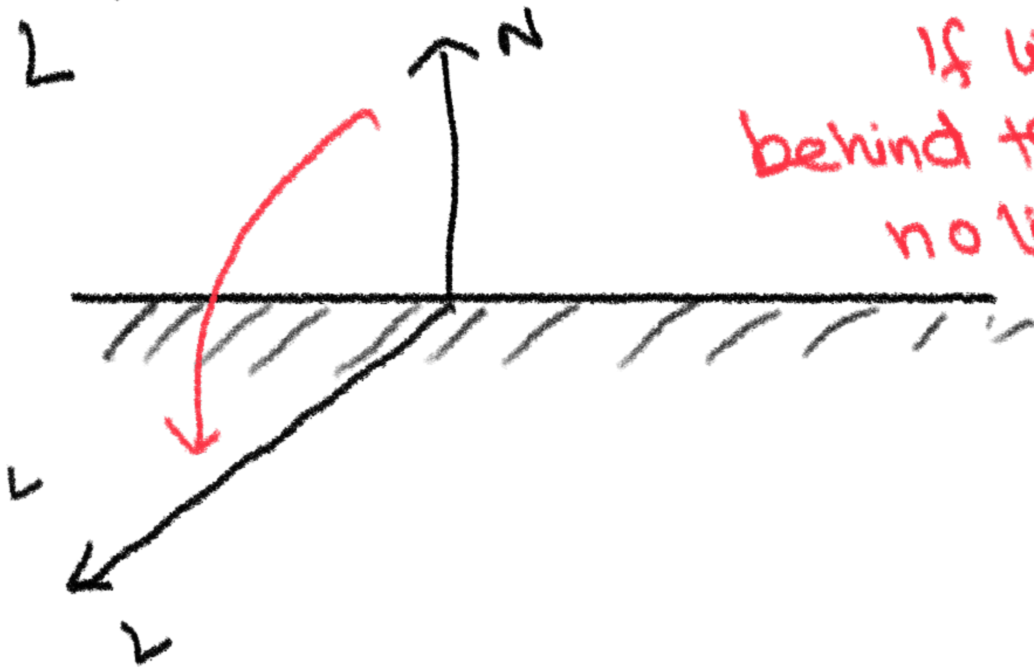
→ Magnitude of reflection depends on the angle (θ) at which ray falls.

The angle betⁿ L & N is smaller so the intensity of r.r will be higher.

θ increases, light intensity decreases.

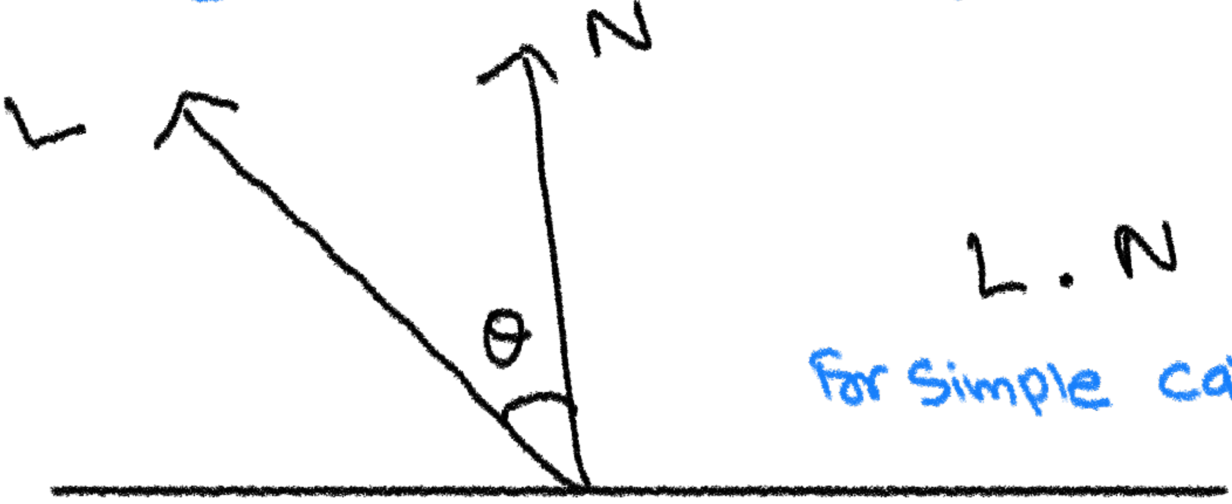
* light intensity = magnitude of reflected vectr.

90° means no light



If light source is behind the surface > 90° no light will be seen.

Why is the direction of L different?

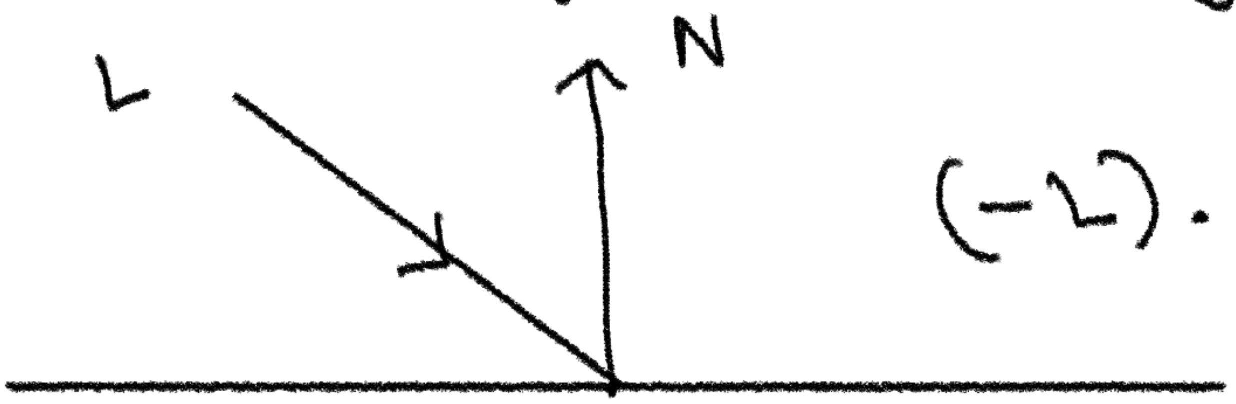


$L \cdot N$

for simple calculation.

If you want to use L.S

in reverse way



$(-L) \cdot N$

$$D = I_p k_d \max[\cos\theta, 0]$$

D: Diffuse reflection

I_p: light intensity from L.S

k_d: Diffuse coefficient $\in (0,1)$

$\cos\theta$ is used because

when $\theta = 0$

$\cos 0 = 1$ (full intensity)

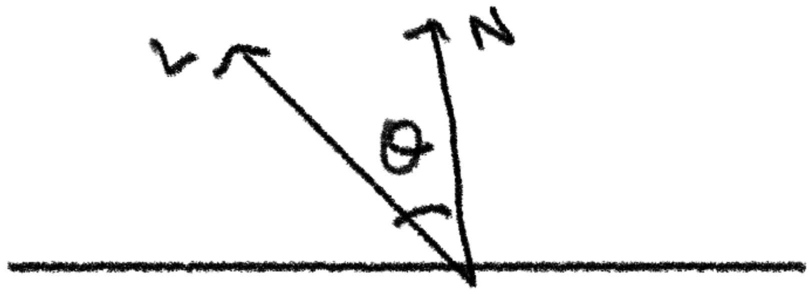
$\cos 90^\circ$ is 0

(no light)

Why $\max[\cos\theta, 0]$?

If θ is $> 90^\circ$ the value will be negative i.e light sorce is behind the surface. light intensity cannot be negative so the minimum value we choose is 0.

How to find $\cos\theta$?



Dot product =

$$L \cdot N = |L|\,|N| \cos\theta$$

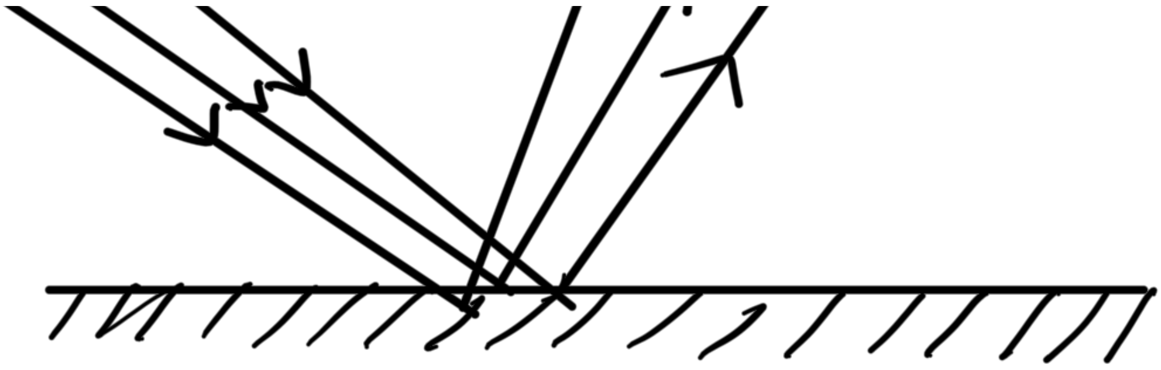
we can assume
$|L|$ & $|N|$ are unit vectors
i.e magnitude is 1

$$\therefore \; L \cdot N = \cos\theta$$

$$D = I_p k_d \max(L \cdot N, 0)$$

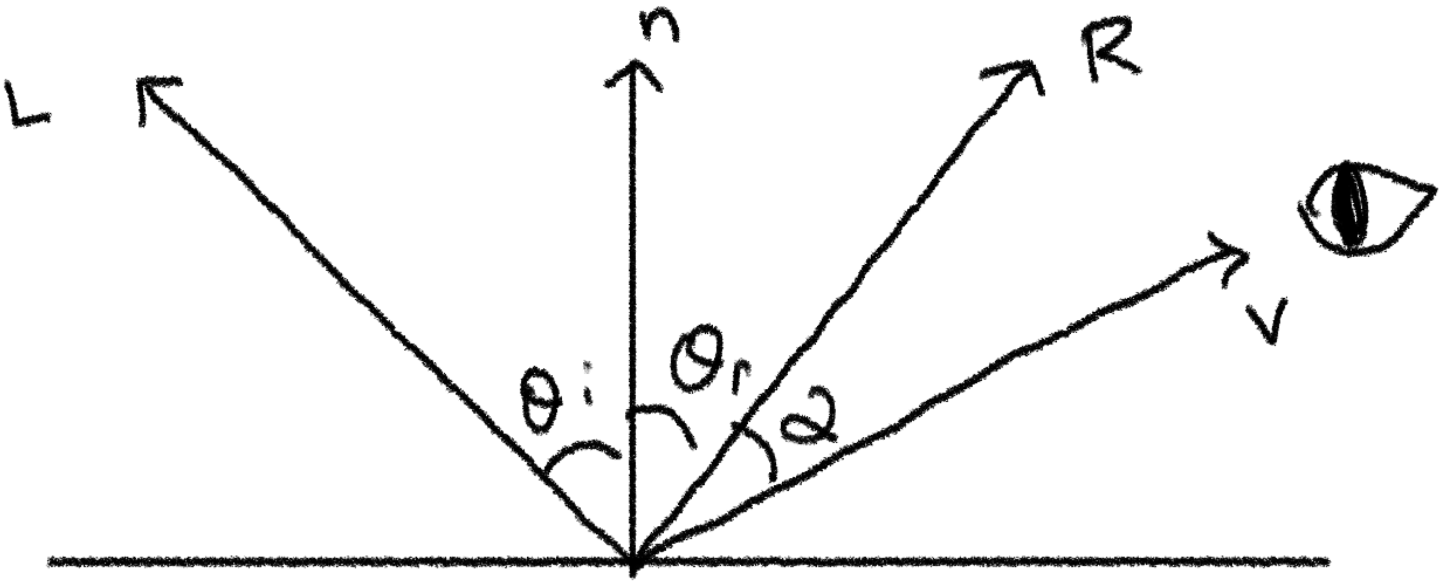
faster & easier.

Specular Reflection



Light falling on smooth surface.

- complex calculation.



If R and V falls in the same line we will see a high intensity light on that surface.

If R and V are seperated we will see lower intensity reflection.

$$S = I_p K_s \cos^n(\alpha)$$

$k_s \in (0,1)$ is specular reflection.

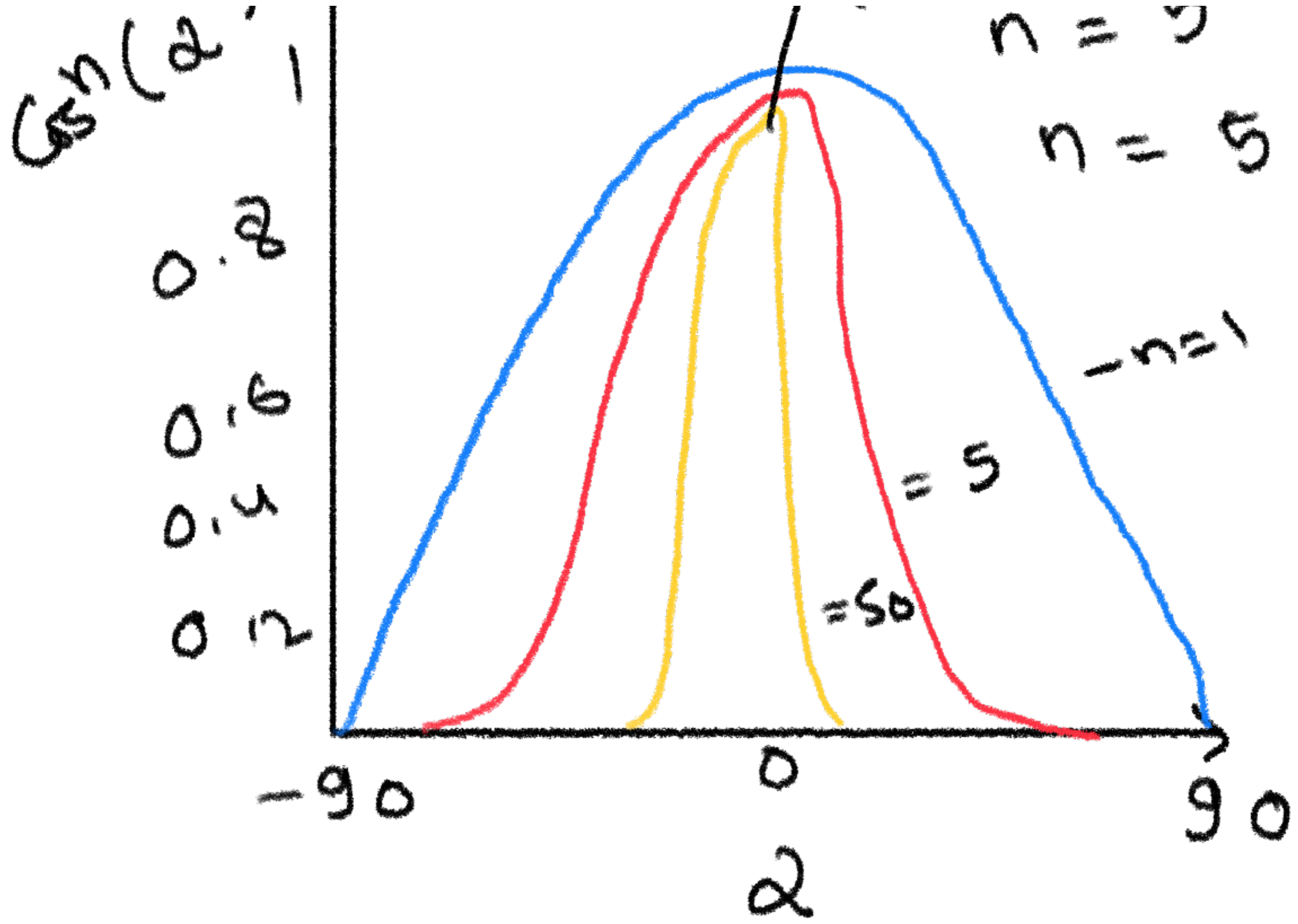
n is speculor exponent (shinninem)

α is angle bet^n R and V

Shinninem

R & V same $\theta = 0$

$n = 1$



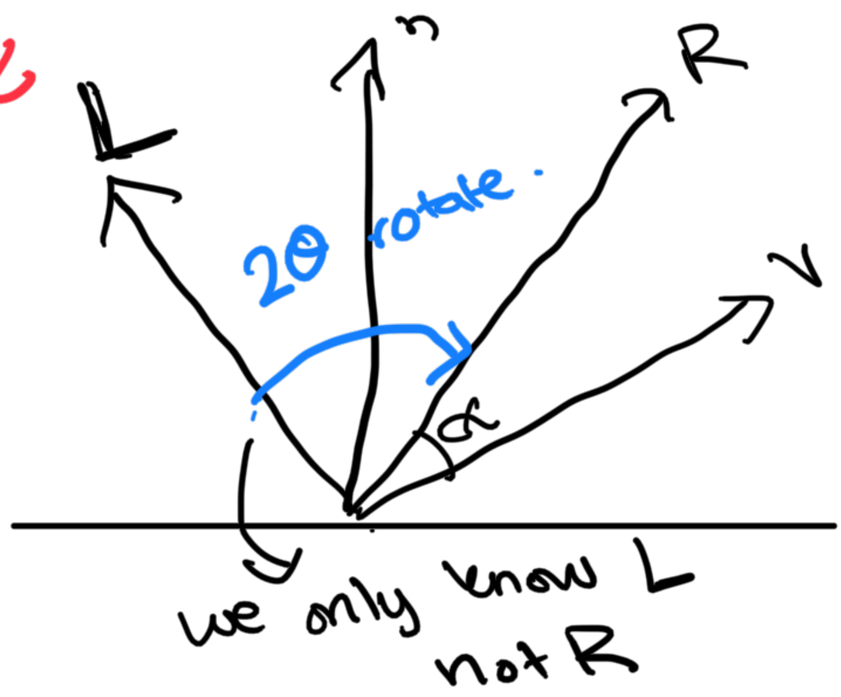
The larger the value of n the lower will be the light intensity in over all object. Only at $\cos 0 = 1$ an intensity can be seen but at other angles with higher power of n the overall value of intensity decreases.

$$\cos^1\alpha > \cos^5\alpha > \cos^{50}\alpha.$$

Calculate $\cos\alpha$

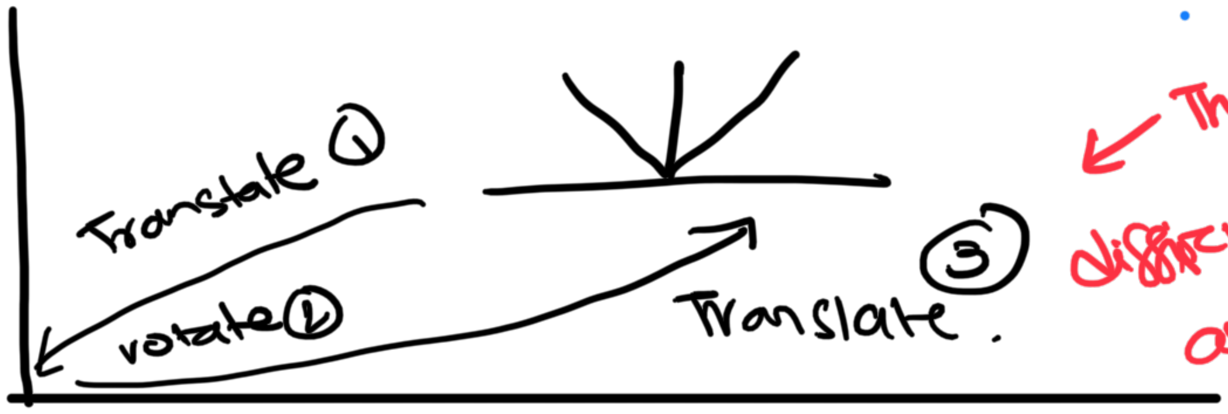
$$\cos\alpha = V.R$$

- R
- using Rotation
- Projection of vector.



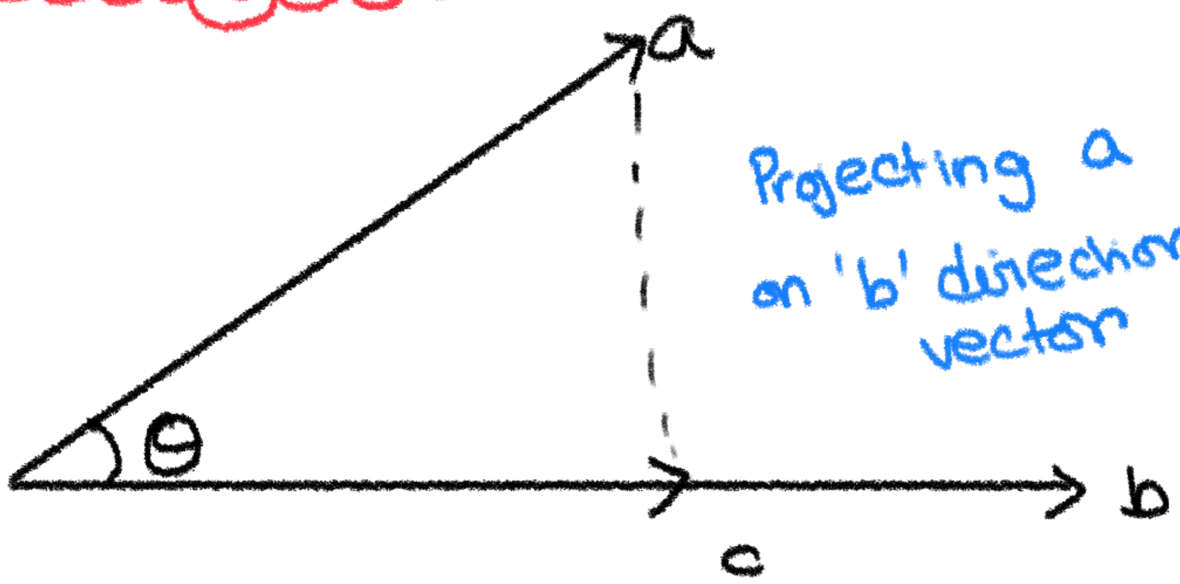
If we rotate L 2θ° we can go to R
However, we learned rotation in centre

(0,0). If we have a general centre what can be done?



This is difficult approach!

Vector Projection



Projecting a on 'b' direction vector

$$a \cdot b = |a||b| \cos \theta$$

$$\cos\theta = \frac{A}{H}$$

$$a \cdot b = |a||b| \frac{|c|}{|a|}$$

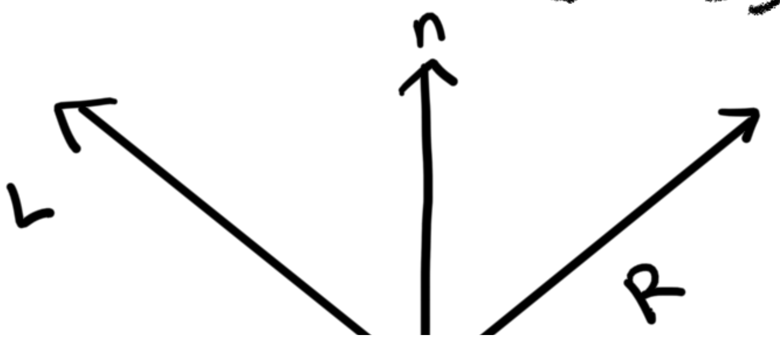
$$a \cdot b = |b||c|$$

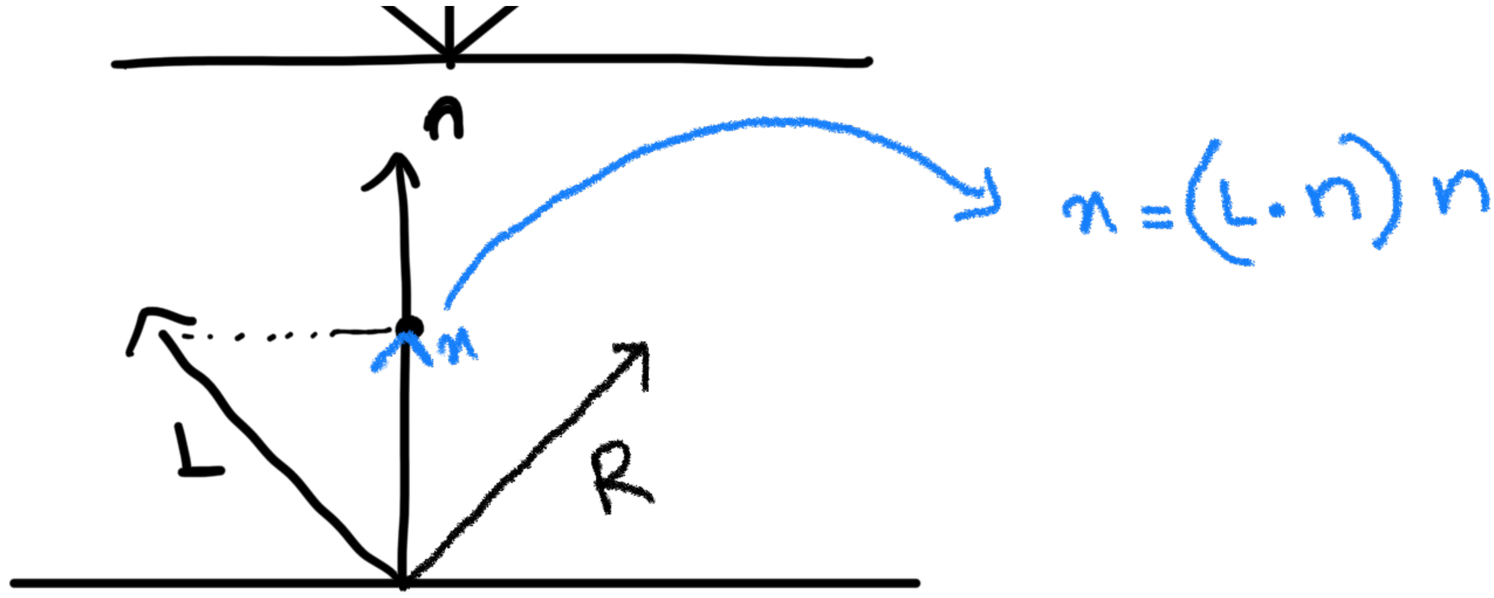
$$|c| = \frac{a \cdot b}{|b|}$$ → b is a unit vector

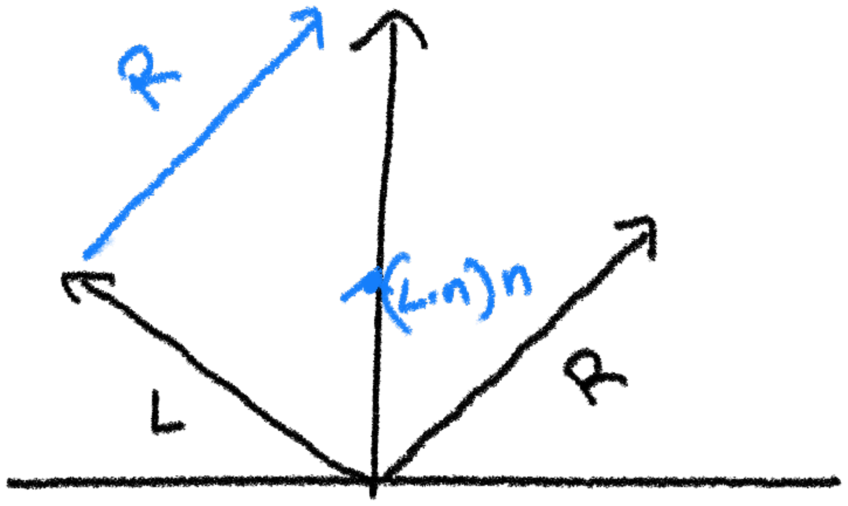
$$|c| = a \cdot b$$

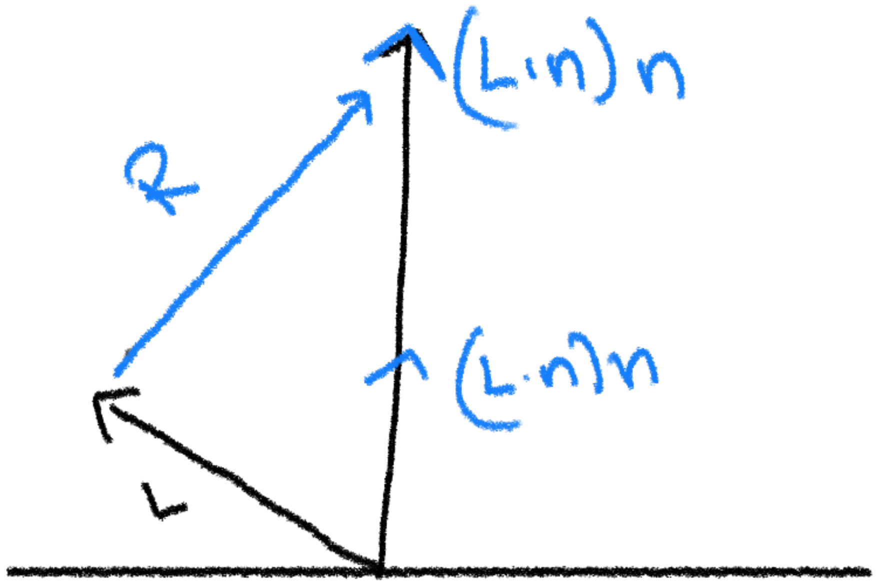
$$c = (a \cdot b) b$$

convert magnitude to direction vector









If we consider this triangle,
using vector rule,

$$L + R - 2(L \cdot n)n = 0$$

$$\boxed{R = 2(L \cdot n)n - L}$$

Compiling everything together,

$$I = \underbrace{I_a k_a}_{A.R} + \underbrace{I_p k_d \max(L \cdot n, 0)}_{D.R} +$$

$$I p k_s (\max(V \cdot R, 0))^{''}$$

S.R

— this is for one single pixel.

* If diffuse reflection D is positive then we will add specular reflection.

If $L \cdot n > 90^\circ$ the object cannot be seen.

Attenuation

The rate at which a light ray loses its intensity as it travels through space is called Attenuation.

There are alot of materials in space that stops light to travel.

$$f_{att} = \frac{1}{d^2}$$

with increase in distance, light intensity decreases.

Problem:

as $1/d^2$ f_{att} will become 0 faster.

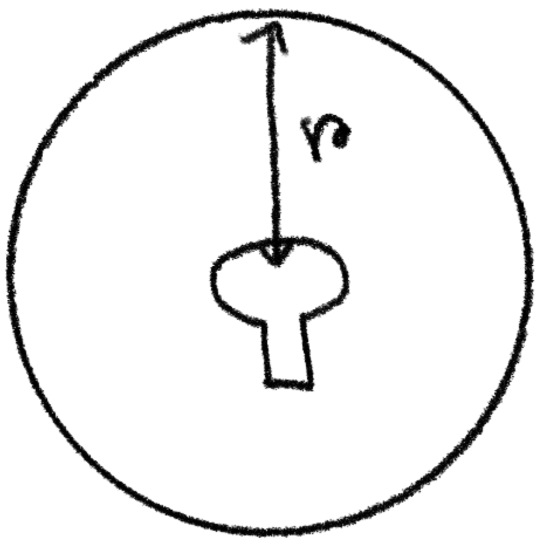
If $d = 0$ we will get f_{att} = infinity.

More Practice model used,

$$f_{att} = 1 \cdot \left(\frac{d}{\ } \right)^2$$

$f_{att} = 1 - \left(\frac{d}{r_0}\right)^2$

↳ radius light source.



If $d = 0$

$f_{att} = 1$ (no infinity)

If $d > R$ then it will be a large number after $\left(\frac{d}{r_0}\right)^2$ and $1 - \left(\frac{d}{r_0}\right)^2$ we will get a negative value. To resolve this

$$\boxed{f_{att} = \max\left[1 - \left(\frac{d}{r_0}\right)^2, 0\right]}$$

Combining Ambient, diffuse, specular and attenuation

$$I = I_a k_a + I_p f_{att}\left(k_d \max(L.n, 0) + k_s (\max(V.R, 0))^n\right)$$

If there are multiple light sources,

$$\underline{I} = I_a k_a + \sum_{i=1}^{m} I_p f_{att}\left(k_d \max(L_i \cdot n, 0) + k_s\left(\max(V \cdot R_i, 0)\right)^n\right)$$