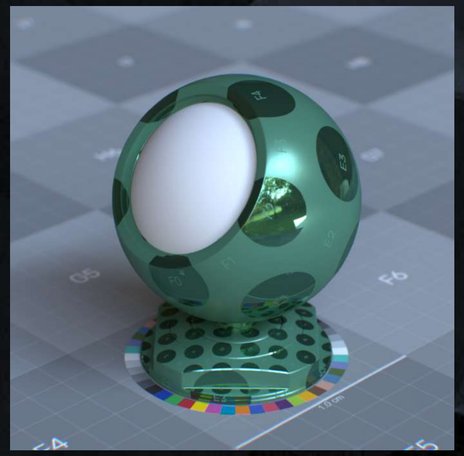
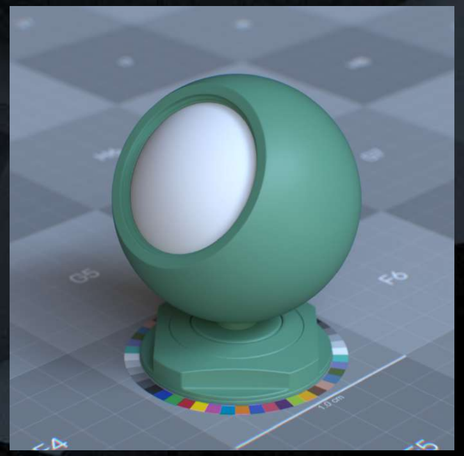
Lighting Concepts:

Specular | Diffuse | Emission





Based on Physically Based Rendering (PBR) Theory

Lighting Concepts:

Descriptors / Adjectives

Specular

- Reflection
- Mirror
- Shiny
- Glossy
- Wet
- Metallic
- Highlights
- Pings
- Crisp
- Sharp
- Polished

Diffuse

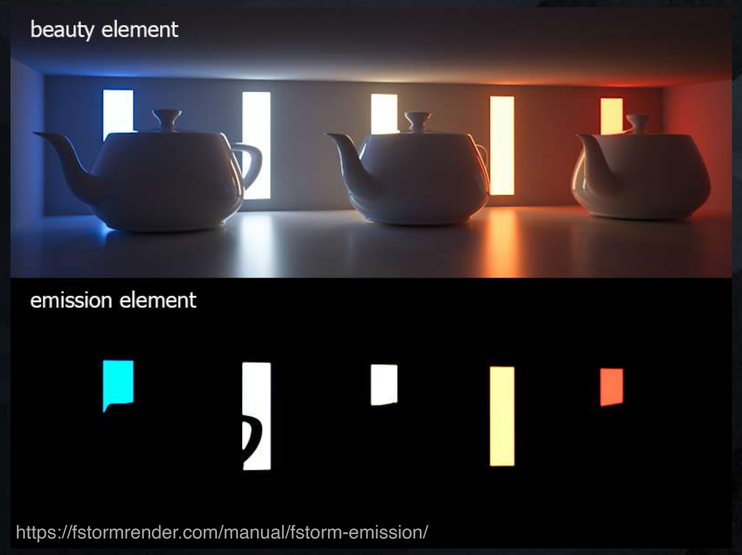
- Soft
- Flat
- Ambient
- Natural
- Rough
- Earthy
- Organic
- Matte
- Weathered
- Dull

Emission

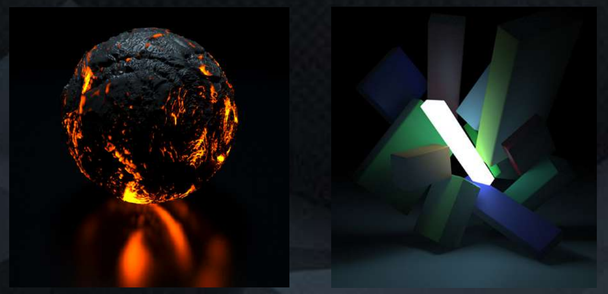
- Bright
- Radiant
- Luminescent
- Glowing
- Self-Illuminating
- Incandescent
- Electric
- Beaming
- Shining
- Luminous
- Illuminated

Lighting Concepts:
Emission

- Emission is any object, material, or texture that is actively emitting light into the scene
- This includes any Lights, Super-heated metals, or Elemental FX like fire/ sparks / lightning / magic etc



https://fstormrender.com/manual/fstorm-emission/



https://help.autodesk.com/view/ARNOL/ENU/?guid=arnold_user_guide_ac_legacy_standard_ac_legacy_emission_html

Star Wars: Force Awakens

Justice League - Snyder Cut 2021

Video by Seth Encina from Pexels

Photo by Kateryna Babaieva from Pexels

https://www.tiktok.com/@bcivicosplay/video/6917467909237378309

Tron: Legacy 2010

Lighting Concepts:
Emission

- Neon Lights, Screens, Monitors are all examples of real life Emission objects

Photo by Junior Teixeira from Pexels

Photo by Ricardo Esquivel from Pexels

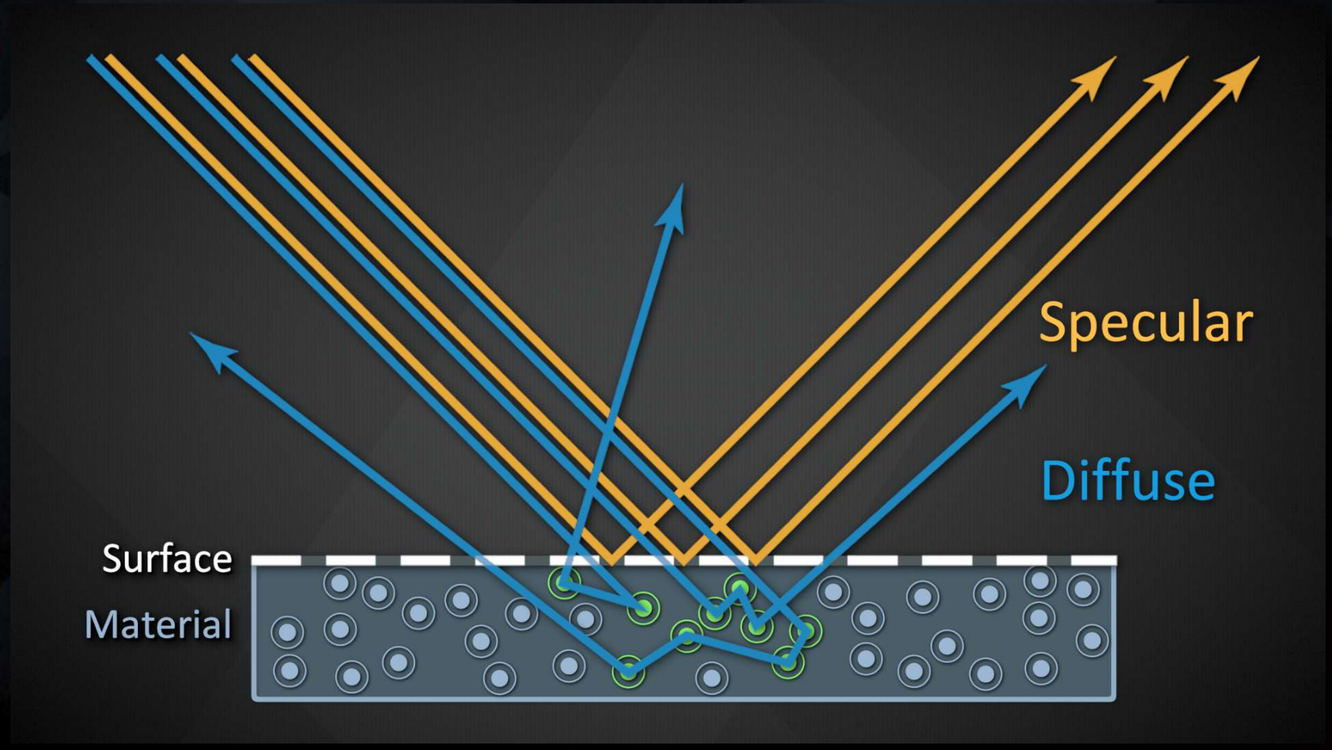
Video by C Technical from Pexels

Photo by Aleksandar Pasaric from Pexels

Lighting Concepts:

Specular | Diffuse

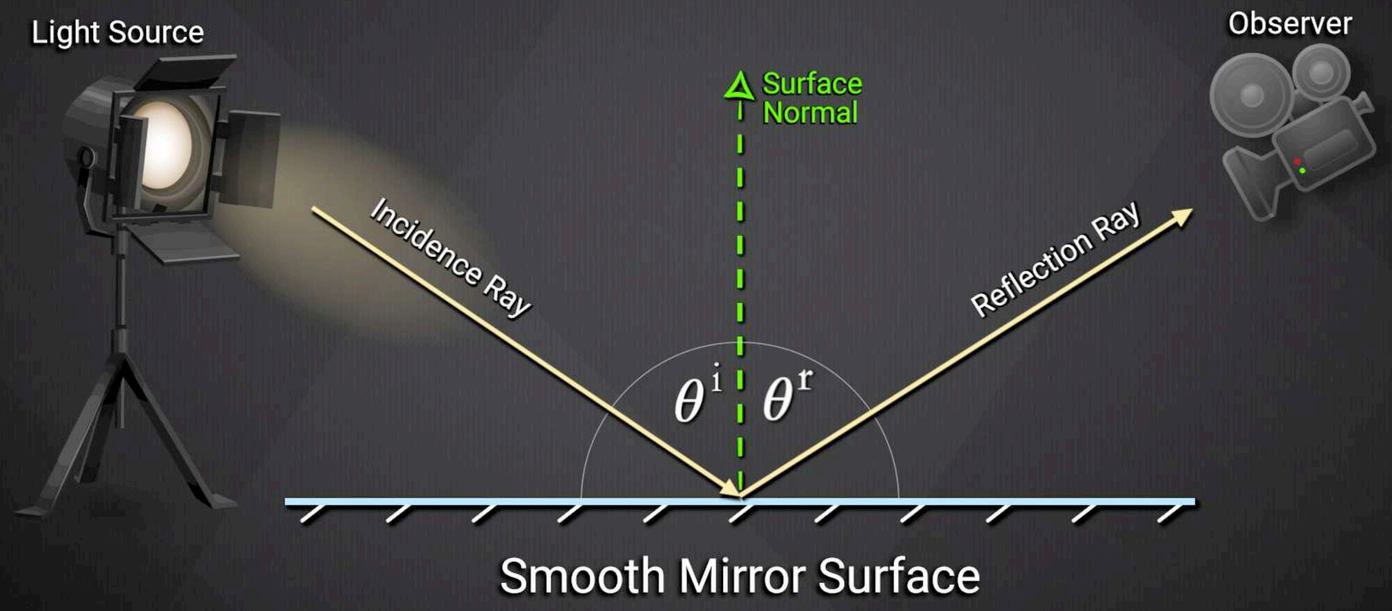
- Specular - Surface Level Reflections
- Diffuse - Light passes through surface and interacts with the material at a molecular level, Scattering and Absorption allow certain colors to re-exit and scatter into scene



Lighting Concepts:

Law of Reflection

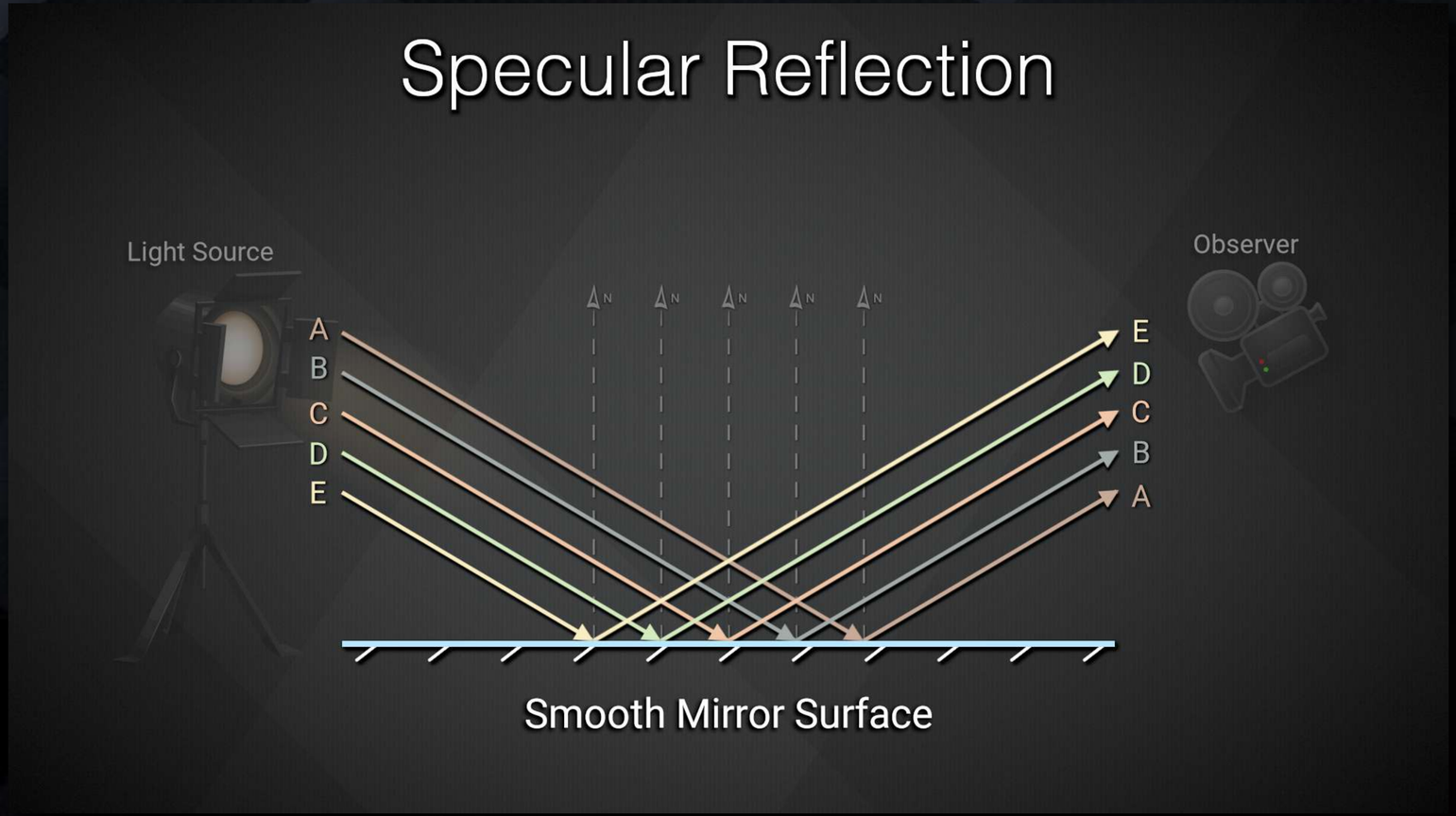
- Angle of Incidence is equal to the Angle of Reflection $\theta^{i} = \theta^{r}$



Lighting Concepts:

Surface Reflections - Smooth vs Rough Materials

- Light Beam = a bundle of parallel light rays
- Light Beam remains parallel on incidence and parallel on reflection



Lighting Concepts:
Planar Mirror and Virtual Image

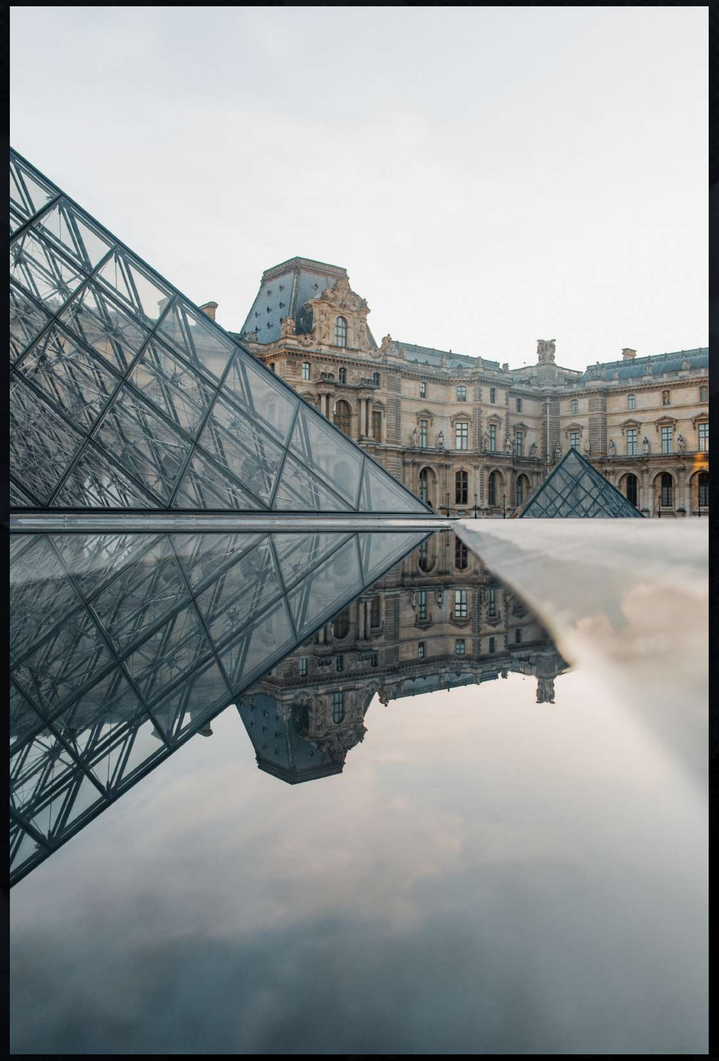


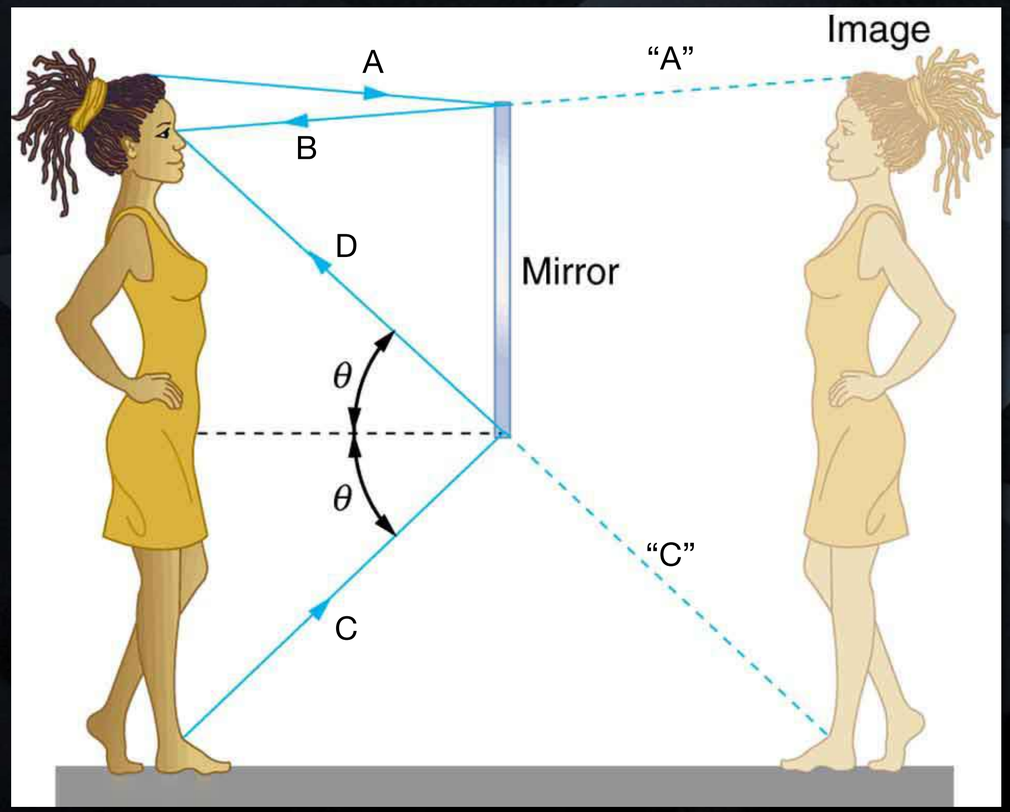
Photo by Max Avans from Pexels:
https://www.pexels.com/photo/glass-pyramids-in-louvre-museum-5088287/

Photo by Rachel Claire from Pexels:
https://www.pexels.com/photo/reflection-of-a-woman-in-white-dress-on-the-pool-water-5531606/

Photo by Alesia Kozik from Pexels:
https://www.pexels.com/photo/colored-glass-bottle-on-round-mirror-7796810/

Lighting Concepts:
Planar Mirror and Virtual Image

- An Image created by planar specular reflection that does not actually exist as a physical object is referred to as a Virtual Image.
- The Virtual Image appears to be located “behind” the mirror
- Virtual Image distance = Object to Mirror + Mirror to Observer.
- Speculum is the Latin word for “mirror”, which is where “Specular” derives from



https://pressbooks.bccampus.ca/introductorygeneralphysics2phys1207/chapter/25-2-the-law-of-reflection/

Photo by Lucas Pezeta from Pexels

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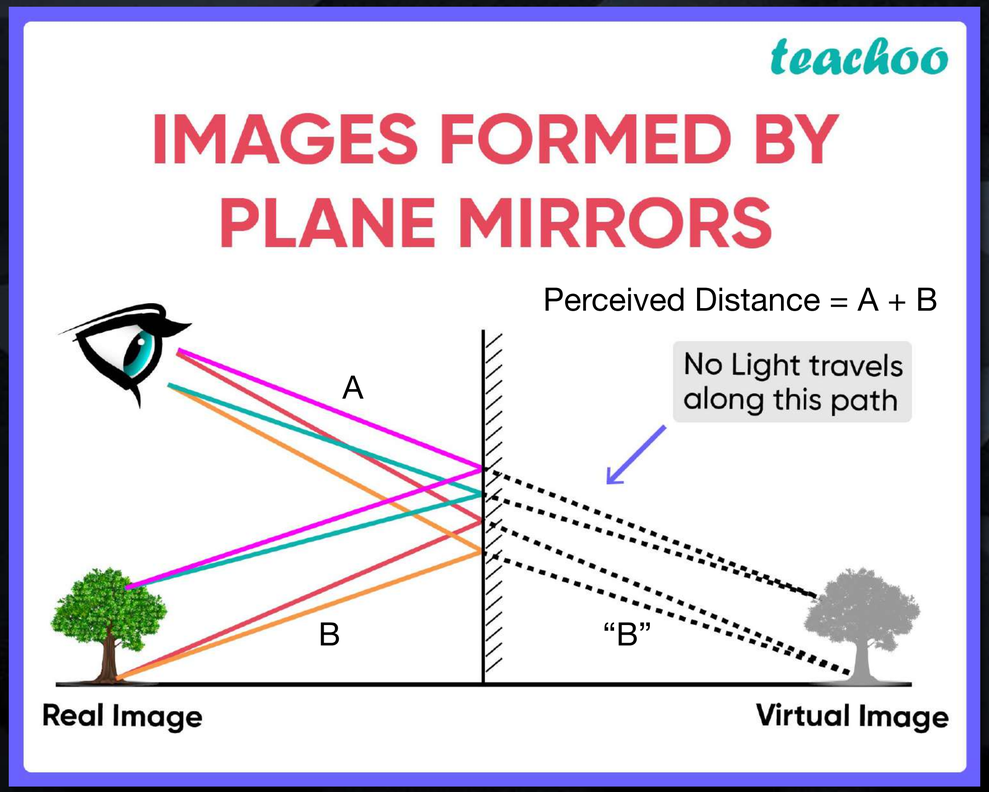

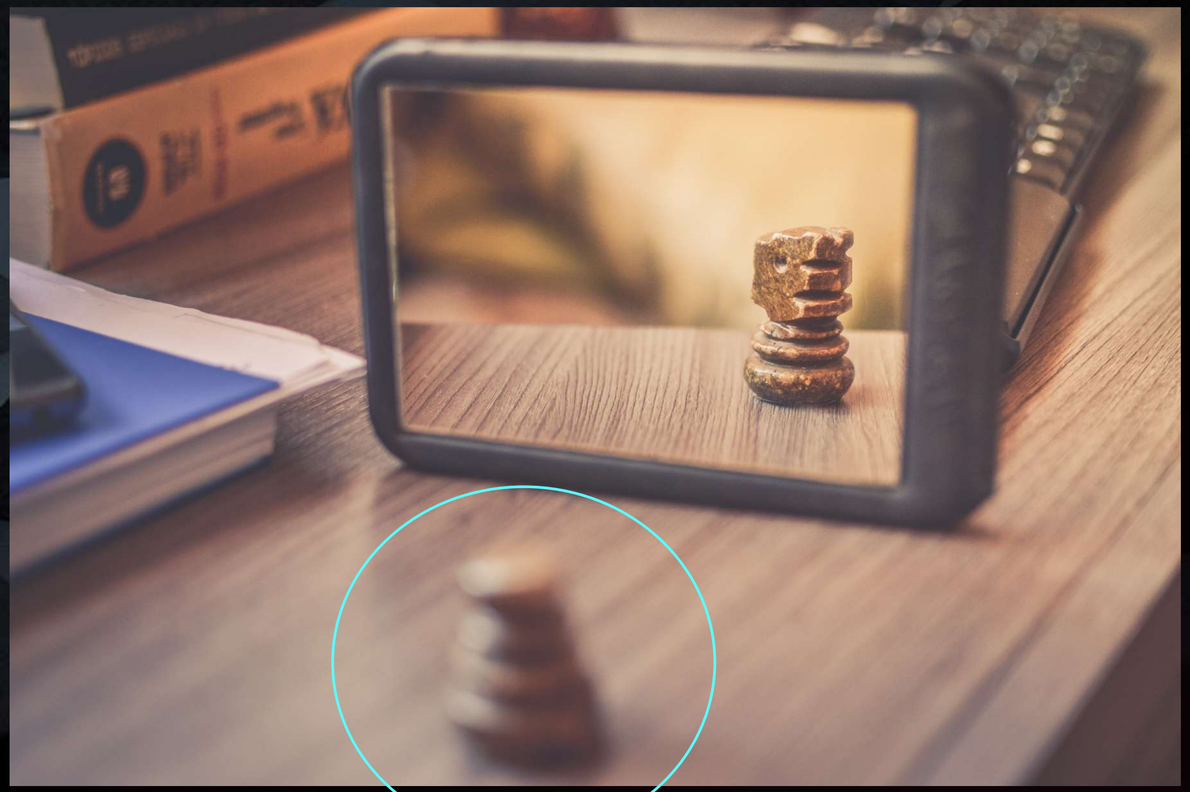

Photo by Caio from Pexels

Lighting Concepts:
Planar Mirror and Virtual Image

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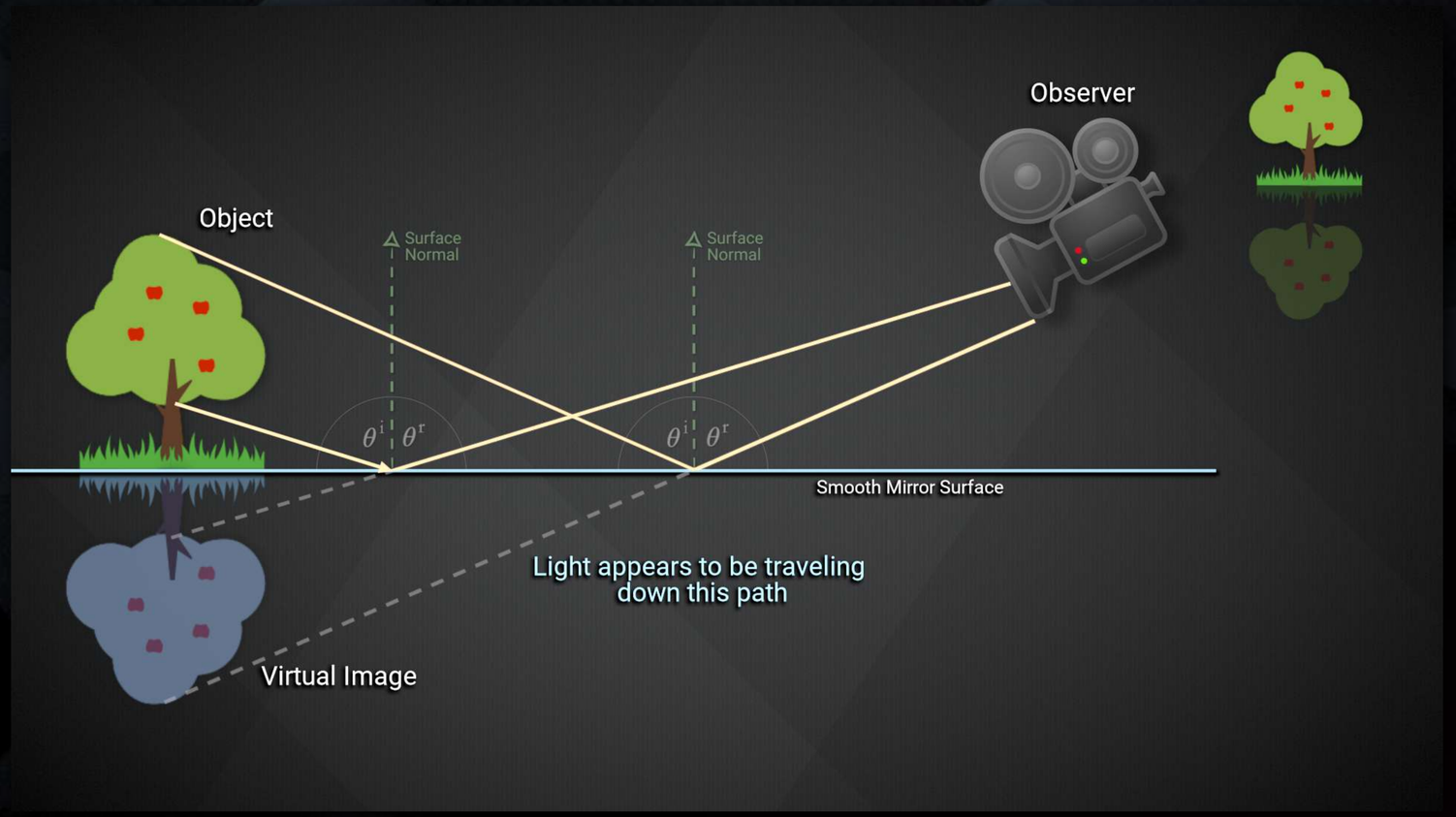
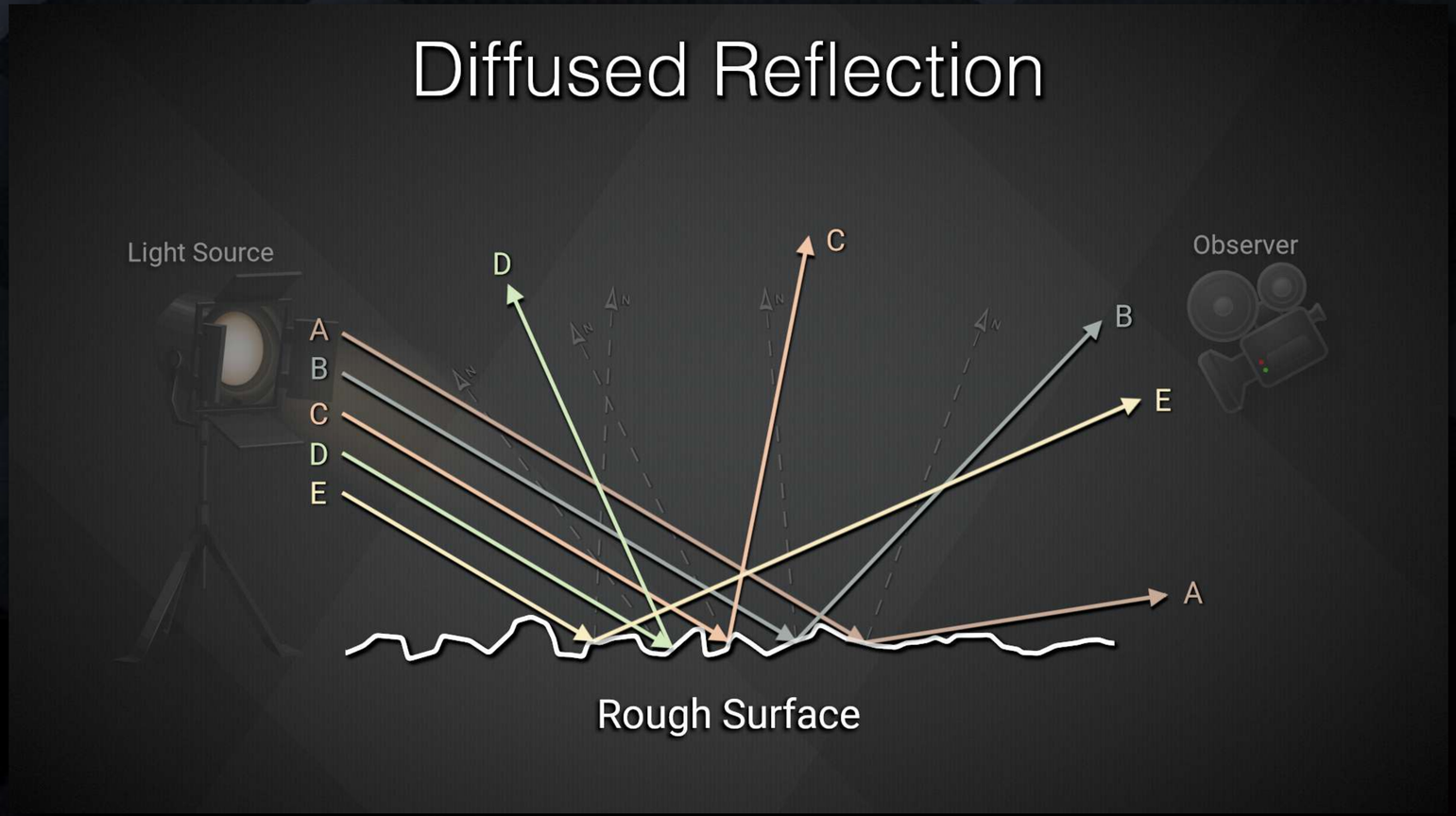


Lighting Concepts:

Surface Reflections - Smooth vs Rough Materials

- The uneven surface causes the Incidence Rays to hit at different angles
- The outgoing reflection rays scatter in different directions

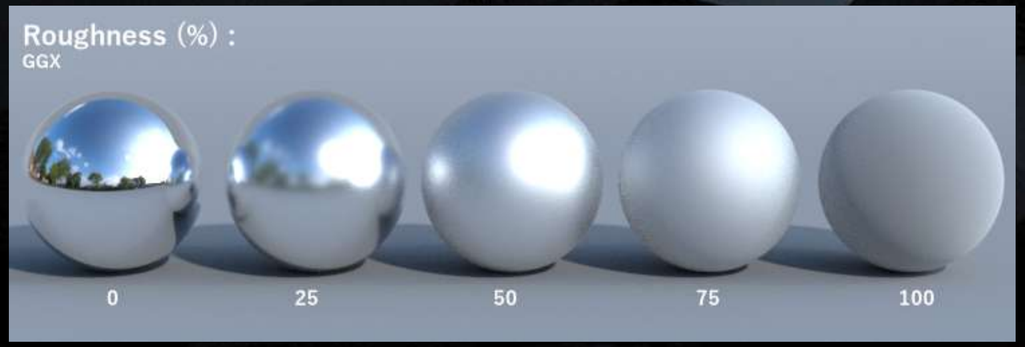


Lighting Concepts:

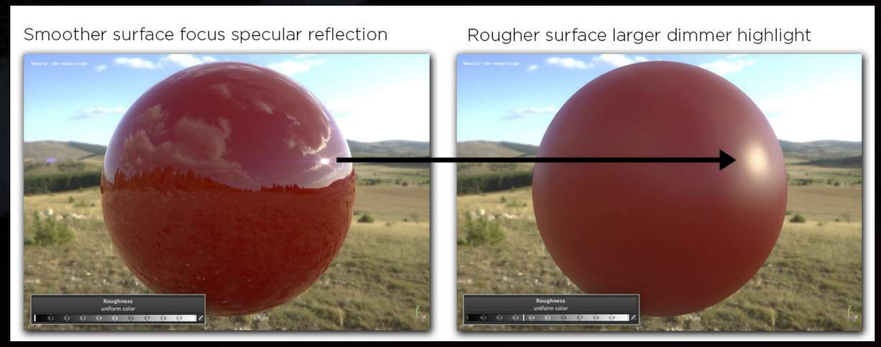
Law of Reflection

- Randomly displacing the vertices of a smooth reflective surface:

Lighting Concepts:
Surface Reflections - Smooth vs Rough Materials



https://clarissewiki.com/3.6/reflection2.html

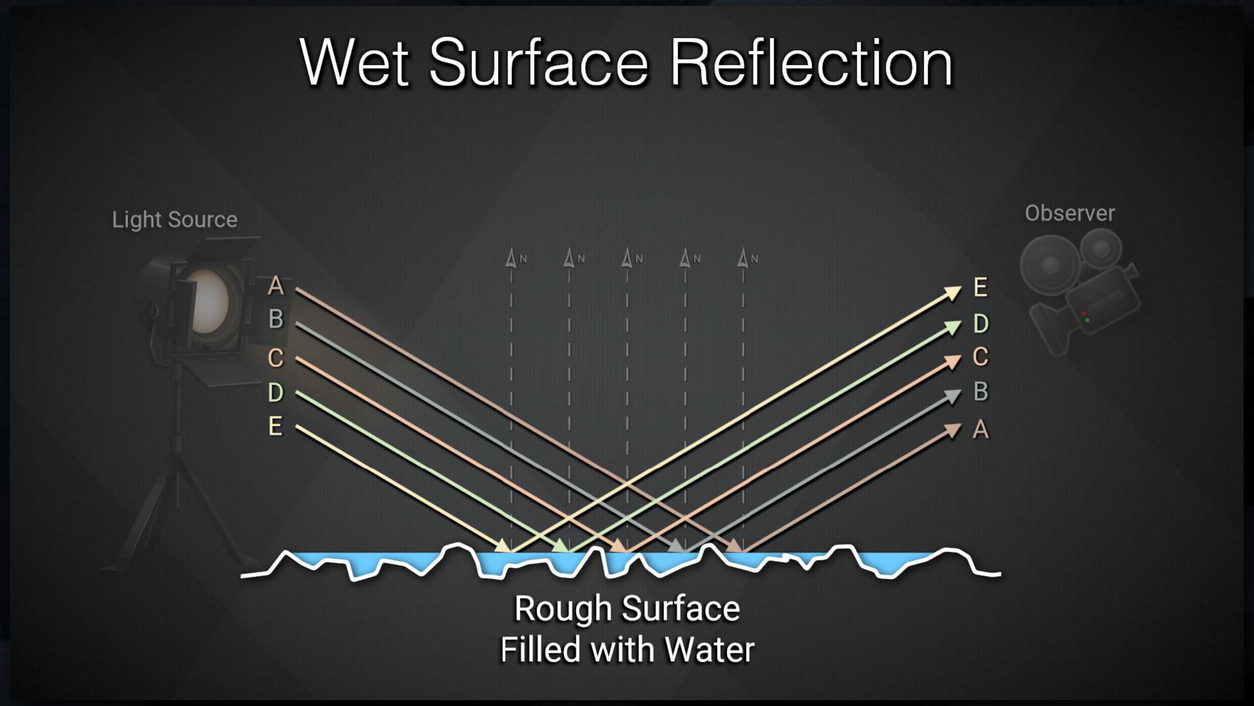


https://substance3d.adobe.com/tutorials/courses/the-pbr-guide-part-1

Lighting Concepts:

Surface Reflections - Smooth vs Rough Materials

- When a surface is wet, the water fills the gaps and flattens the surface and causes more a specular reflection

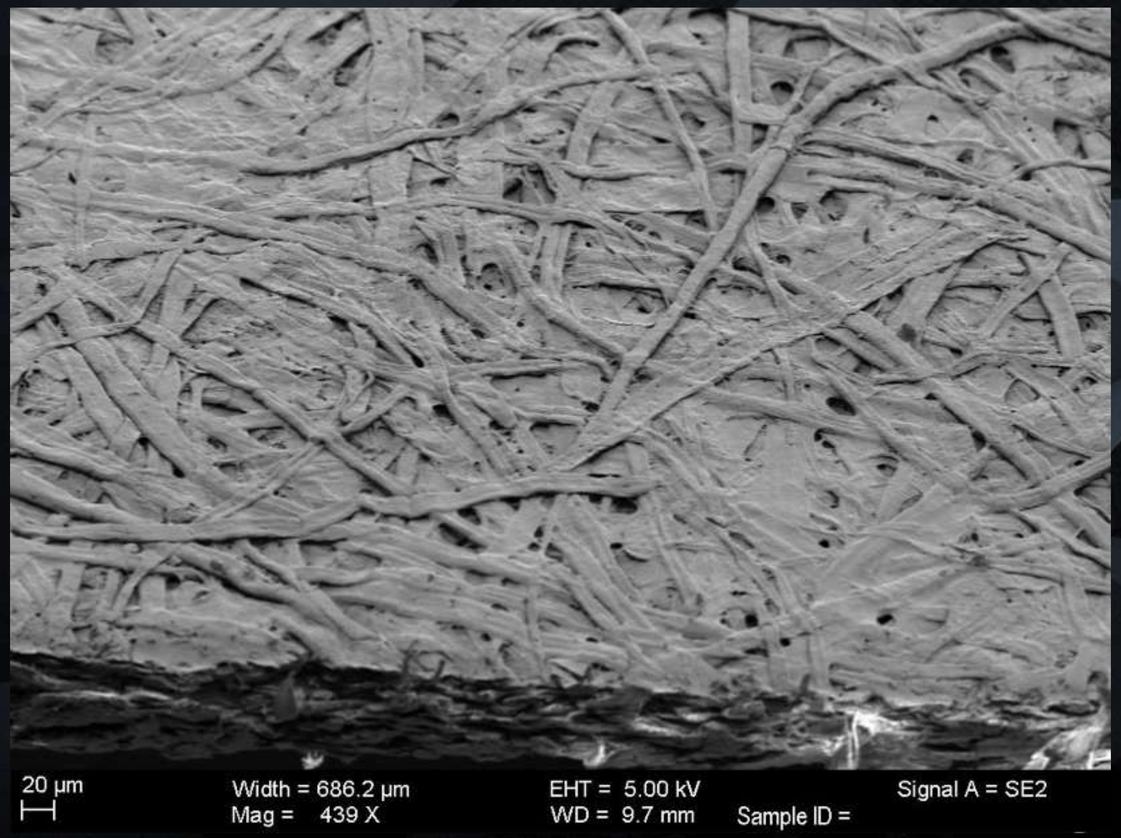


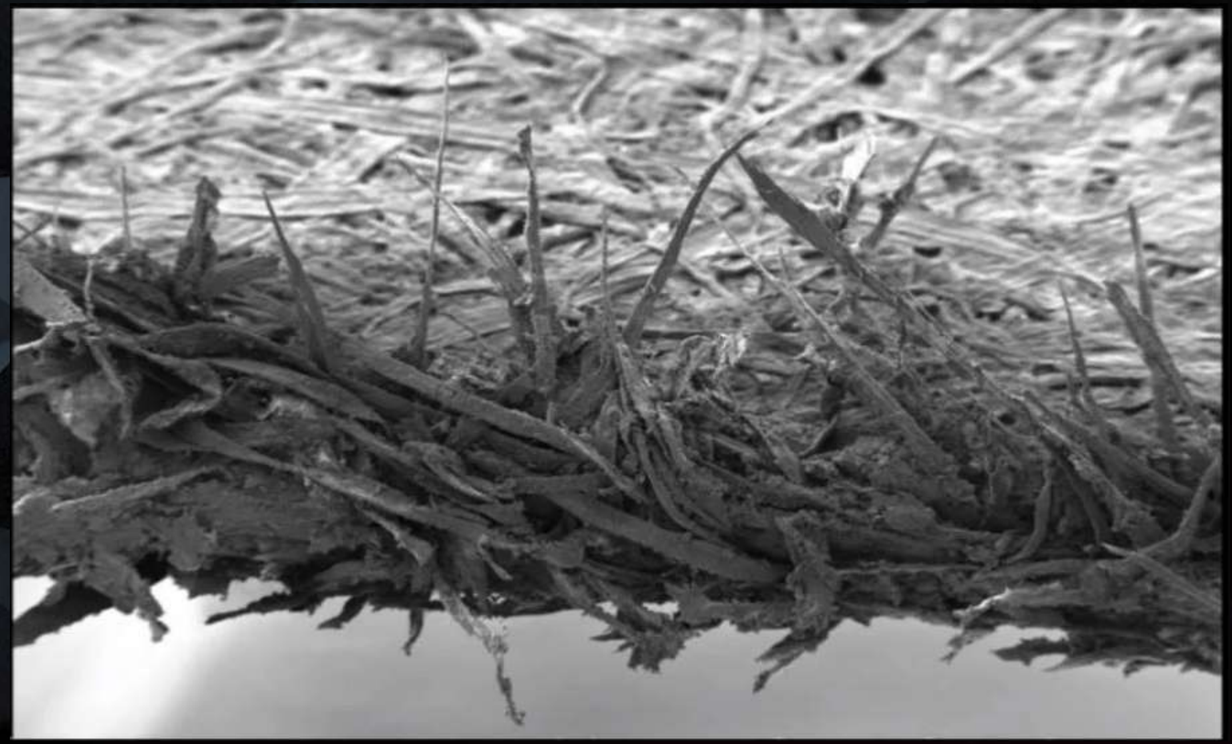
Lighting Concepts:

Surface Reflections - Smooth vs Rough Materials

- Roughness / Smoothness at a microscopic level.

This a regular piece of paper surface zoomed in:

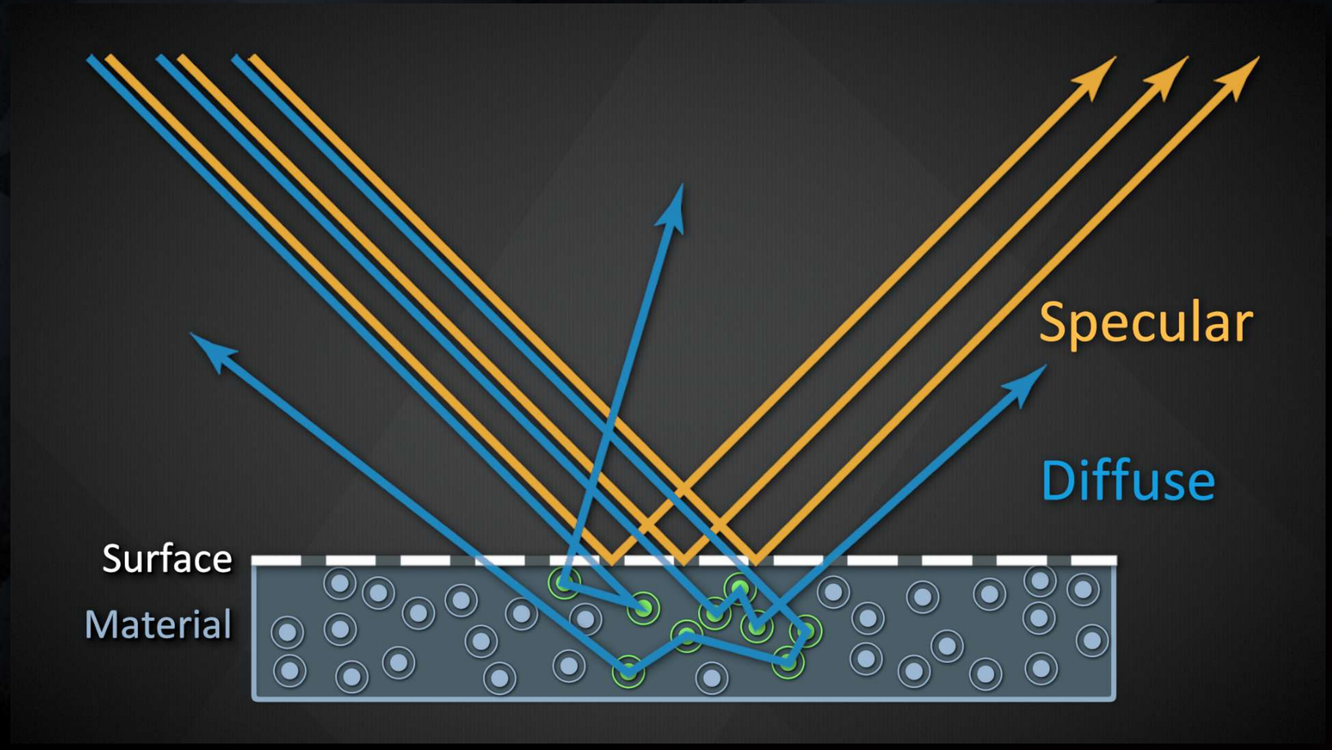




Lighting Concepts:

Specular | Diffuse

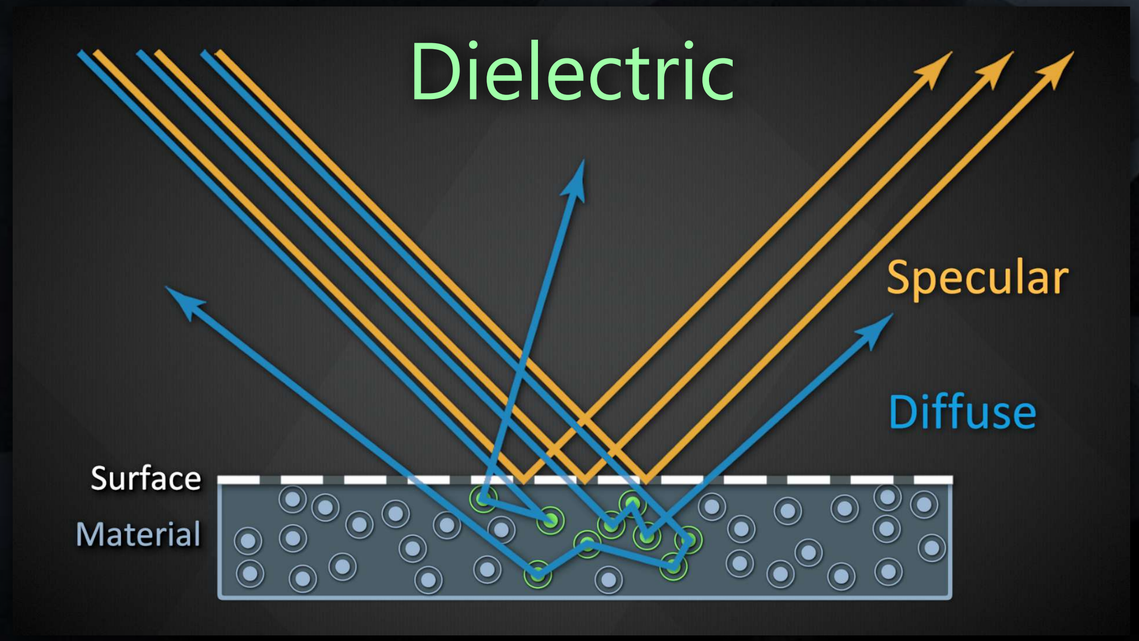
- Specular - Surface Level Reflections
- Diffuse - Light passes through surface and interacts with the material at a molecular level, Scattering and Absorption allow certain colors to re-exit and scatter into scene

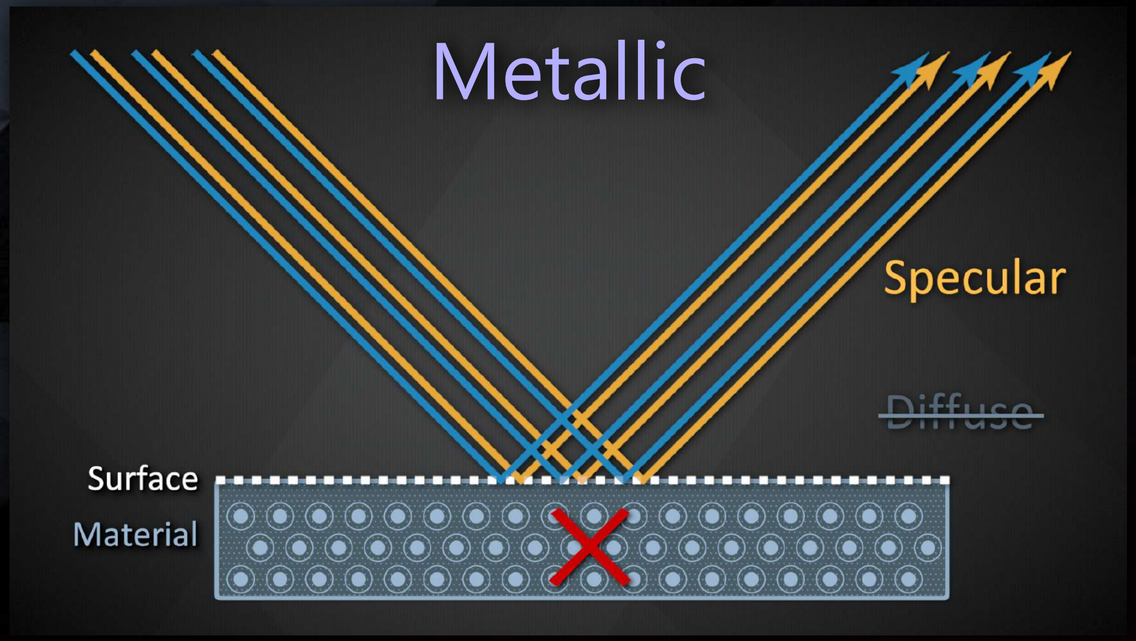


Lighting Concepts:
Metallic | Dielectric
(Non-Metallic)

The diffuse and specular terms describe two distinct effects going on. The Light interacts with materials differently depending on if the material is a metal, or a non-metal (Dielectric)

- **Dielectric** - Absorbs and Scatters light.
- **Metallic** - Does not Absorb light. Only Reflects

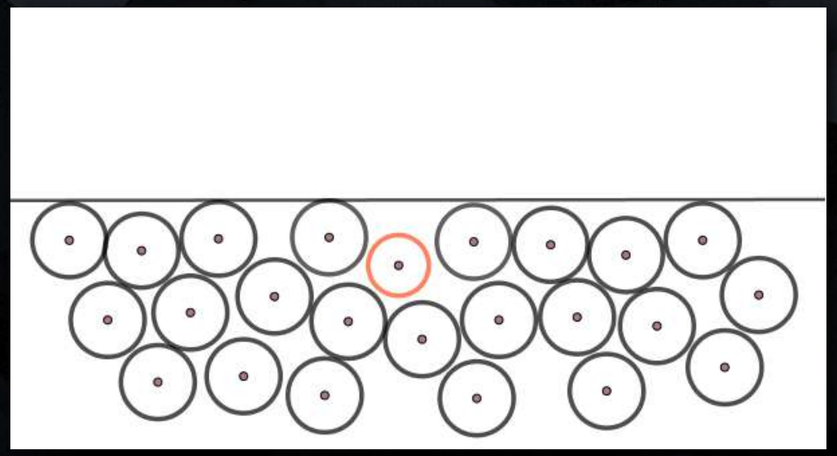




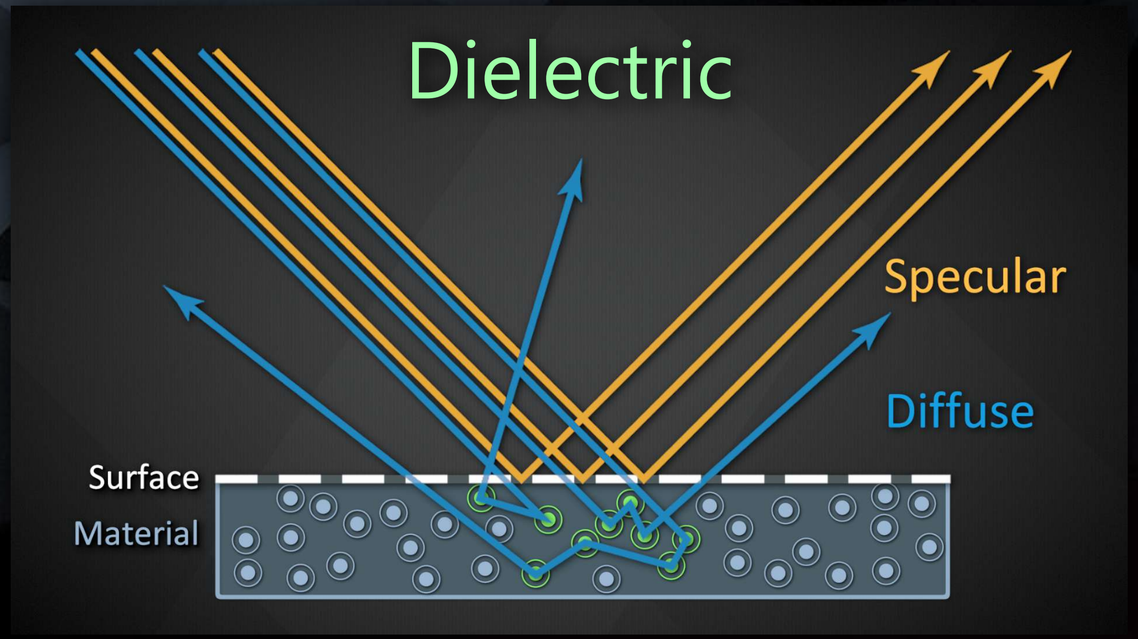
Lighting Concepts:
Dielectric (Non-Metallic)

- Light penetrates the surface level and the molecules of the material absorb and scatter the light within
- The light photons excite the atoms they hit below the surface. Some of the light is absorbed, and this energy is converted to heat. Then new light rays (photons) are emitted from the excited atoms. Those might excite nearby atoms or exit the surface as new photons. These new photons are same color as our material.
- The Base Color Texture (Albedo Map) - determines the color of the diffusely scattered photons from excited atoms. It's the color that is scattered back out and not absorbed by the material

Photons excite atoms which emit new photons and excite nearby atoms. This the "scattering" process



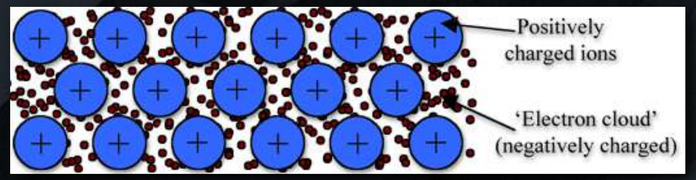
https://cglearn.eu/pub/advanced-computer-graphics/physically-based-shading



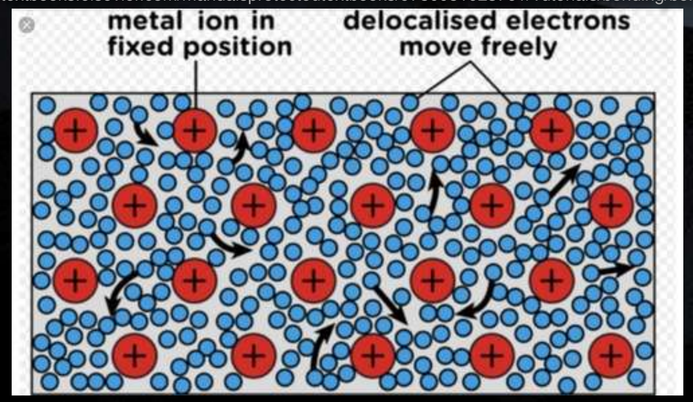
Lighting Concepts:
Metallic

- Does not Allow light to penetrate the surface and does not Absorb light. They only Reflect light on the surface
- Metals can be thought of as positively charged ions suspended in a “sea of electrons” or “electron gas”. Attractions hold electrons near the ions, but not so tightly as to impede the electrons flow. This explains many of the properties of metals, like conductivity of heat and electricity
- The incoming photon does not excite the atoms, but bounces directly off the electron gas
- The Base Color (Albedo) is used to describe the color tint of the specular reflection

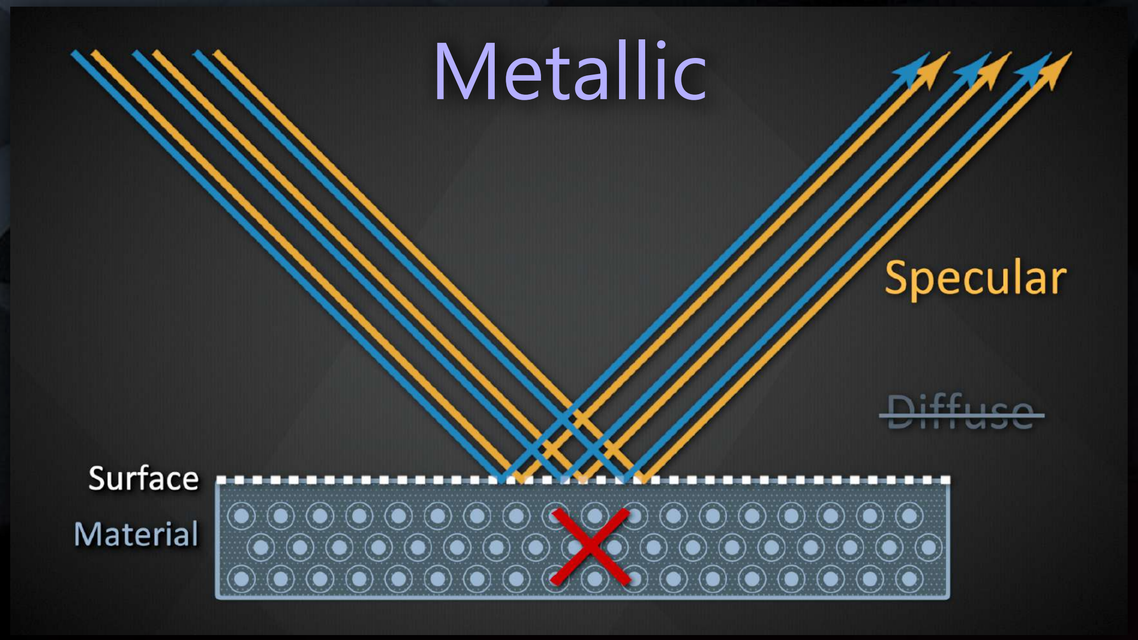
“Electron Gas” Model



https://textbooks.elsevier.com/manualsprotectedtextbooks/9780081023761/Tutorials/bonding/bonding2f.htm



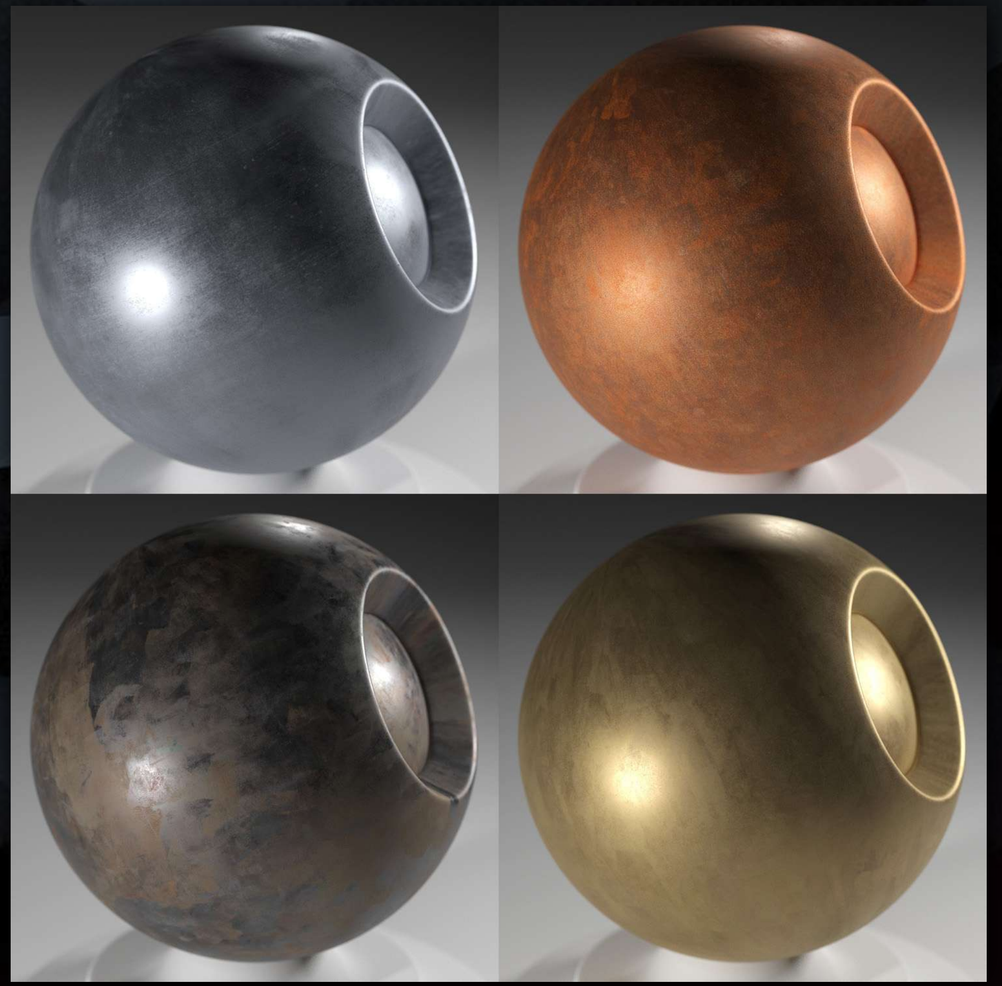
http://www.mstworkbooks.co.za/natural-sciences/gr8/gr8-ec-03.html



Lighting Concepts:

Metallic | Dielectric
(Non-Metallic)

https://cglearn.eu/pub/advanced-computer-graphics/physically-based-shading

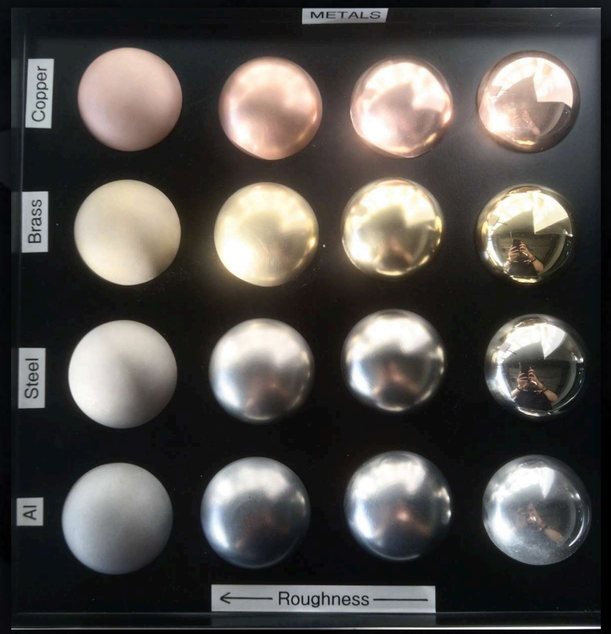


https://store.chocofur.com/free-metal-shaders/blender_model/blender-3d-cycles-shaders-materials-free-metal-steel

Lighting Concepts:

Metallic | Dielectric
(Non-Metallic)

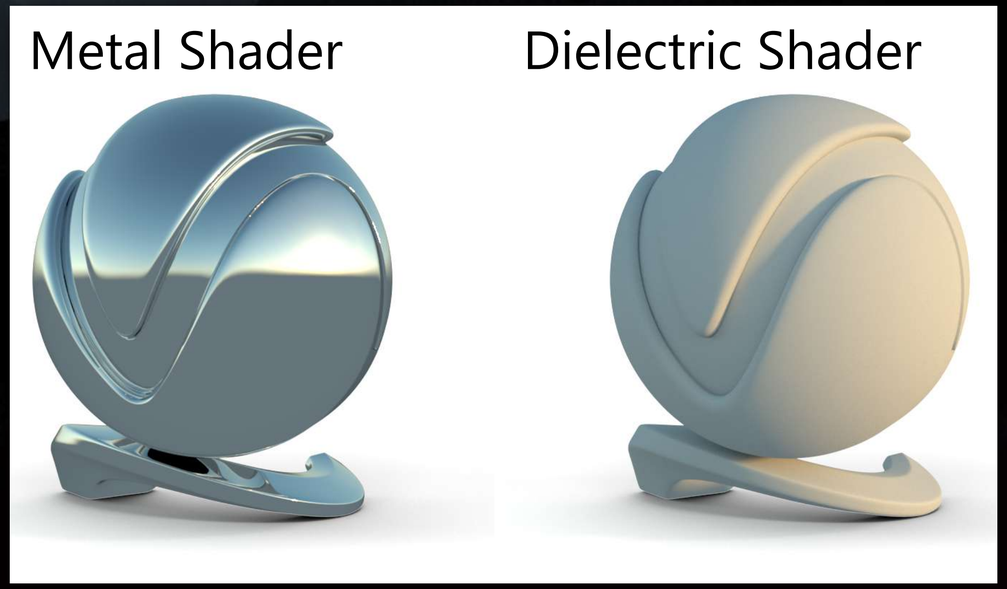
- **Metallic** - Does not Absorb light. Base Color (Albedo) tints the Specular Reflection
- **Dielectric** - Absorbs and Scatters light. Base Color describes which light wavelength is allowed to scatter off the material into the scene, the color not absorbed



https://cglearn.eu/pub/advanced-computer-graphics/physically-based-shading

Metals

Dielectrics



https://docs.chaos.com/display/VMAYA/VRaySky

Lighting Concepts:

Metallic | Dielectric
(Non-Metallic)

Metals

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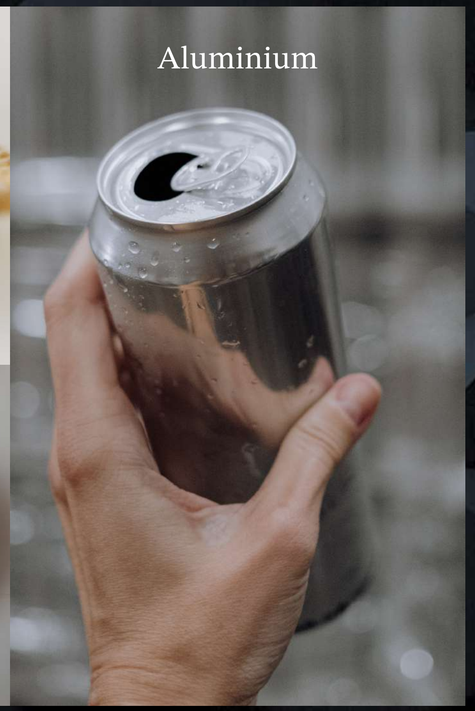

Photo by CottonBro Studio from Pexels

Dielectrics

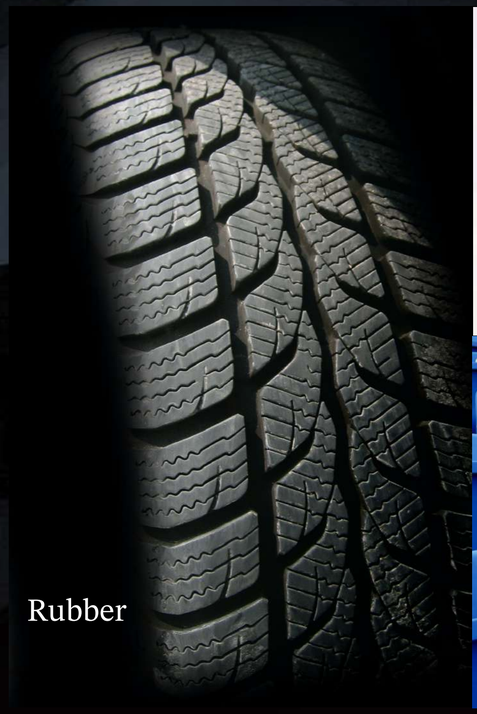

Photo by Gerd Altmann from Pexels

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Photo by Pixabay from Pexels

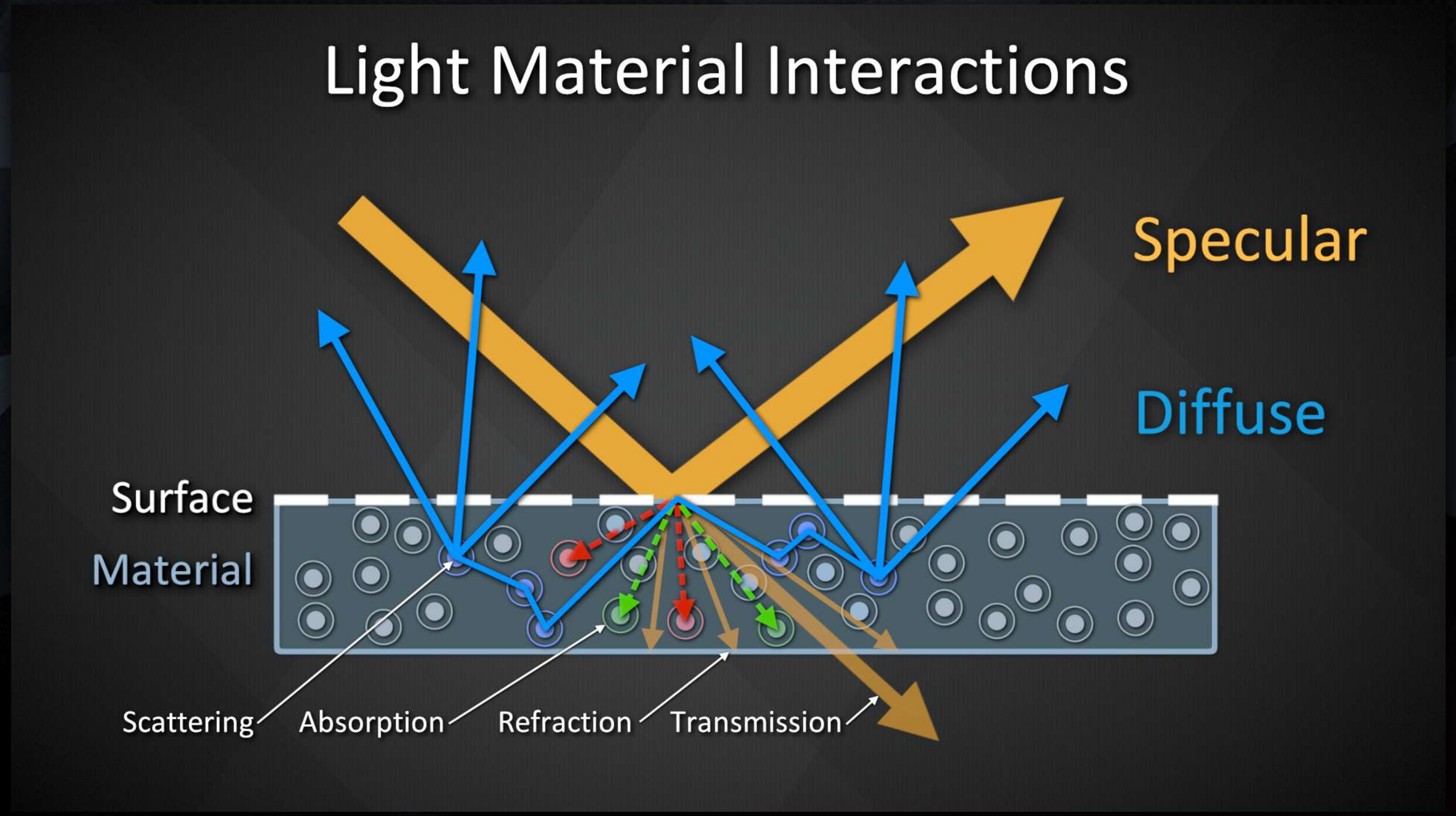
Lighting Concepts:
Chrome Sphere and Diffuse Ball

- Used as a reference to see what something 100% Smooth and Metal (Specular) and 100% Rough and Dielectric (Diffuse) looks like in the scene.

DAIWTONG824@OUTLOOK.COM

https://vfxsuperstore.com/products/10-50-50-chrome-and-grey-vfx-ball

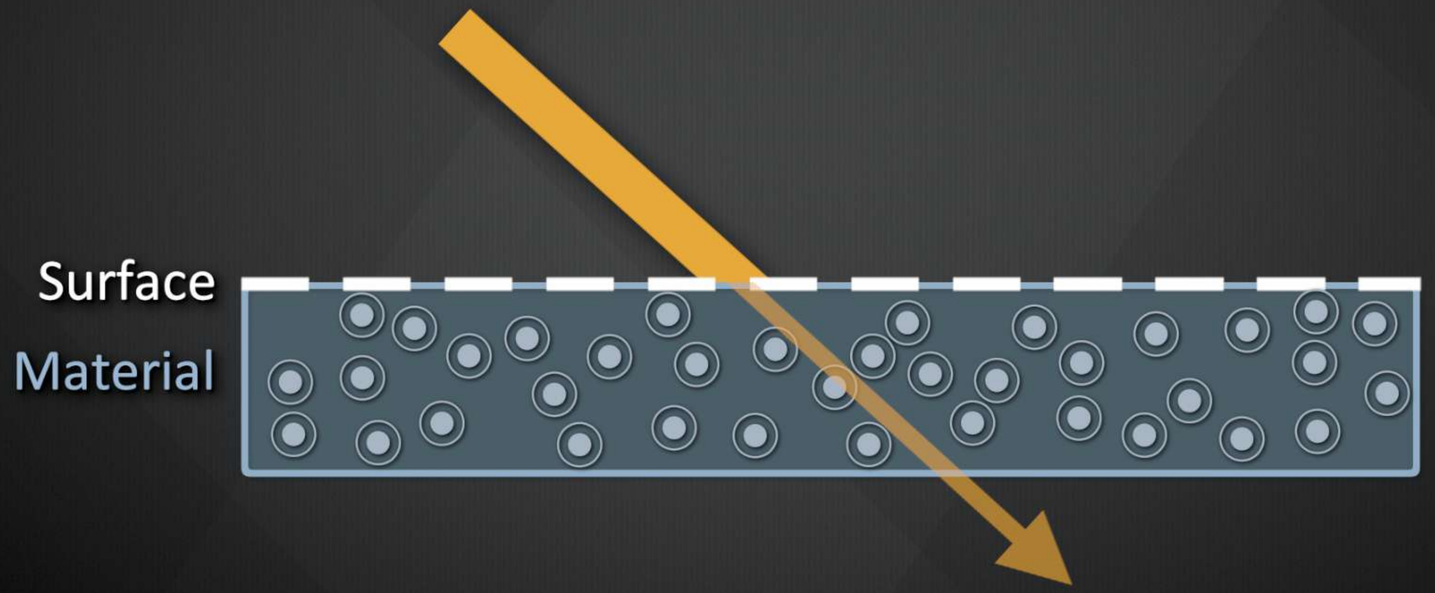
Lighting Concepts:
Diffuse



Lighting Concepts:
Diffuse

Light Material Interactions

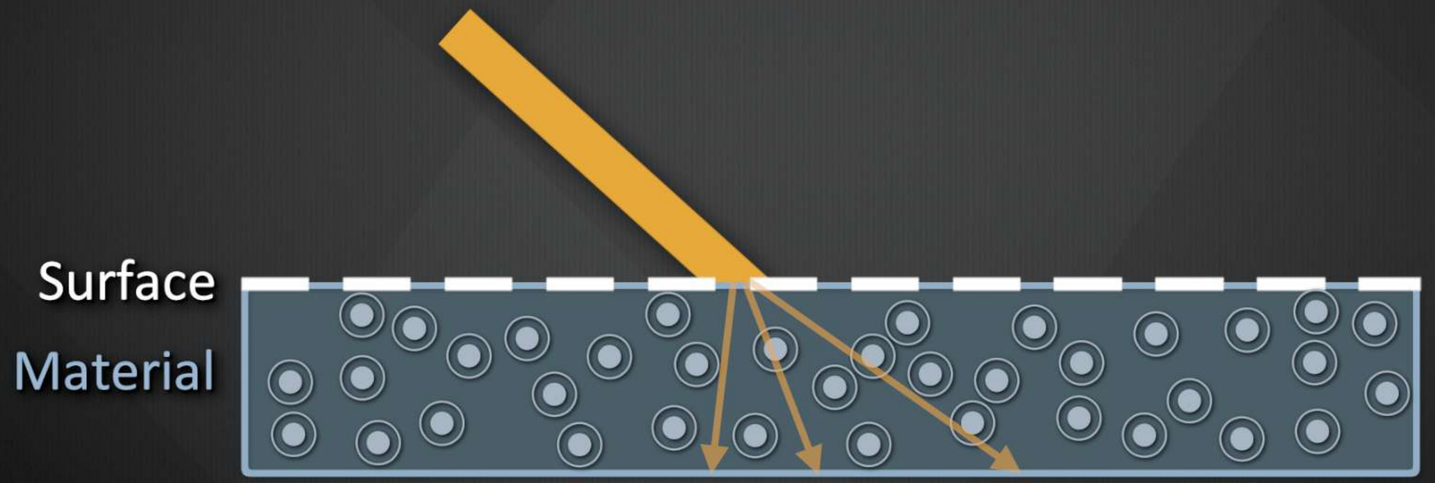
Transmission - Light Passing through a material / surface
- Transparency



Lighting Concepts:
Diffuse

Light Material Interactions

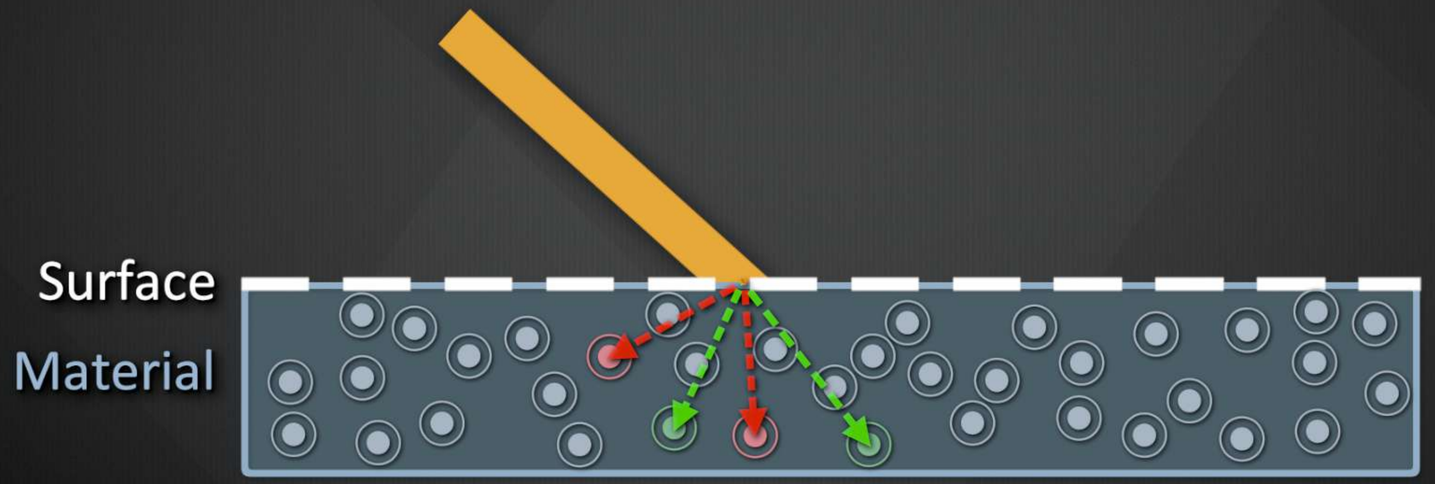
Refraction - When light changes direction as it goes through different materials



Lighting Concepts:
Diffuse

Light Material Interactions

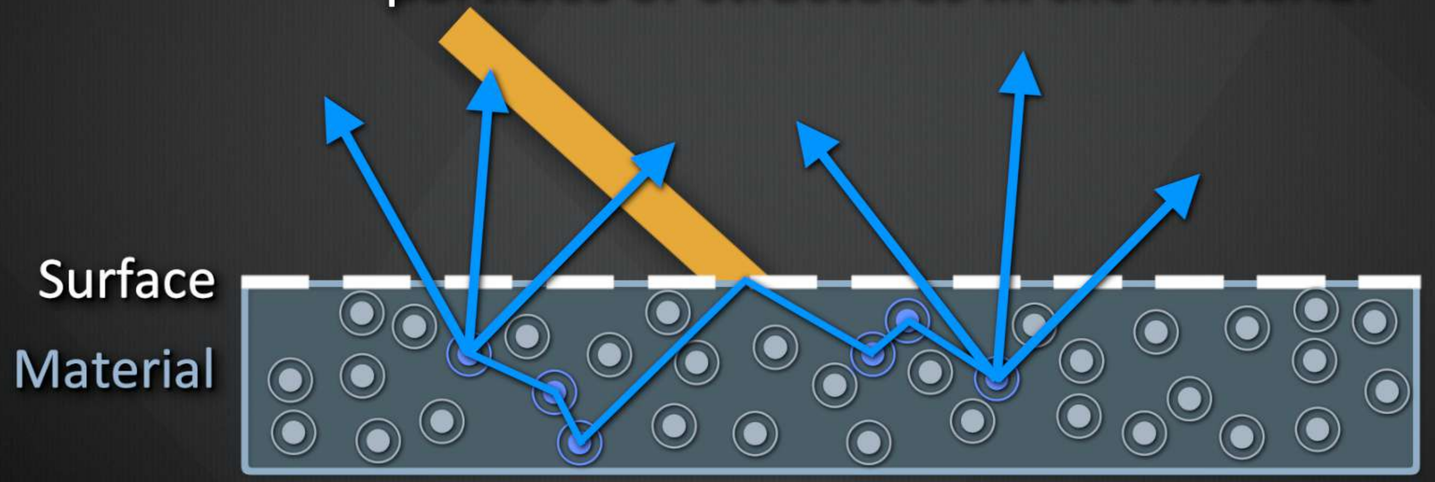
Absorption - When certain wavelength colors of light get absorbed by the material



Lighting Concepts:
Diffuse

Light Material Interactions

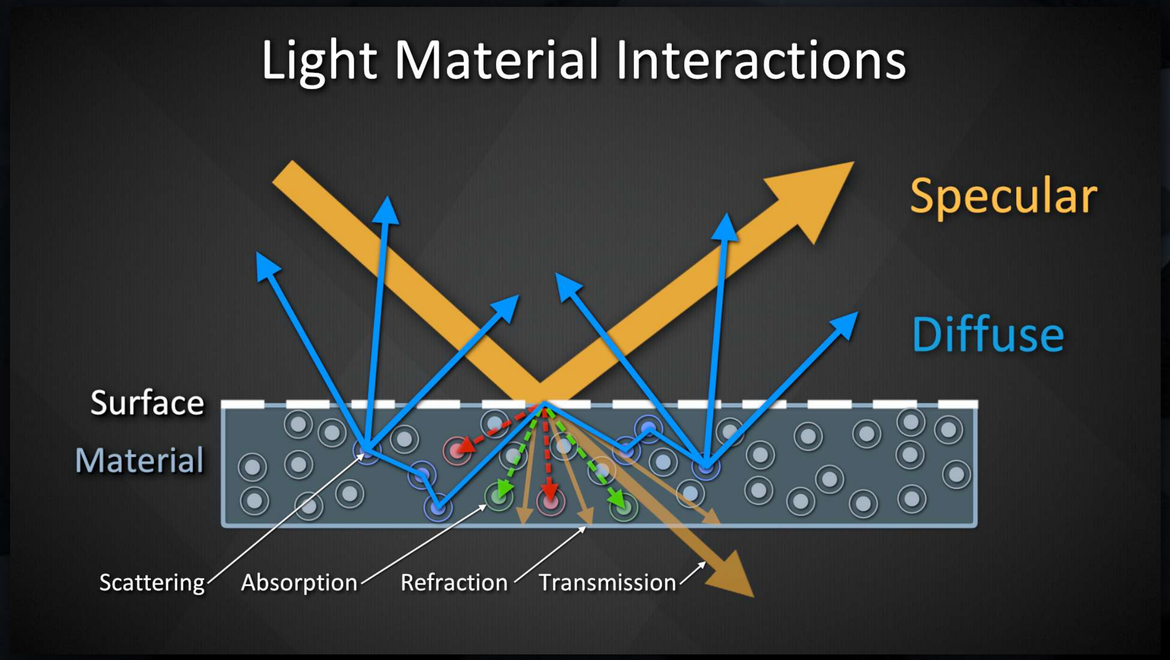
Scattering - When light is dispersed in many directions when it comes into contact with small particles or structures in the material

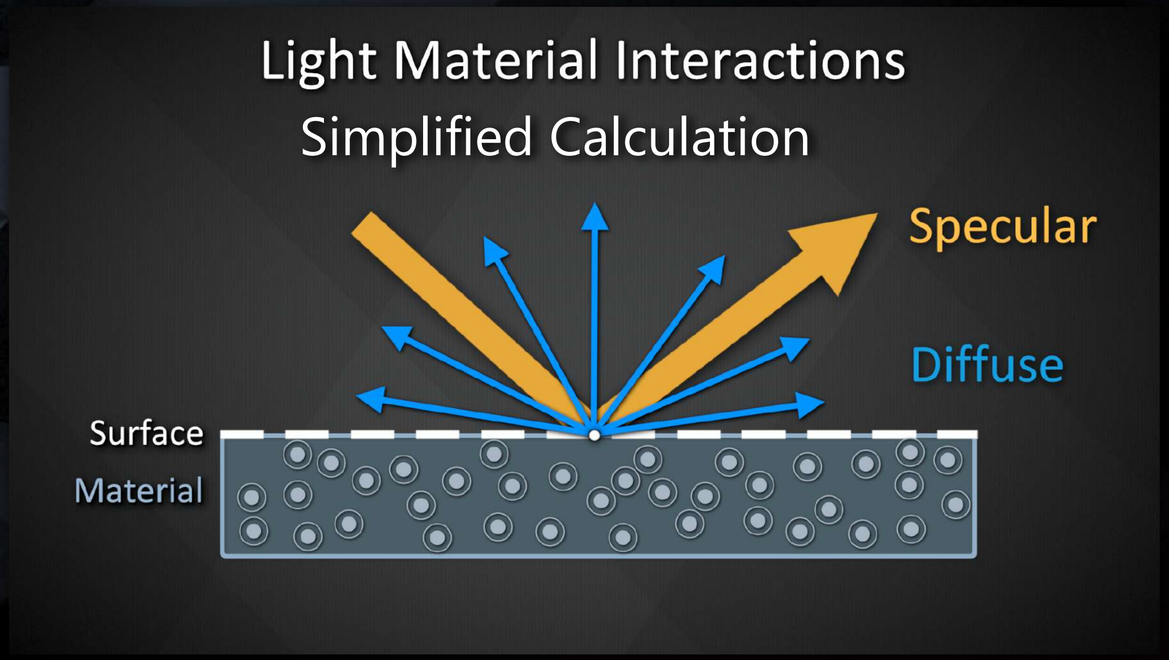


Lighting Concepts:

Specular | Diffuse

- When the distance that light travels beneath the surface is insignificant and negligible, the calculation can be simplified by the renderer and just calculated at the surface point where the light hits. It uses the Base Color Texture (Albedo) as the Diffuse Color that will scatter.





Lighting Concepts:

Diffuse | Sub Surface Scattering (SSS)

- When the distance the light travels beneath the surface of the material is significant, the interior scattering must be calculated. This is referred to as Sub Surface Scattering (SSS)

Photo by Brett Sayles from Pexels

Photo by Marc Winter from Pexels

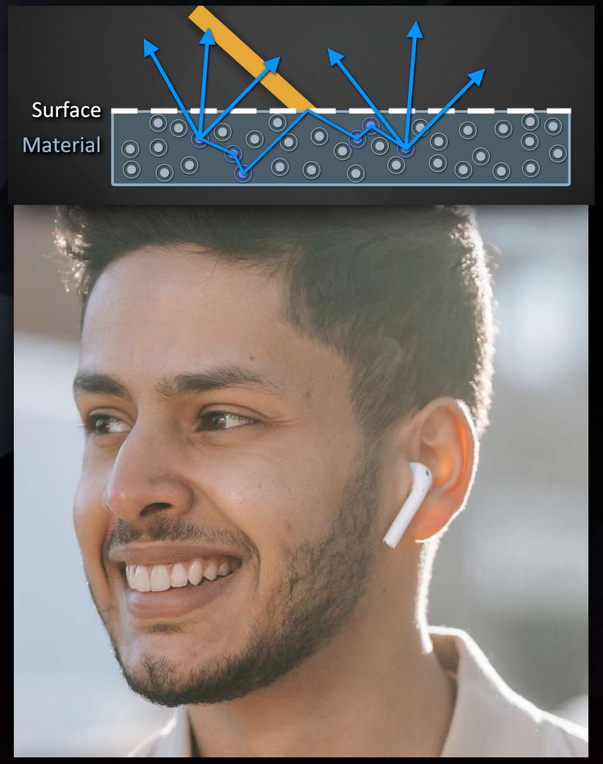


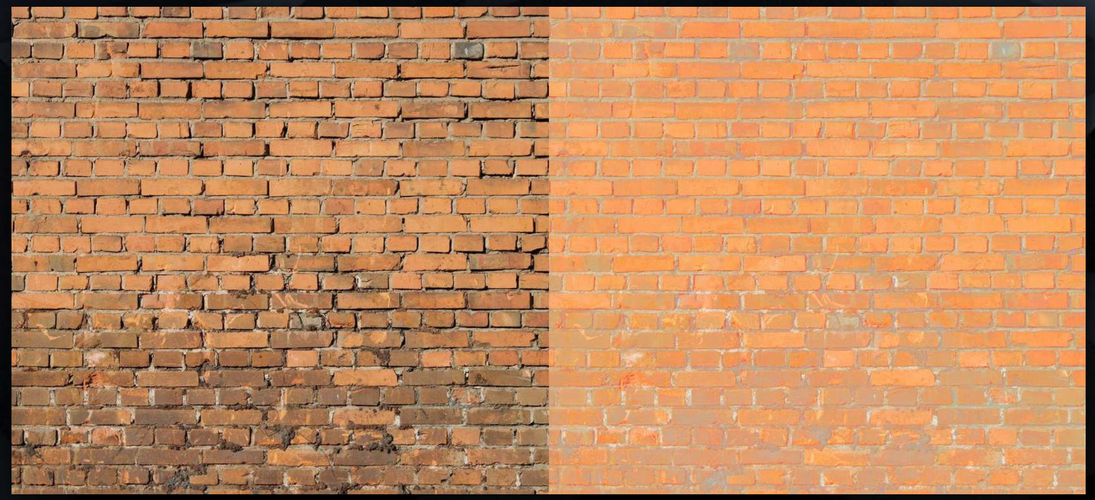
Photo by Michael Burrows from Pexels

Lighting Concepts:

Physical Based Rendering Terminology

Albedo - Base Color Texture Map

- On Dielectrics (non-metal) refers to color of material
- On Metals, refers to the color tint of the specular reflection
- Texture map is without highlights, shadows, or ambient occlusion



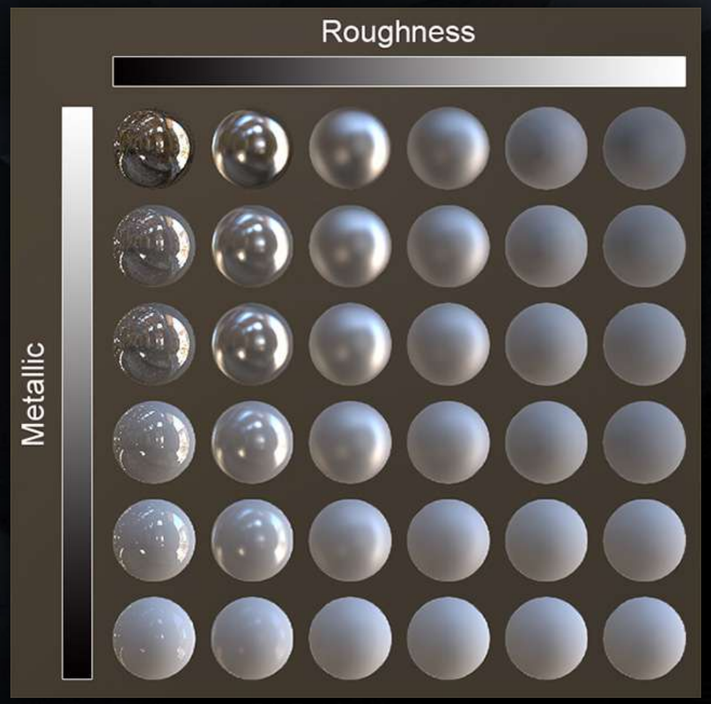
https://3dcoat.com/forum/index.php?/topic/26168-what-is-an-albedo-map-and-how-to-use-it-by-alex-glawion/

https://www.artstation.com/blogs/luismesquita/jGXd/everything-about-pbr-textures-and-a-little-more-part-2

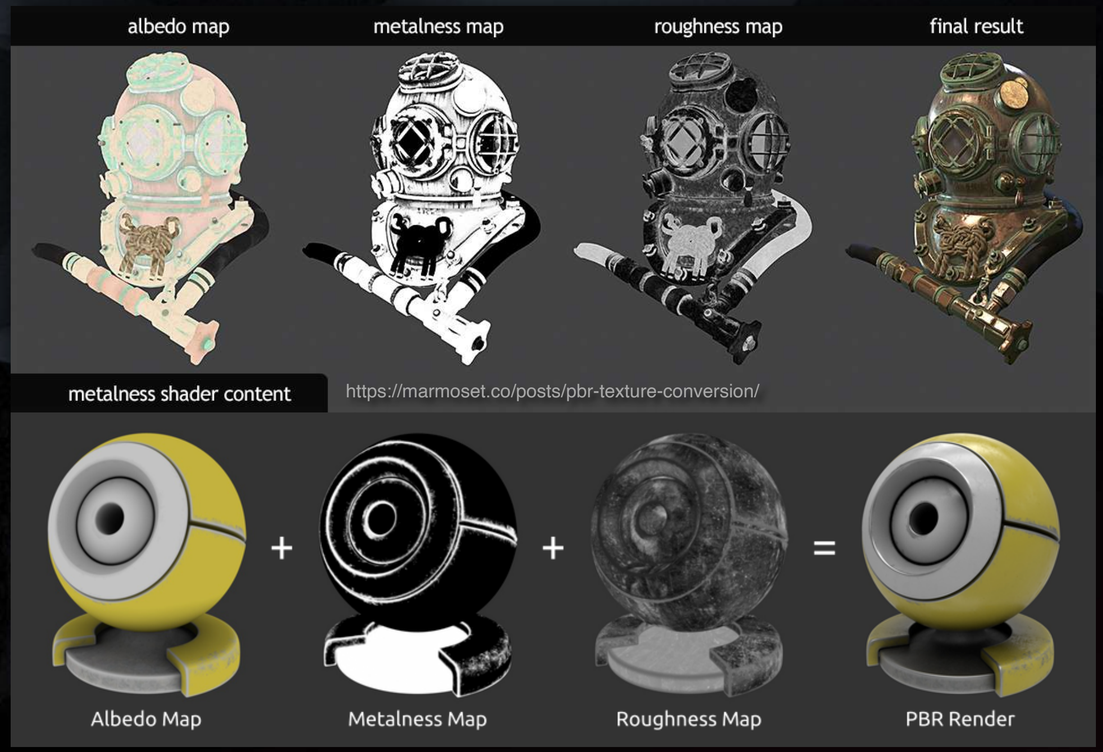
Lighting Concepts:

Physical Based Rendering Terminology

- Albedo - Base Color Texture. On Dielectric (non-metal) refers to color of material, on Metals, refers to the color tint of the specular reflection.
- Metalness - What area is metallic or not. (will use Albedo Color differently). Usually Black or White
- Roughness (Glossiness) - How blurry or how sharp the reflection will be



https://forum.reallusion.com/PrintTopic309180.aspx

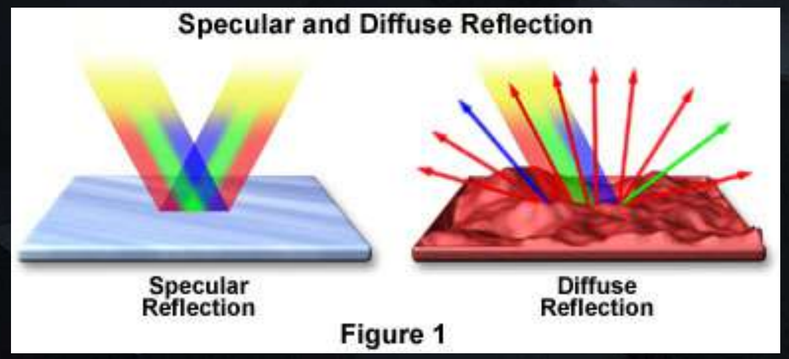


https://meshlogic.github.io/posts/blender/materials/nodes-pbr-basic-shader/

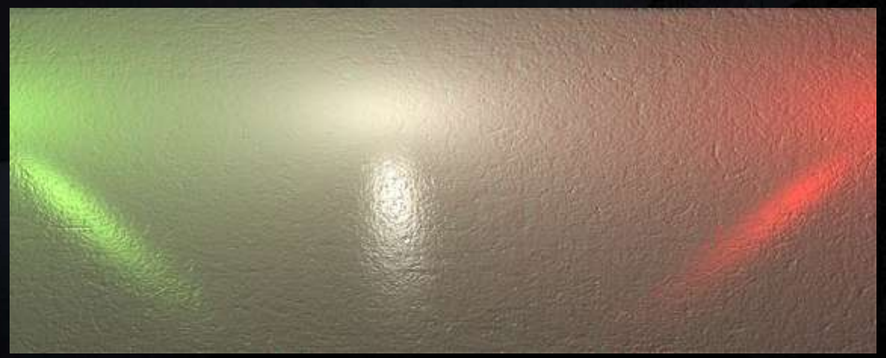
Lighting Concepts:

Specular vs Diffuse

- Real life objects and materials often have both Specular and Diffuse components



https://www.olympus-lifescience.com/en/microscope-resource/primer/java/reflection/specular/



https://forum.unity.com/threads/specular-color-based-on-light-color.134412/
User: TwiiK

Photo by Tima Miroshnichenko from Pexels

Lighting Concepts:

Iridescence

- There is also Iridescent materials that change specular color depending on viewing angle.
- Iridescence is a kind of structural coloration due to wave interference of light in microstructures or thin films.

https://commons.wikimedia.org/wiki/File:Dieselrainbow.jpg

Photo by Kindel Media from Pexels

Photo by Darina Belonogova from Pexels

https://commons.wikimedia.org/wiki/File:Soap_Bubble_-_foliage_background_-_iridescent_colours_-_Traquair_040801.jpg

Photo by Laura Paredis from Pexels

Photo by Egor Kamelev from Pexels

Lighting Concepts:

Specular | Diffuse | Emission

Recap

- Emission / Illumination materials emit light
- Specular and Diffuse can be separated by Surface Level Reflections and below surface Material Interactions
- Each individual light ray follows the Law of Reflection.
- The smoother a surface is, the more mirror-like the specular reflection will be.
- The roughness of a surface will cause the reflected rays to scatter, and reflection to be blurred.
- Metallic materials do not allow light to enter the surface. They only reflect light
- Dielectric materials allow light to enter the surface. Light rays are refracted, absorbed, scattered by the materials molecules. Certain color wavelengths re-exit the surface in random directions, which is what we perceive as the materials color
- Albedo - Base Color Texture. On Dielectrics - color of material | On Metals - color tint of the specular reflection.
- Sub Surface Scattering is when light below the surface travels a significant distance before re-exiting
- Iridescent materials tint the color of the specular reflection depending on viewing angle.

Specular | Diffuse | Emission

- Specular - Surface Level Reflection. Light bounces off surface.
- Diffuse - Light passes through surface and interacts with the material at a molecular level. Absorption and Scattering
- Emission - Material that is emitting light into the scene.

Metallic | Dielectric
(Non-Metallic)

- Metallic - Does not Absorb light. Base Color tints the specular reflection.
- Dielectric - Absorbs and Scatters light. Base Color describes which light wavelength is allowed to scatter off the material into the scene, the color not absorbed.