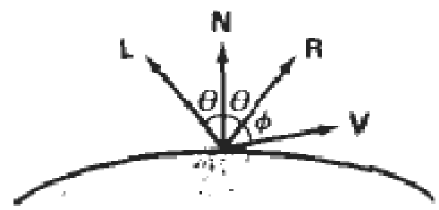
Phong Model/Specular Reflection

When we look at an illuminated shiny surface, such as polished metal, an apple etc we see a highlight or bright spot , at certain viewing direction this phenomenon is called "specular reflection" and is the result of total or near total reflection of the incident light in a concentrated region around the "specular reflection angle".

This angle is equal to the angle of incidence.

N – unit normal surface vector
R – unit vector in the direction of ideal specular reflection
L – unit vector directed towards point light source
V – unit vector pointing to viewer from the surface position
ø – viewing angle relative to specular reflection direction R

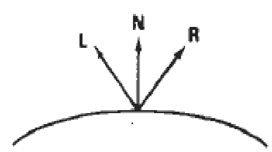


For ideal reflector (perfect mirror) incident light is reflected only in the specular reflection direction i.e. V and R coincide (ø = 0).

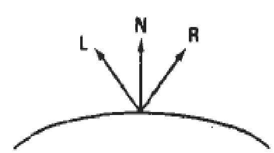
Shiny surfaces have narrow ø and dull surfaces have wider ø

An empirical model for calculating specular reflection range was developed by Phong Bui Tuong called "Phong specular reflection" model and it sets the intensity of specular reflection directly proportional to $\cos^{ns}ø$ ø → 0 to 90
Specular reflection parameter n_s is determined by type of surface

Very shiny surface has large n_s value
Very dull surface has smaller n_s value (down to 1)



Shiny Surface
(Large n_s)

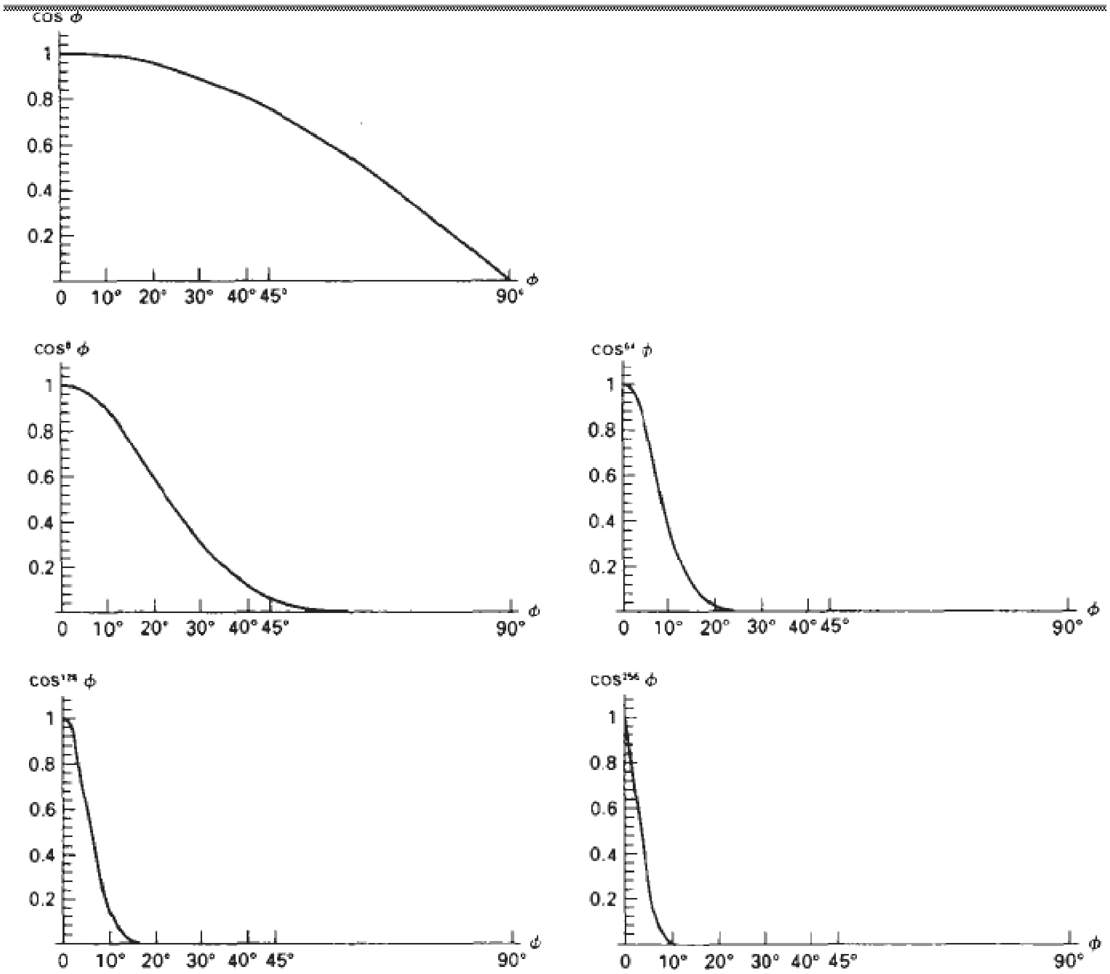


Dull Surface
(Small n_s)

Rough surface, e.g. chalk has n_s = 1

Intensity of specular reflection depends on material properties of surface, 0,other factors such as polarization , color of incident light.

For monochromatic specular reflections intensity variations can be approximated by SR coefficient W(θ)



W(ϴ) tends to increase as ϴ increases, at ϴ = 90 W(ϴ) = 1 and all incident light is reflected.

Fresnal's law of reflection describes specular reflection intensity with ϴ and suing W(ϴ), Phong specular reflection model as

$$I_{spec} = W(\theta)\ I_L\ \cos^{ns} \varnothing$$

where I_L is intensity of light source

ø is viewing angle relative to the specular reflection direction R.

So transparent materials like glass exhibit specular reflection as 0 approaches 90. At 0 = 0 about 4 percent of the incident light on a glass surface is reflected.

Now also $I_{spec} = W(\varnothing)\ I_L\ (V \cdot R)$ **as** $V \cdot R = \cos^{ns} \varnothing$

R can be calculated in term of N and L

$R + L = (2N \cdot l)N$ **or** $R = (2N \cdot l)N - L$

Simplified Phong model is obtained by halfway vector H between L and V to calculate the range of SRs

Replacing V . R in equation with N . H → Cos ø replaced by Cos α Half way vector H

$$H = \underline{\ L+V\ }$$

$|L + V|$

If both viewer and light source are sufficiently far from surface both V and L are constant over the surfaces. Hence H is constant.

For non Planar surfaces N.H requires less computation than V.R

If V is coplanar with l and R(also N) then $\alpha = \phi / 2$

If V,L,N are non coplanar then $\alpha > \phi / 2$

Combined diffuse and specular reflections with multiple light sources

For single point light source

$$I = I_{diffuse} + I_{spec} = K_a I_a + K_d I_L (N . L) + K_s I_L (N . H)^{n_s}$$

For multiple light sources

$$I = K_a I_a + \sum_{i=1}^{n} I_{Li} [(K_d (N . L_i) + K_s (N . H_i)^{ns}]$$