# Understanding Light and Shaders

Specular Reflection

- Specular reflection is often thought of as the reflection of your light sources on your object. While this is true it is not the only parameter that defines specular reflection.

- Specular reflection is the reflection of light off the very top of the surface of a material where there is no interaction between the light itself and the material.

- In specular reflection the light is reflected at a specific angle. That angle is measured with respect to the normal of the surface.

Specular Reflection

The Law of reflection
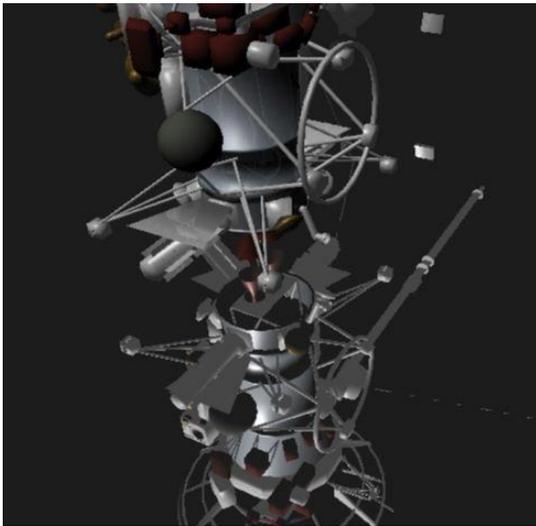Angle of Incident = Angle of Reflection
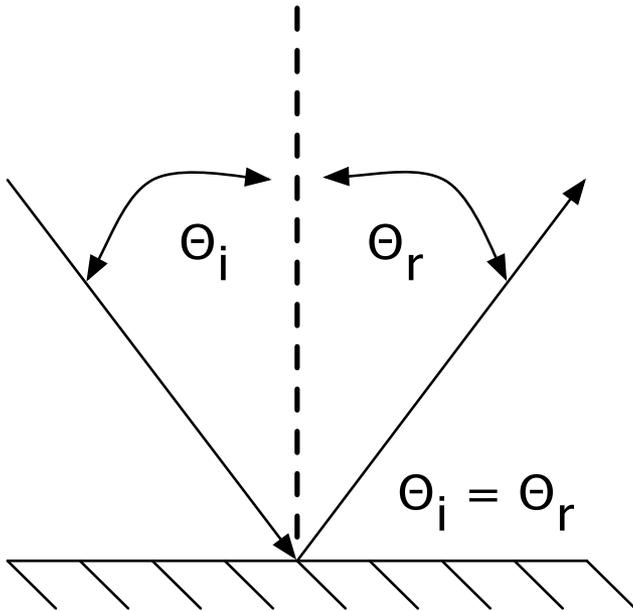
The eye sees different things in the scene
depending upon the angle. Like looking in a
mirror and moving your head. This is specular reflection

Θ_i Θ_r

$\Theta_i = \Theta_r$
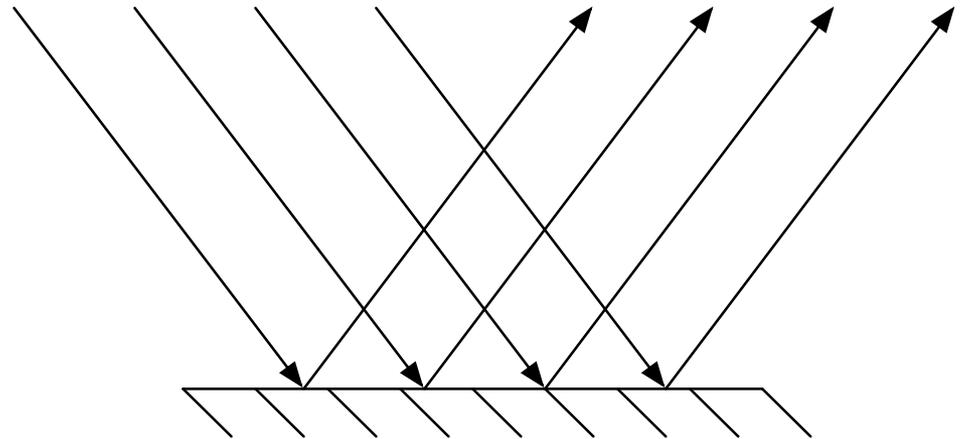
Example Surfaces: Shiny metal, mirror, glass, smooth plastic

More Specular Reflections

Note the Specular reflections. CG spacecraft is above a mirror with no distortion. Glass on table is close to mirror with some distortion. Reflection on bathroom fixtures are more pronounced and if you look close you can even see my iPhone!
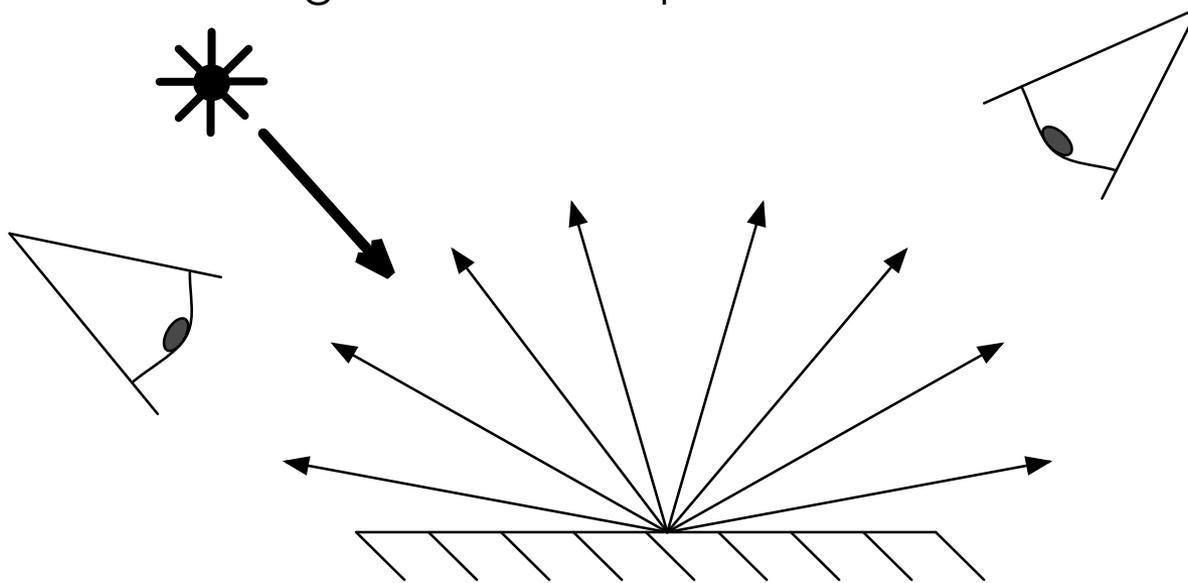
Diffuse Reflection

- With diffuse reflection there is an interaction between the light and the surface of the object. In a diffuse reflection part of the energy of the light is absorbed.

- With a diffuse reflection the light is reflected at a random direction.

Diffuse Reflection

The energy of a point source is divided equally between all reflected rays. This means the intensity of the reflection is the same regardless of the point of view of the observer

Example Surfaces : Dirt, foam, any course surface such as rubber, highly brushed metal.

Example Diffuse Reflection

Fresnel Reflection

- In the world of 3D modeling and animation, Fresnel (pronounced frenel, the "s" is silent) reflections come from a property of a surface (shader) where the amount of reflection is dependent upon the viewing angle of the camera. While this effect is exhibited to a modest degree on metal materials, it is most pronounced on dielectric materials.

Real world example of Fresnel reflections

Incident

Color of the table top goes from wood to white

In all 3 pictures the lighting is exactly the same and there was no flash. Exposures were set to auto so there is an obvious difference in that respect

As the camera angle increases the "color" of the tabletop turns from wood to white. Note also the increase in specular reflection. The reflected leaves from the outside plant go from blurry on the left to almost clearly defined on the right.

Camera is approx. 10-15 degrees to table top

Camera is approx. 1- 5 degrees to table top

Creating Fresnel Reflections

- To create Fresnel reflections you either need to use a shader that has support for Fresnel built in, such as a mental ray mia material or you need to build it from scratch using the sampler info node and a ramp.

- Using the samper info node allows you to vary any parameter such as reflection or transparency based upon the angle the camera is facing to the surface normal.

Technical Note: Ramps in Maya and some other known 3D software are actually not linear in how they map intensity across a UV surface. To be completely photorealistic you should always use precise material IOR data such as what you find on http://refractiveindex.info/. In addition you should correct all non-linear mappings so that you use correct values for reflection at all angles of incidence to surface normal.
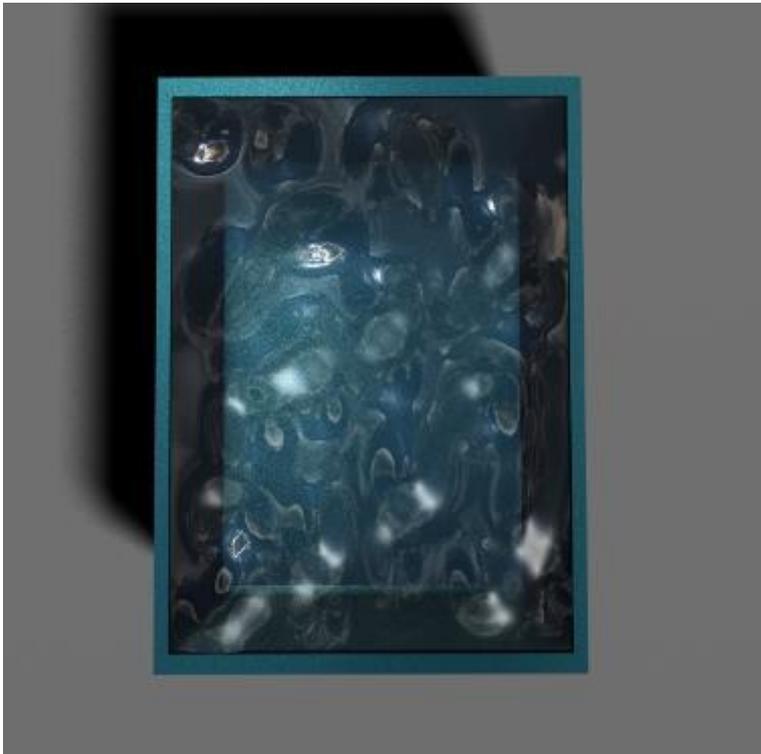
Phong shader Without Fresnel   Phong shader With Fresnel
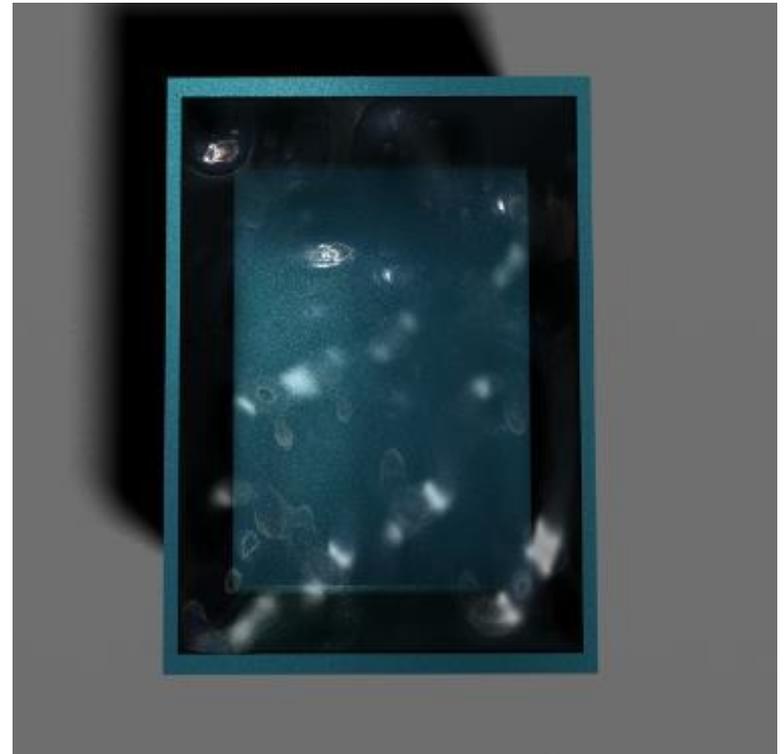
Note reduced environment reflections

10cm

10cm
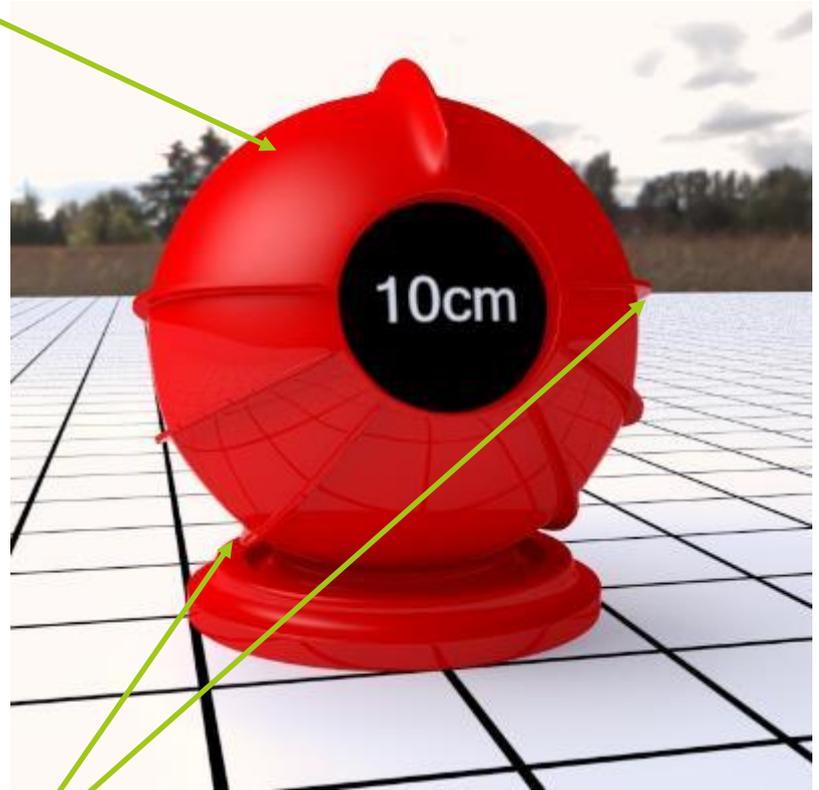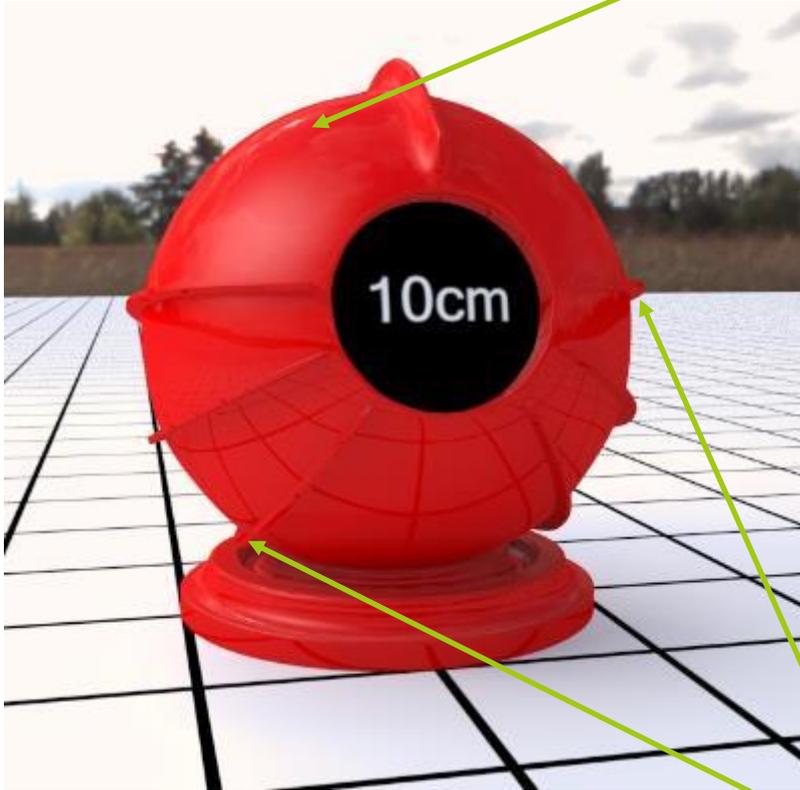
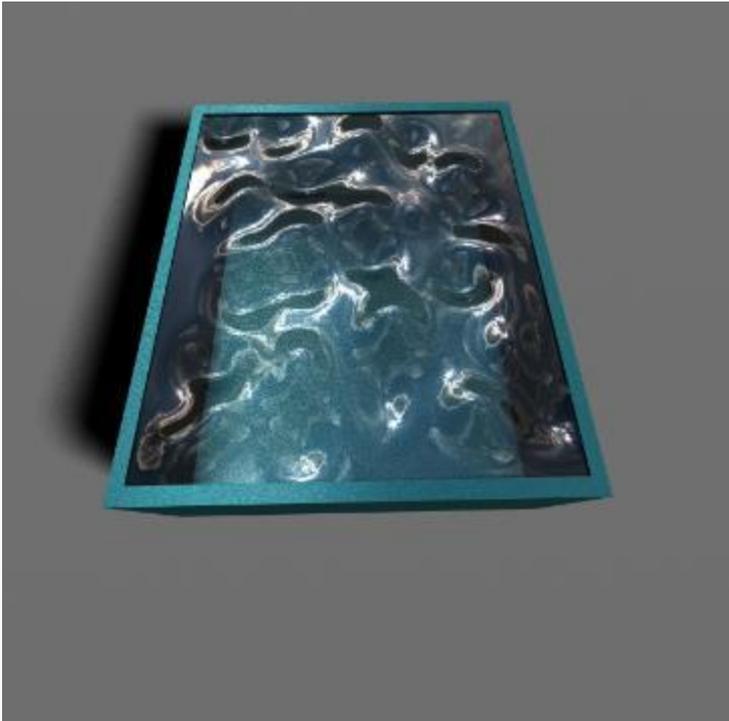Note light spot

Phong shader Without Fresnel
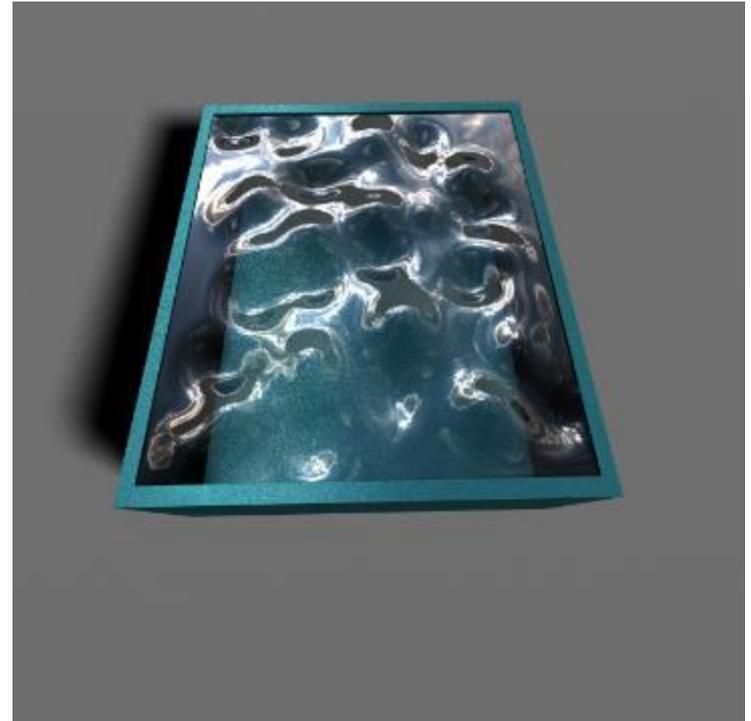
Phong shader With Fresnel

Note the high degree of reflectivity on the left where there is no Fresnel compensation to reduce this when the camera is looking straight down.

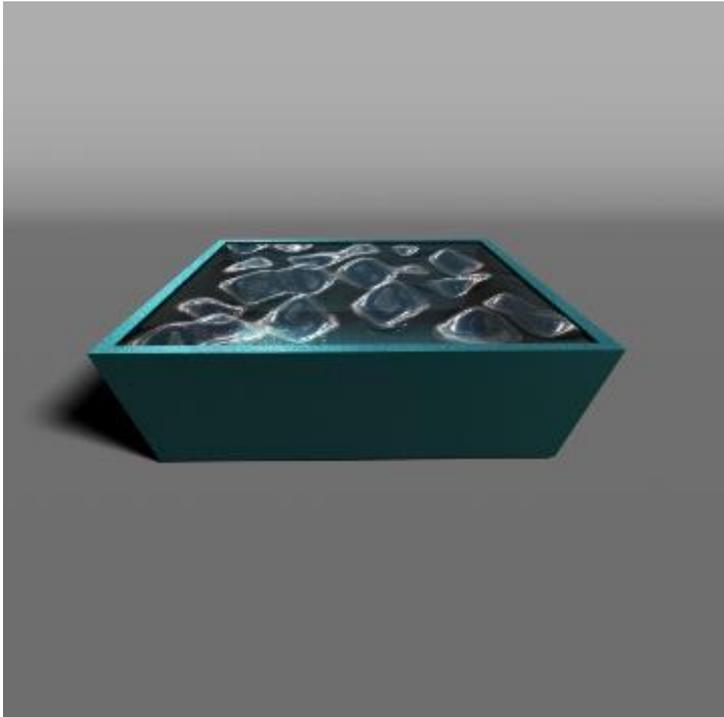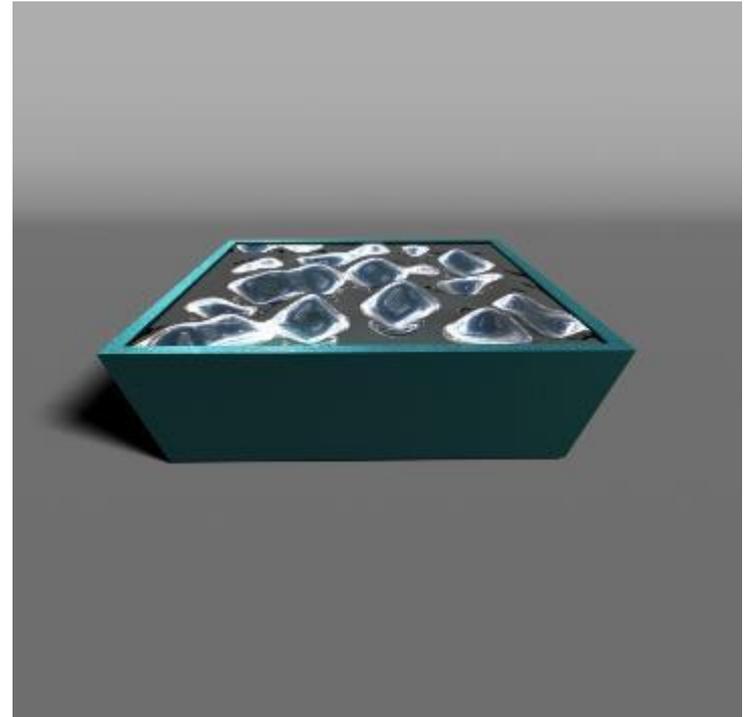Phong shader Without Fresnel

Phong shader With Fresnel

Now, at an angle with Fresnel, the reflectivity is increasing while the transparency is decreasing. On the left there is no reduction to transparency.

Phong shader Without Fresnel

Phong shader With Fresnel

The image in the left is completely wrong. There is far too much transparency and the reflectivity is not nearly high enough.

Material Types

- All materials can be broken down into two main types
  - Metals – (Materials that conduct electricity)
    - Very high reflectivity both at incident and grazing angles. Shows little Fresnel effect compared to dielectric materials. (Exceptions are chrome, mercury, aluminum, platinum)
    - Strong specular reflections and almost no diffuse reflections.
  - Dielectrics – (Materials that do not conduct electricity)
    - Faint specular reflections and either diffuse reflections or transmission. Most dielectrics have only 2% - 4% incident angle specular reflections.

Material Cheat Sheet - Dielectrics

- Most dielectrics will have a combined diffuse and specular amount that will be between 5% and 40% of the total intensity or less.

    - To calculate the diffuse intensity, get the average of the RGB intensity and multiply by the diffuse amount.

        - ie. If your RGB values are 0.7, 0.2, 0.4 and your diffuse amount it set to 0.7 then the total diffuse component is given by $((0.7+0.2+0.4)/3)*0.7= 0.303$ or 30.3%

    - The specular (or reflection) amount on all dielectrics (with the exception of gemstones) is between 0% - 4%.

- Dielectrics will exhibit a large amount of Fresnel effect when the glancing angle approaches 90 degrees.

- Color is defined by the diffuse color

- Reflected color should equal 1 (white) and specular color can vary depending upon desired effect. Neutral grey (.5) is a good place to start.

- The 40% is not a hard limit but only special circumstances would dictate a diffuse energy higher than this amount.

Material Cheat Sheet - Metals

- Metals have no diffuse component. Set this to zero.
    - This can vary if you are modeling a brushed metal surface. In this case you should use bump maps to create a textured surface either in the specular color or a bump added to the reflectivity of the surface.
    - For phong, blinn shaders you set Color, Transparency, Ambient Color to 0 (black)

- Metals have a very high reflectivity, 95% or greater.

- To best match color use real material reflectivity amounts by color from known source, ie, http://refractiveindex.info
    - For a phong or blinn shader, the color of the metal is defined by the Specular Color. The Reflected Color should be set to 1 (white)
    - R = 0.680um, G = 0.533um, B = 0.473um
    - If you want to create a custom curve for Fresnel use non-polarized data at the color green (0.533um). 0 degrees of Angle of Incidence is looking straight down on the surface. 90 degrees of Angle of Incidence is looking parallel to a surface.

Materials Cheat Sheet - Glass

- Glass is a dielectric so it's general parameters will follow those of the dielectric cheat sheet.

- Phong and blinn shaders can be used for clear glass but the fall short in that they have no refracted color parameter. Without this it is very difficult to create colored glass with these materials. Use a mental-ray mia_material which has a parameter for refracted color.

- Because there is a Fresnel effect that approaches 100% reflectivity at the edge of glass, conservation of energy dictates that the transparency of the glass will go to zero at the edge. To make correct looking glass that darkens at the edge you should really make two curves, one for reflectivity and the other for transparency.

BRDF for Glass