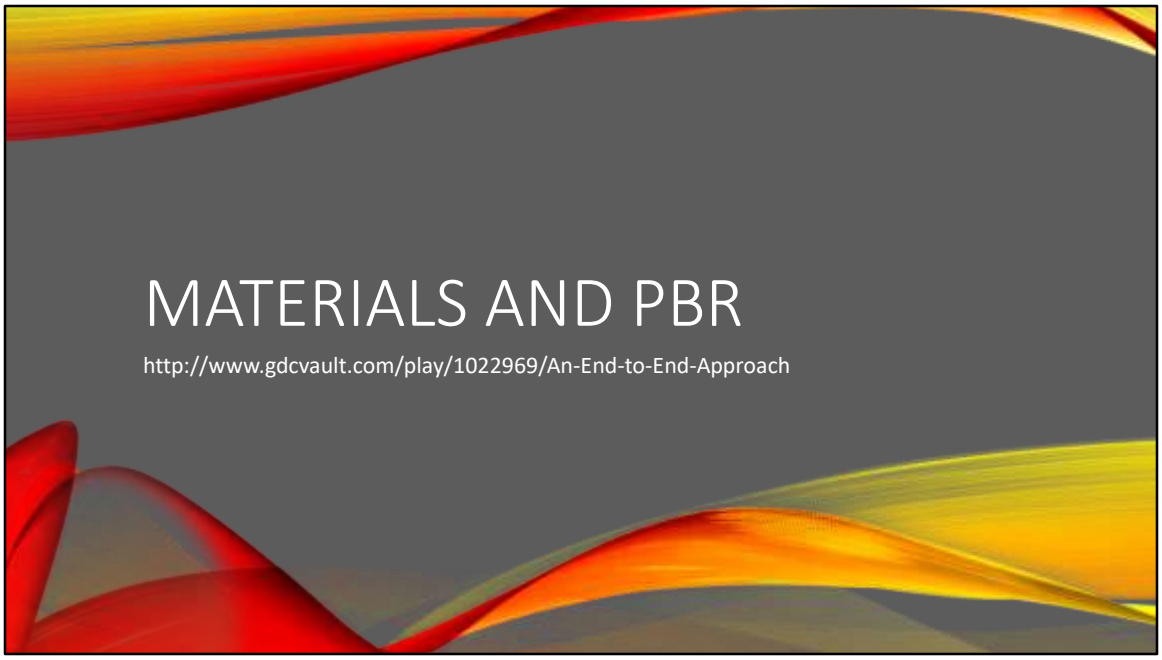
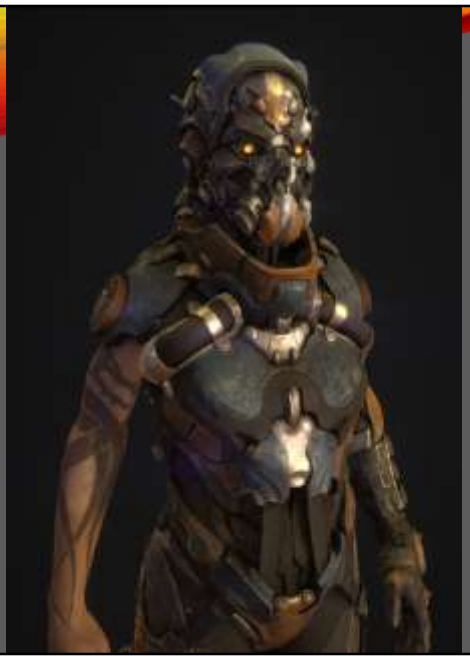

MATERIALS AND PBR
http://www.gdcvault.com/play/1022969/An-End-to-End-Approach



What is PBR?

As the name suggests, physically-based rendering (PBR) is a method of shading & rendering, used in order to provide a more accurate representation of the real (physics-based) world around us.

WHY BOTHER TO LEARN THE SCIENCE?

- As artists it's important for us to understand how light interacts with surfaces in order for us to be able to realistically re-create this within our own content.

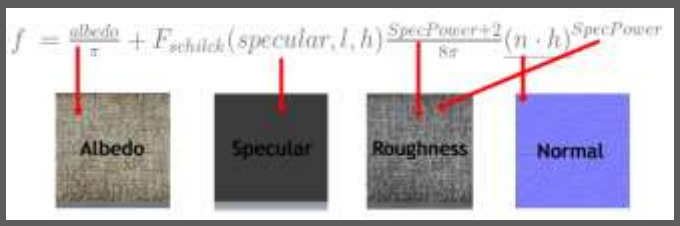
Better understanding = Better content

Why should the audience bother or care to learn about PBR?

As an artist, why is it important to grasp some of the more technical concepts and theories behind how it works?

BRDF

- So what is BRDF a function of?
  - How much certain wavelengths are absorbs or reflected from a specific surface
  - Incoming light direction
  - The positional variance of the surface
  - View direction



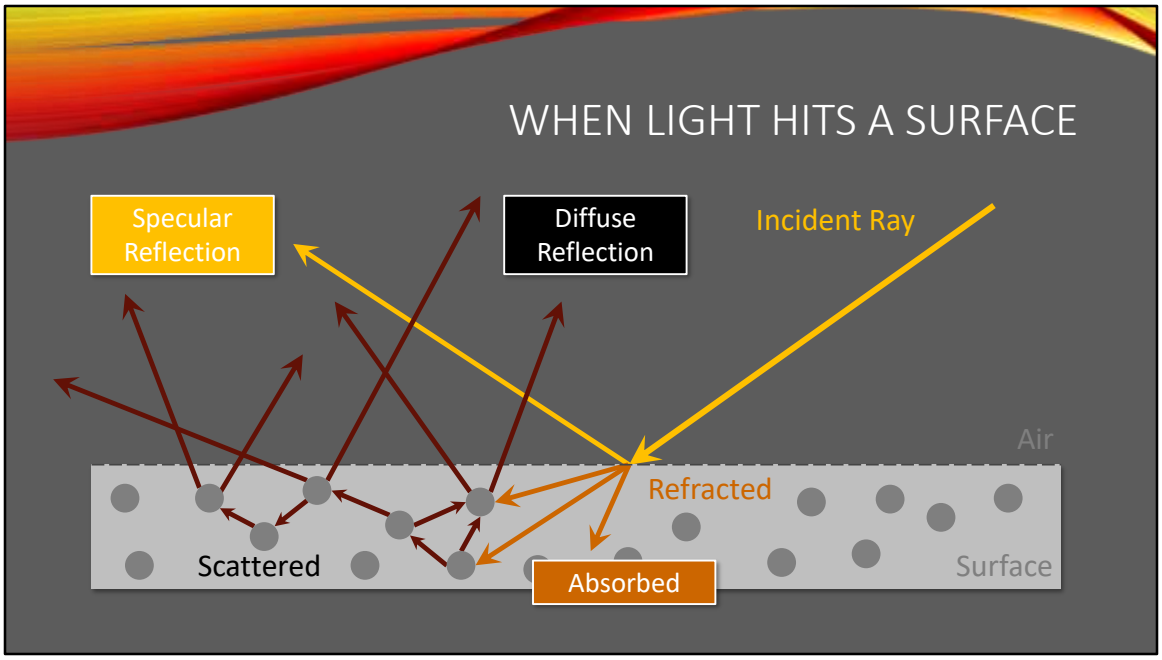
KEY CONCEPTS OF PBR

1. Specular and Diffuse Reflection
2. Microfacet Theory
3. F0 Reflectance
4. Energy Conservation

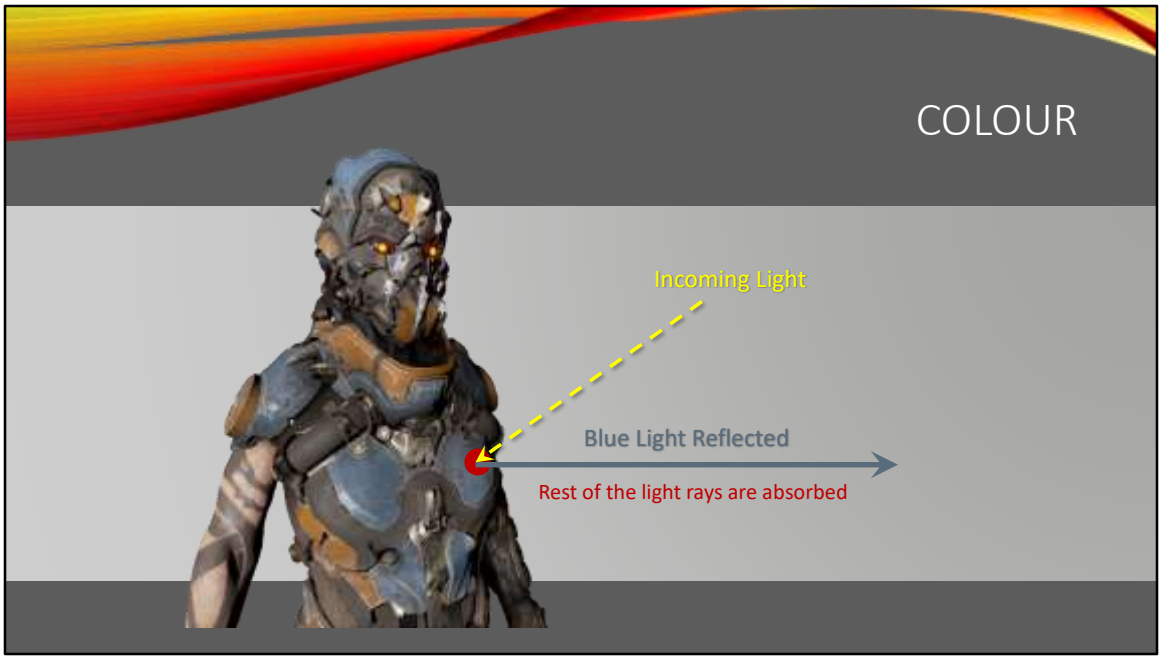
Material by Pierre Fleau

Unfortunately there is not enough time in this session to go into all topics of PBR or get into them at any great depth, but we'll touch on some of the core concepts to:

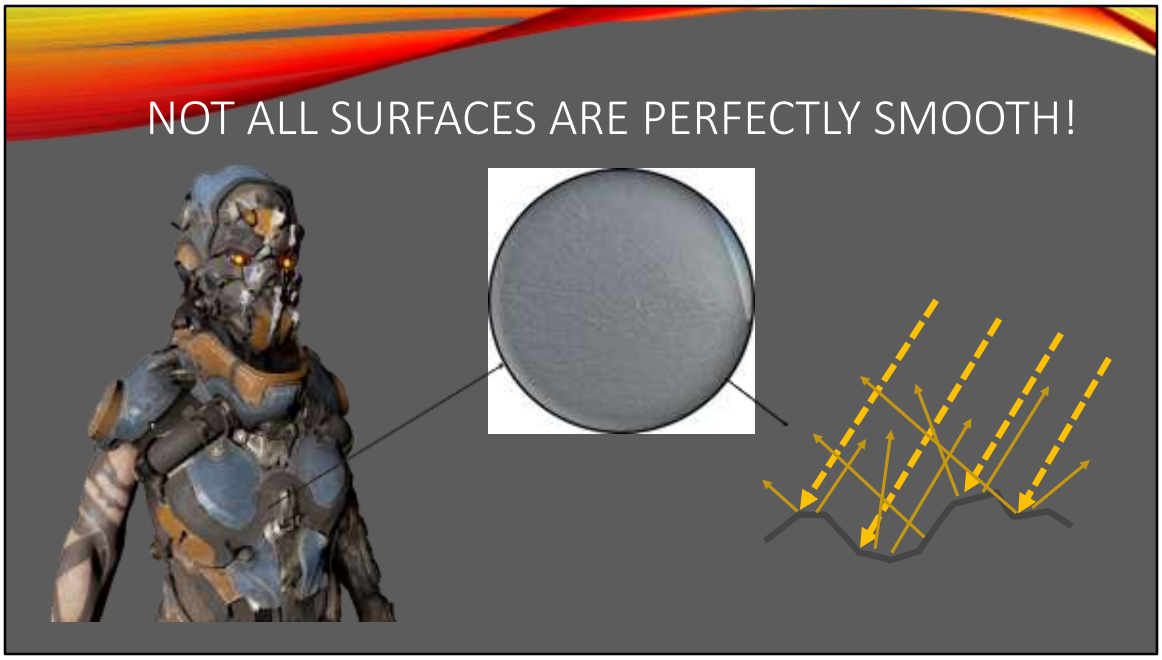
a) They're not overly complex ideas
b) To help try and provide a bit more background to some of the authoring stuff that Wes is going to demonstrate.



Light which reflects off a surface is called Specular Reflection.
Light which refracts into a surface and never makes it back out is Absorbed.
Light which refracts into a surface, scattered around and refracted back out again is called Diffuse Reflection.



Different wavelengths of light will get reflected, scattered and absorbed differently and this is in fact what determines an object's colour.
For example, as the incoming light hits our character, only the blue wavelengths are scattered back outside of the breast plate and the others are absorbed. This is why we perceive it as blue!



Diffuse and specular reflection is not the complete story.
In reality, surfaces have lots of tiny imperfections and irregularities which dramatically affect the diffusion and reflection of light.
To simulate this in PBR we use define the roughness of surfaces using a roughness map.

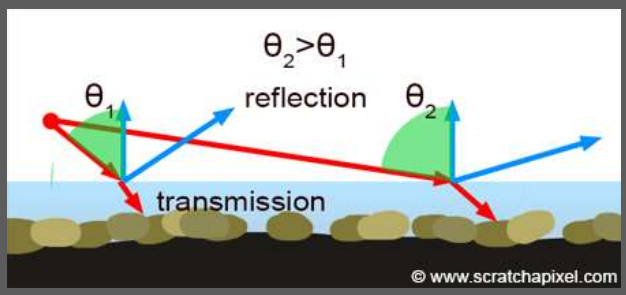
NOT ALL SURFACES ARE PERFECTLY SMOOTH!

Microfacet Theory

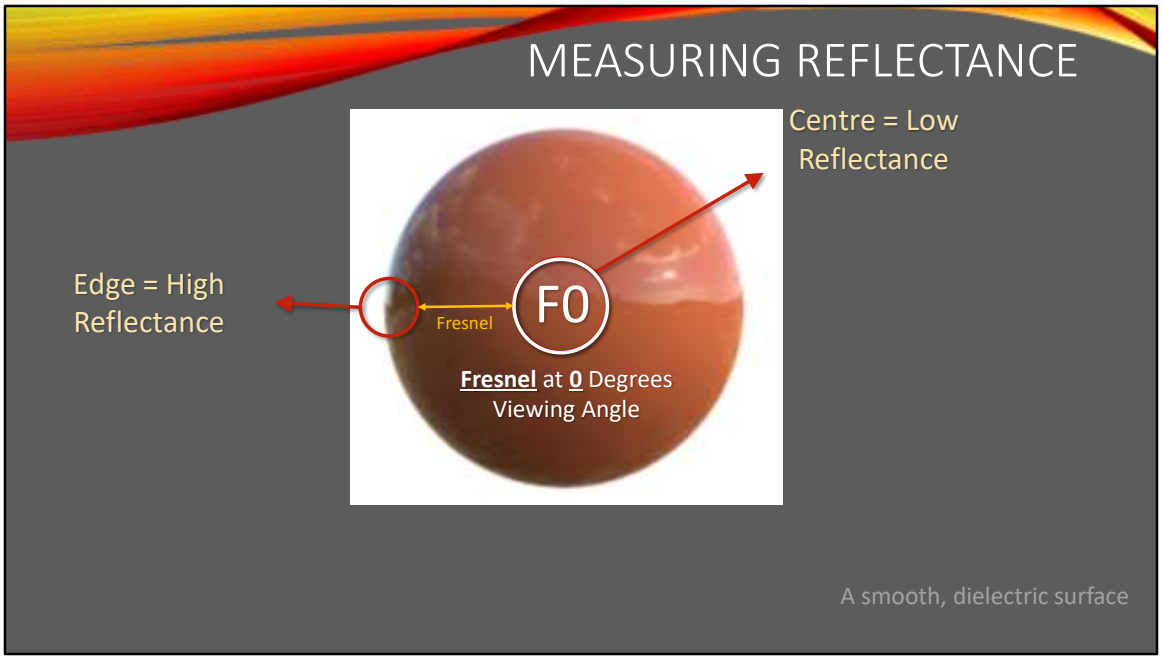
This whole concept is referred to as **Microfacet Theory**.

FRESNEL

- **Fresnel** describes how the light you see reflects at different intensities based off of the angle you are viewing it from



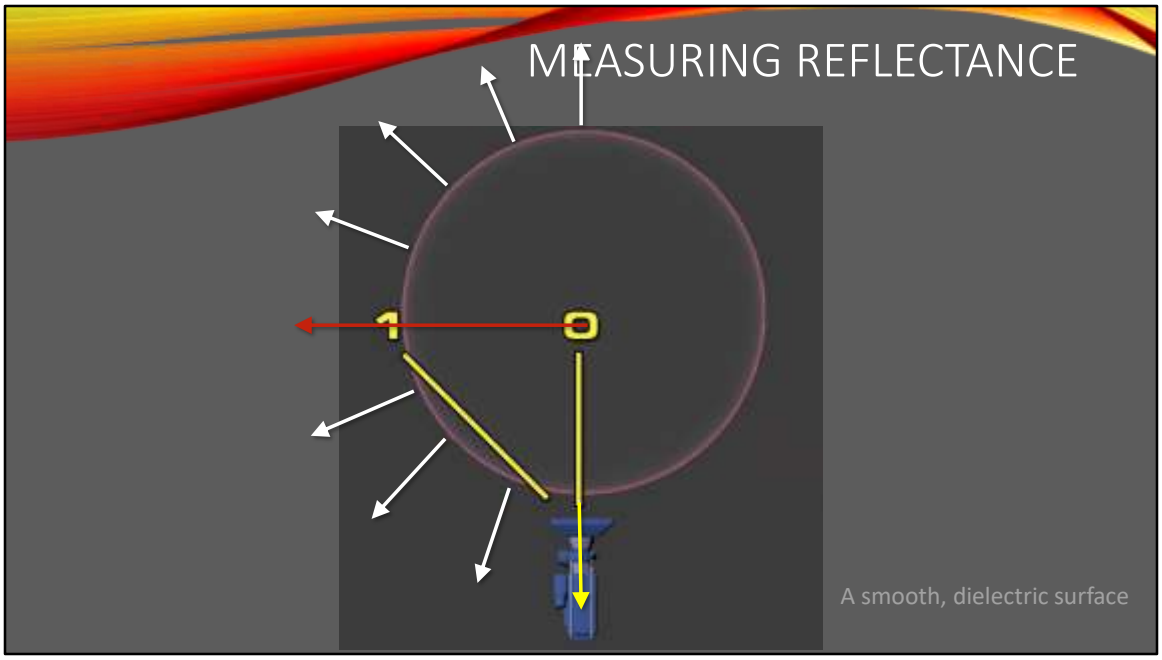
For example, if you are standing over a pool looking straight down at the pool, you will not see a lot of reflections in the water. As you start to move your head so that the water in the pool becomes more and more parallel to your eye level, you will begin to notice more and more reflections in the water.



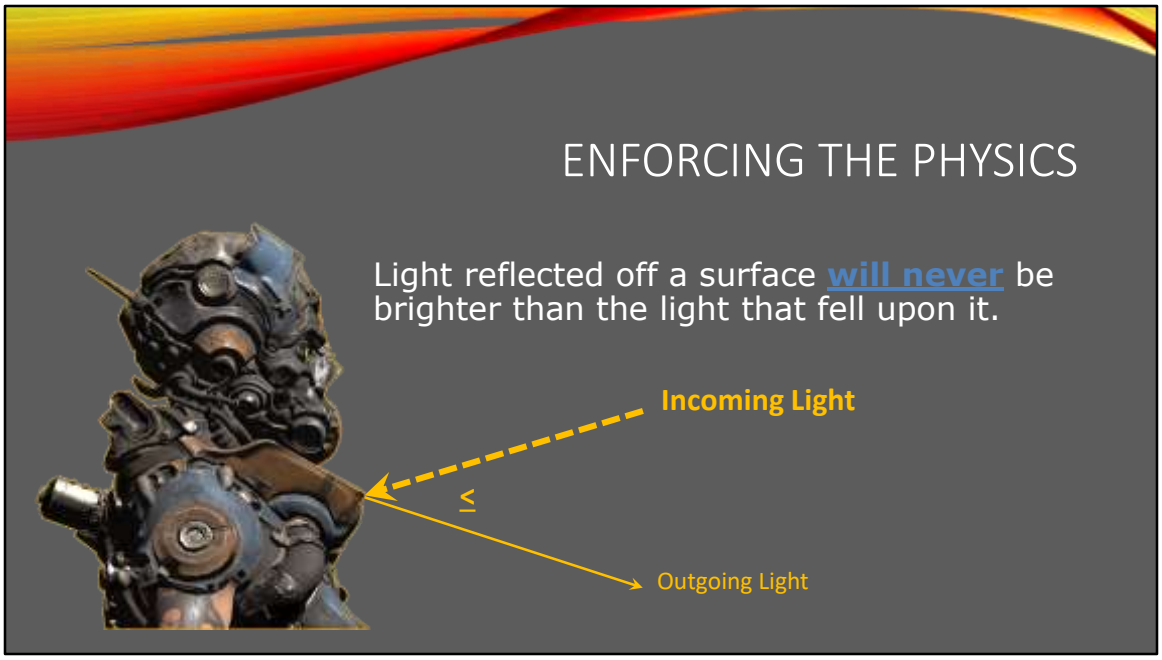
Fresnel is nothing new to us as artists and it tells us that the amount light you see reflected from a surface depends on the viewing angle at which you perceive it.

With PBR this effect is handled in the shader automatically for us! :)

All the shader requires is a reference point for how much light is reflected back when it hits a surface at a measurable angle (at 0 degrees)
The fancy term they give this reference point is **The Fresnel at 0 degree viewing angle (F0).**



In UE4, the Fresnel Material Expression node calculates a falloff based on the dot product of the surface normal and the direction to the camera. When the surface normal points directly at the camera, a value of 0 is output meaning there should be no Fresnel effect happening. When the surface normal is perpendicular to the camera, a value of 1 is output meaning the full effect of the Fresnel should be taking place. The result is then clamped to [0,1] so you do not have any negative color in the center. The following image demonstrates this concept.



One of the best benefits of PBR is material consistency regardless of lighting conditions
This is achieved because we are now enforcing the laws of physics within our shading model
Physics tells us that light reflected off a surface will never be brighter than the light that fell upon it

By enforcing this law; known as **Energy Conservation** it:
- Makes artists' lives easier
- Ensures materials are more physically accurate & consistency

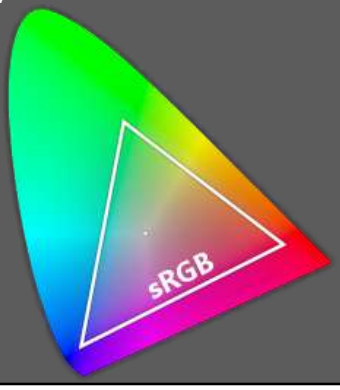

WORKFLOWS


Metallic Workflow
Base Color
Roughness
Metallic
Normal
Specular Workflow
Diffuse
Glossiness
Specular
Ambient Occlusion


testmat
Base Color
Metallic
Specular
Roughness
Emissive Color
Normal
World Position Offset
Ambient Occlusion
Pixel Depth Offset

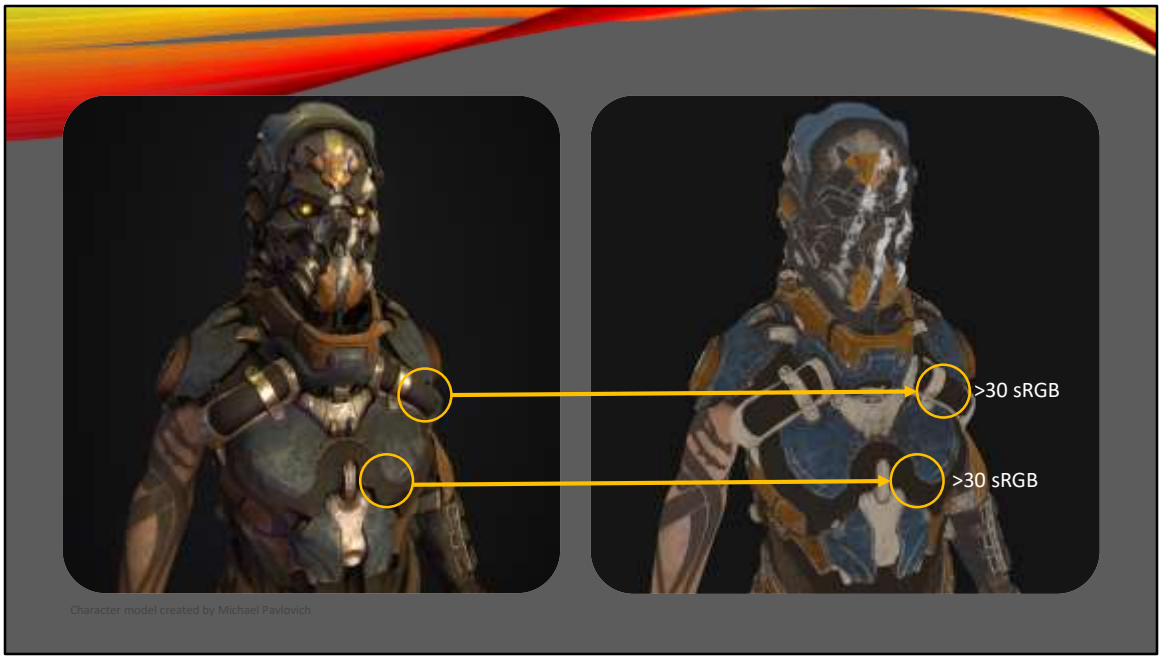
COLOR SPACES

- A **color space** simply describes the range of colors that a device can display. Picking a color space and working in it will determine the color range you can work in.



BASE COLOR (ALBEDO)

- Devoid of lighting information *exception micro-occlusion
- No dark values below 30 sRGB (50 sRGB – strict mode)
- No bright values above 240 sRGB



- Devoid of lighting information with the exception of micro-occlusion
- Dark values should not go below 30 sRGB (tolerant range) - 50 sRGB (strict range) *exception of raw metal (black) in difffuse
- Bright values should not go above 240 sRGB

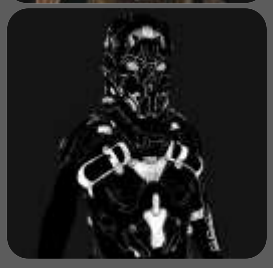
METALNESS MAP

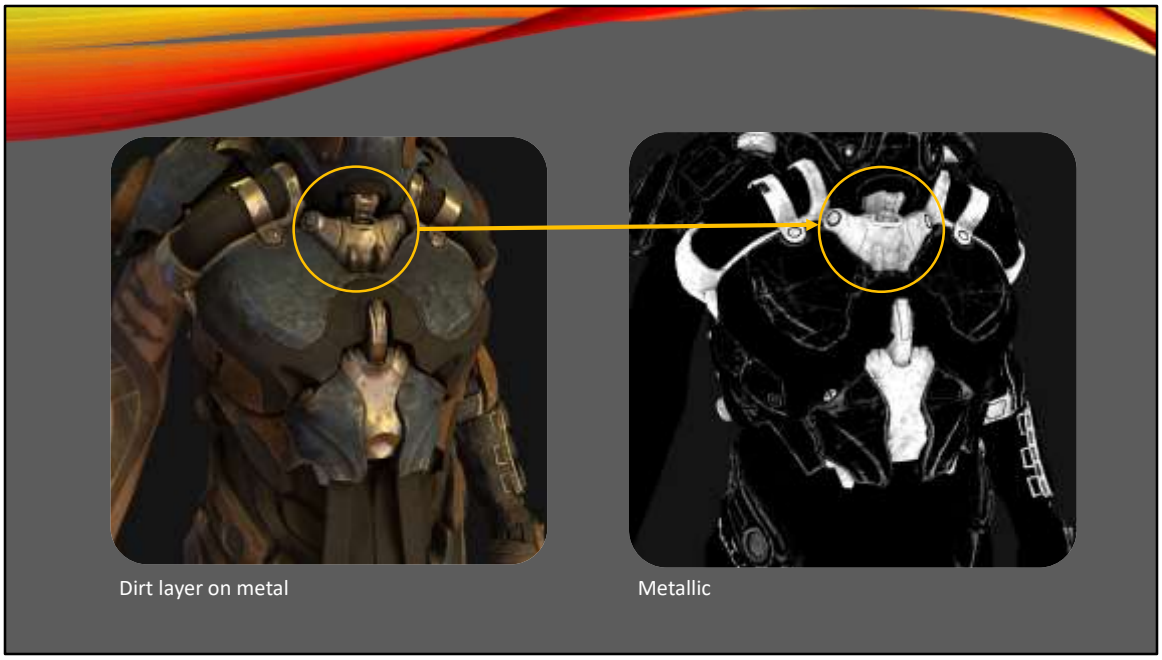
- Literally controls how "metal-like" your surface will be
- A black and white map*
- White = metal
- Black = dielectric (nonmetal)

*when creating hybrid surfaces like corroded, dusty, or rusty metals, you may use some value between 0 and 1

METAL REFLECTANCE VALUES BASE COLOR & METALLIC

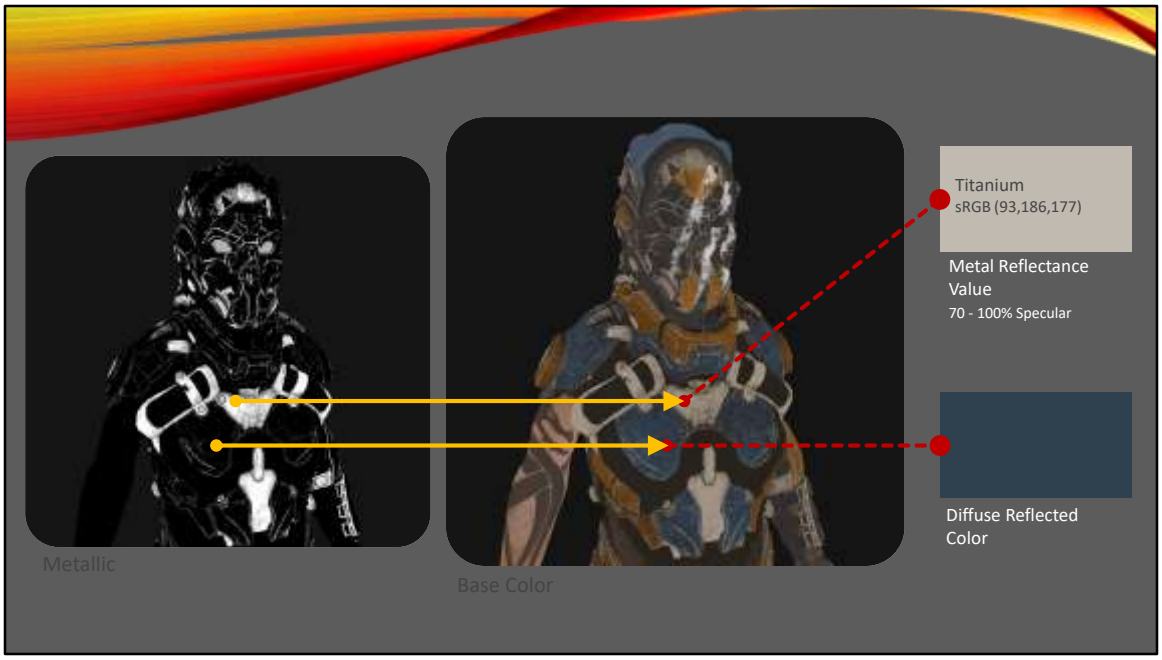
- 70-100% specular (180-255 sRGB)
- Some metals can be corroded
- Painted or coated metal is dielectric
- Dielectric layer affects metallic map examples: dirt and rust





- Dirt or oxidation affects reflectance values
- For metal map values lower then 235 sRGB, the reflectance needs to be lowered in the base color

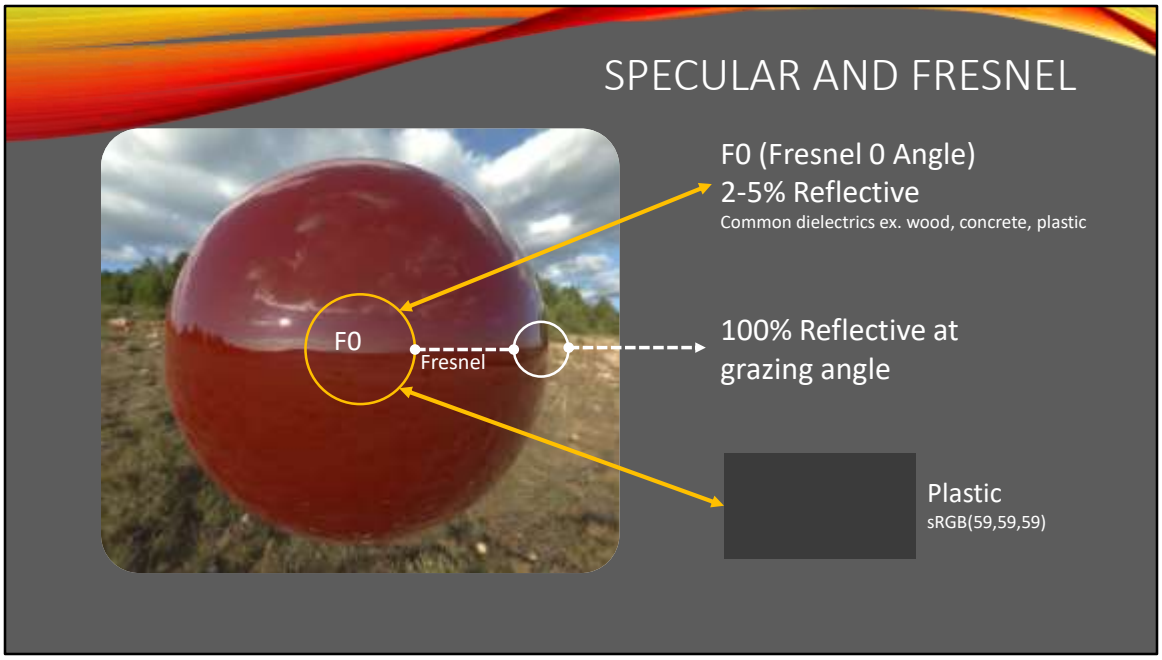
metalness of 0 metalness of 1



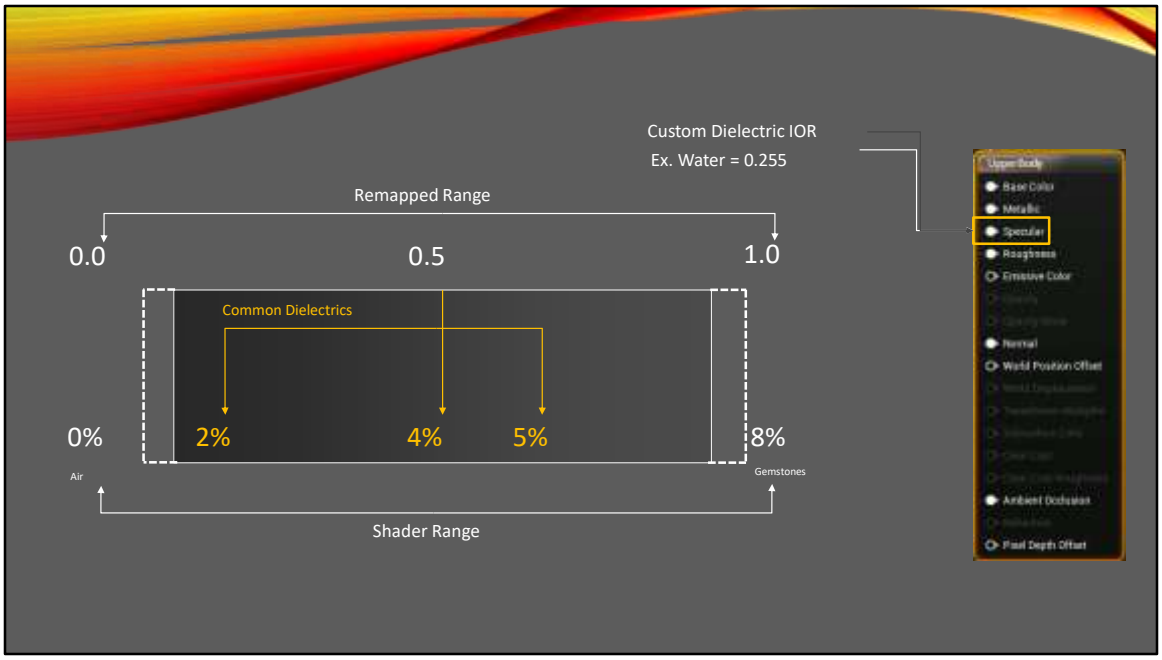
- Range is high - 70-100% specular (180-255 sRGB) and some metals can be corroded
- Some metals absorb light at different wavelengths. Gold absorbs blue light at high-frequency end of the visible spectrum so it appears yellow as a result. Since the refracted light is absorbed, the color tint of metals come from the reflected light and thus in our maps we don’t give metals a diffuse color.

Measured BaseColors for metals:

Material	BaseColor (R, G, B)
Iron	(0.560, 0.570, 0.580)
Silver	(0.972, 0.960, 0.915)
Aluminum	(0.913, 0.921, 0.925)
Gold	(1.000, 0.766, 0.336)
Copper	(0.955, 0.637, 0.538)
Chromium	(0.550, 0.556, 0.554)
Nickel	(0.660, 0.609, 0.526)
Titanium	(0.542, 0.497, 0.449)
Cobalt	(0.662, 0.655, 0.634)
Platinum	(0.672, 0.637, 0.585)



- F0 range for common dielectrics 0.02 – 0.05
- F0 reflectance value is what we are concerned witth.
- F0 for non-metals doesn’t change drastically.



- Dielectrics reflect smaller amount of light than metals
- Shader is mapped to a range of (0.0-0.08 linear), as zero is needed to represent air.
- Metallic workflow, handled by shader, default 4% (0.04 linear)
- Common dielectrics around
  2-5% reflective (40 – 75 sRGB)
  (0.02 – 0.05 linear)
- Can’t find an IOR, use 4%
  (0.04 linear) Plastic rang

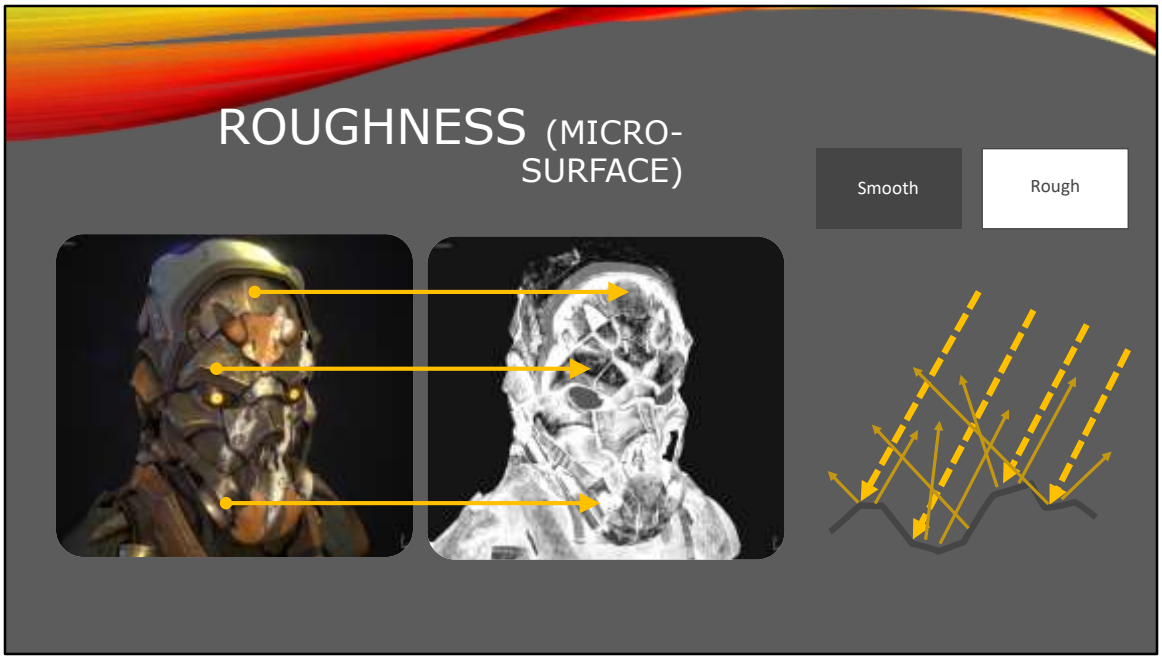
SPECULAR

- The Specular input should not be connected and left as its default value of 0.5 for most cases
- Only works on non metallic surfaces (metallic = 0)
- Artistic tweak related to how bright the specular hit is
- Can be used to add micro occlusion or small scale shadowing from tiny cavities only represented in the normal map

BASE COLOR

- **Base Color** simply defines the overall color of the Material

Material	BaseColor Intensity
Charcoal	0.02
Fresh asphalt	0.02
Worn asphalt	0.08
Bare soil	0.13
Green grass	0.21
Desert sand	0.36
Fresh concrete	0.51
Ocean Ice	0.56
Fresh snow	0.81



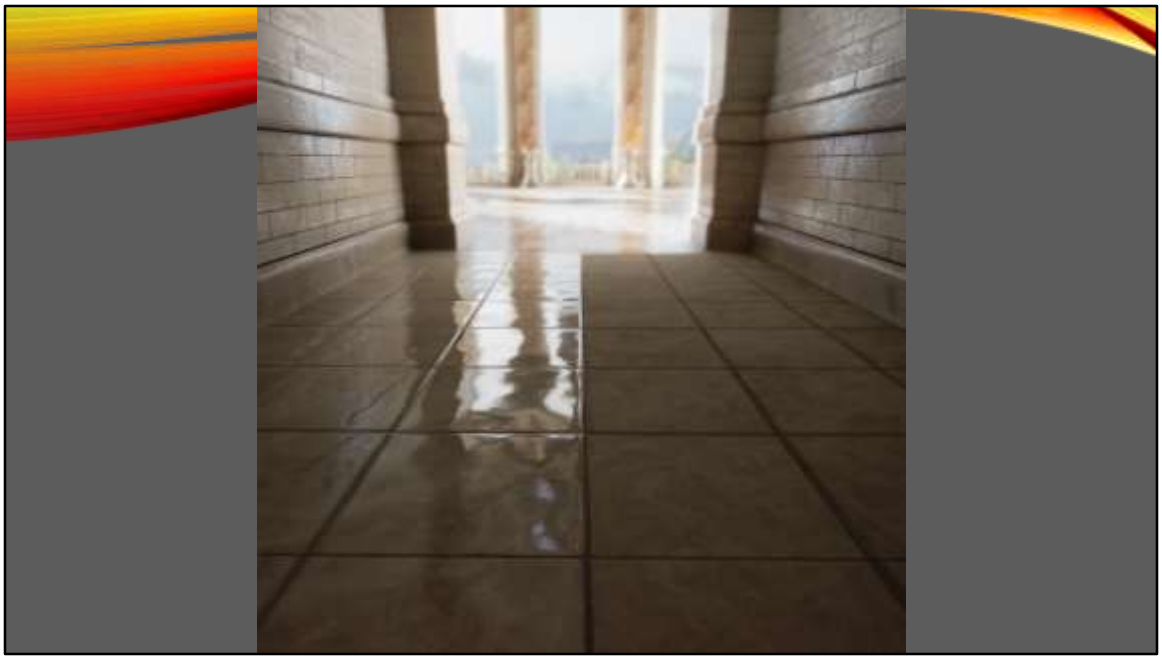
- Most creative map – can't go wrong
- Relates to the normal map (high freq detail) roughness (micro-surface detail)

ROUGHNESS

- Literally controls how rough the Material is
- A rough Material will scatter reflected light in more directions than a smooth Material
- The higher the value of roughness (between 0 and 1) the blurrier the reflection
- A roughness of 0 has a mirror reflection
- A roughness of 1 is completely matte or diffuse

This image shows a material with a roughness of 0.1, 0.5 and 0.9

You really should avoid 0 and 1 – even though it's fun to set your materials to those extremes. The problem is nothing is real life is either 0 or 1



In the following image you can see the surface on the left has a roughness of 0, and appears to have much more specular reflection than the surface on the right which has a roughness of 1.