PBR, PPS & Renderman Materials

In this lesson we'll take an in depth look at physically based rendering, physically plausible shading and renderman.

Revision: 001

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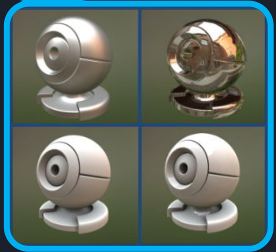
PBR & Renderman|Contents

1

2

3



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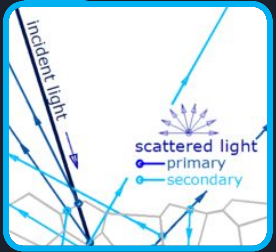

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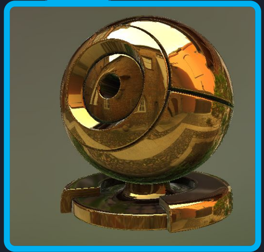

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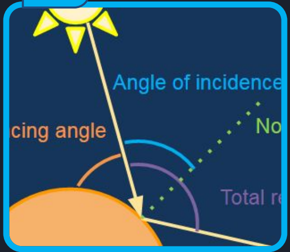

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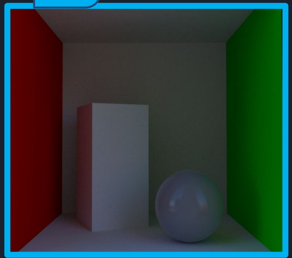

Topics in this lesson include:

1. Overview
2. History of Shading
3. Albedo
4. Dielectric Materials
5. Conductive Material
6. Terminology of Reflectance
7. Fresnel Effect
8. PBR Texturing apps
9. Renderman Shaders

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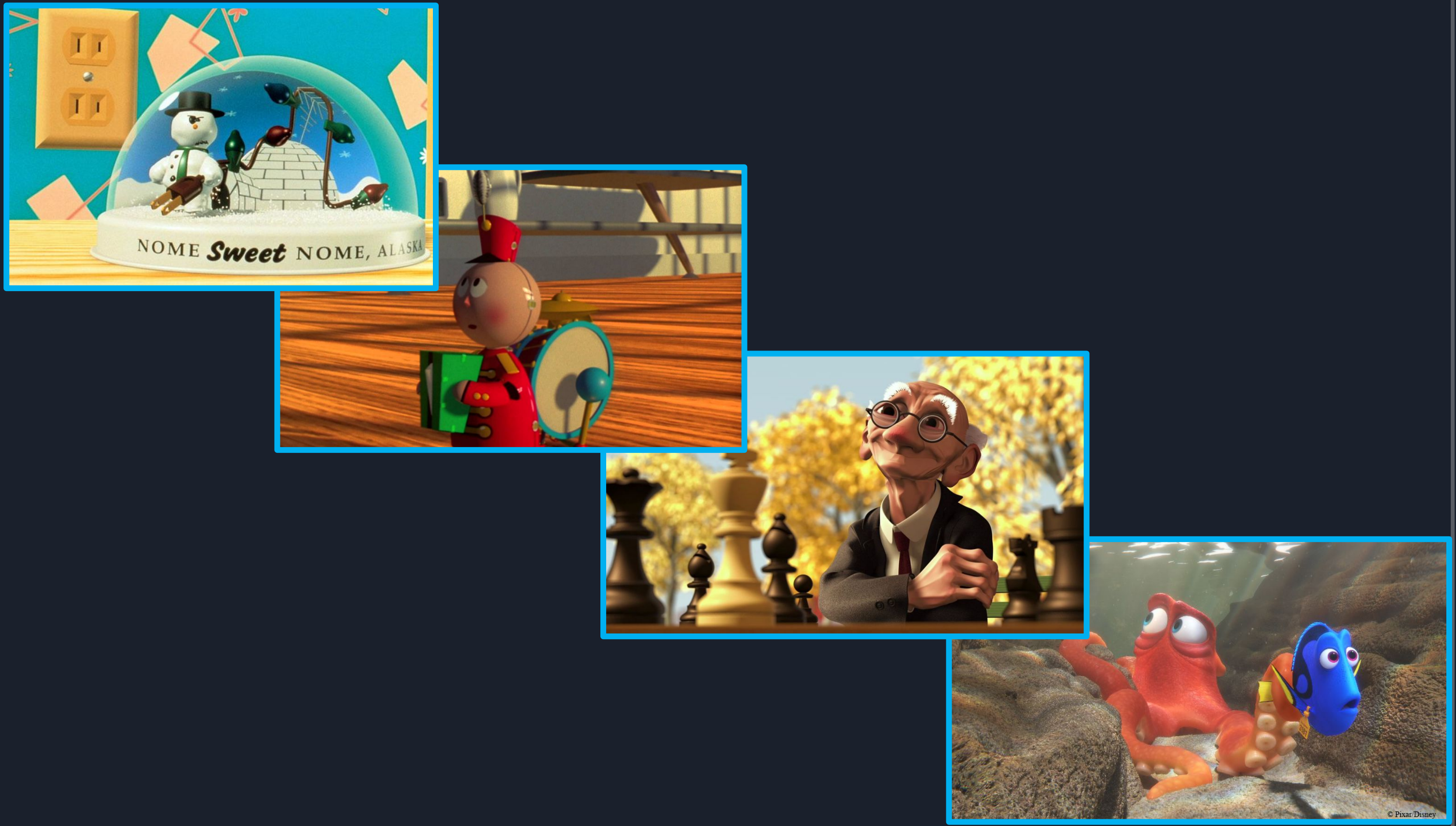
PBR & Renderman|Overview



This lesson will further your understanding of PBR and introduce methods for producing high quality renders of objects using typical PBR textures.

We'll start by learning a bit about the history of shading in CG, and how PBR methods have impacted modern workflows in surfacing and look development.

This will be followed with an in depth look at the material aspects most closely identified with PBR, namely albedo and metalness. We'll look at what metalness actually is and what makes something look "metallic".

We'll follow this with a practical exercise using Renderman to render materials produced in WYSIWYG texturing apps such as Mari, Substance Painter and 3d Coat.

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PBR & Renderman|History

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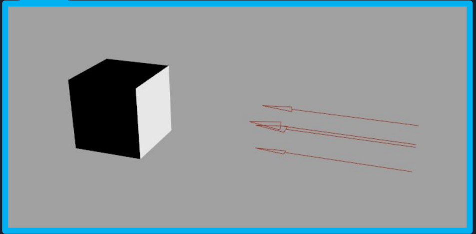

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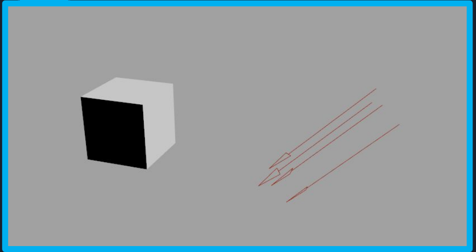

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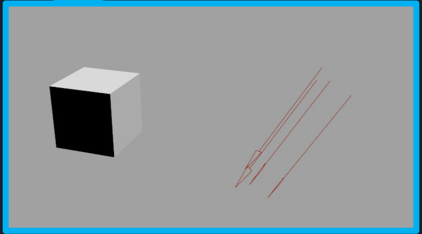

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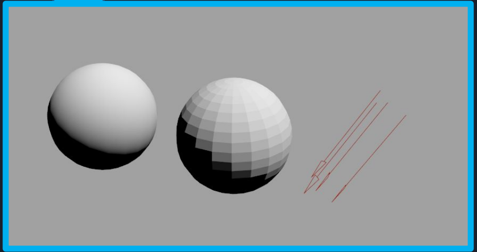


Johann Lambert

Lambert shading is a shading method that colours a surface based on the angle to the light.

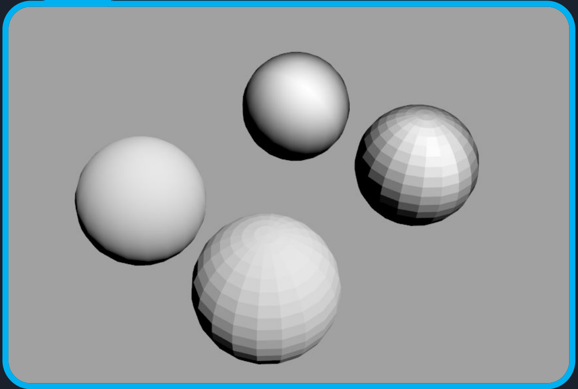
1. In this image the surfaces perpendicular to the light rays receive no illumination.
2. In this image, two surfaces receive the same illumination as the light is angled perfectly at 45°.
3. In this image the surface receives a different shade for all three surfaces as the light is now angled differently for all three faces.
4. With more complex surfaces, the illusion of 3d shading becomes more convincing. The illusion is completed when the vertex normals of the object are averaged.

The lambert model is an accurate model of how much light reaches a surface based on the light to surface angle relationship.

PBR & Renderman|History

1

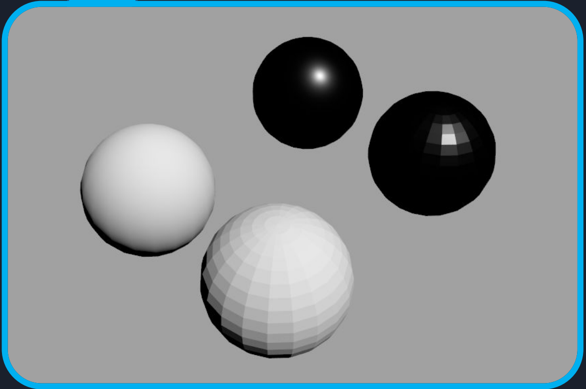
Blinn



Lambert

2

Blinn



Lambert

Jim Blinn

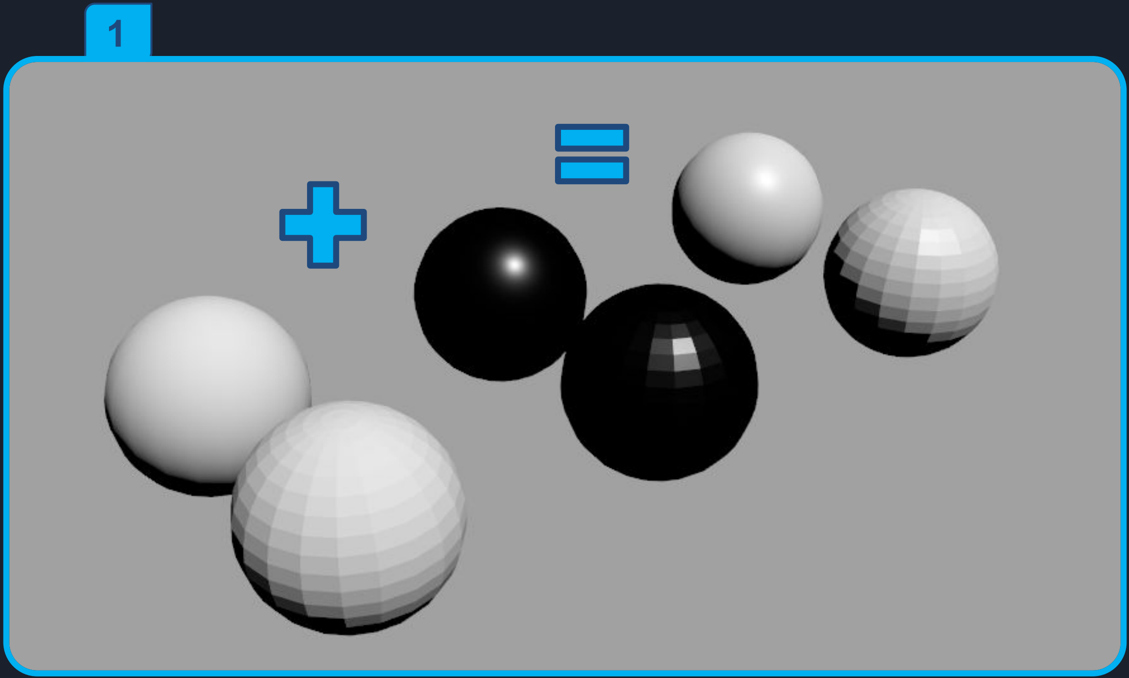
By tightening the falloff in the relationship between the surface angle and light angle, and taking the camera angle into account, the illusion of a “shine mark” or “specular highlight can be achieved.
This is the basis of the Blinn/Phong specular shading models.

1. In this image you can see how similar the Blinn and Lambert shading models can appear.

2. By altering the **eccentricity** of the Blinn shader, the illusion of a specular highlight becomes apparent. Tightening it makes objects look more “shiny”

The Blinn/Phong highlight is an approximation that gives the effect of specular reflections of a light source. It is not based on real world physics of light.

PBR & Renderman|History



The Blinn/Phong specular model is combined additively in a standard Blinn shader.

This gives the effect of a plastic like surface.

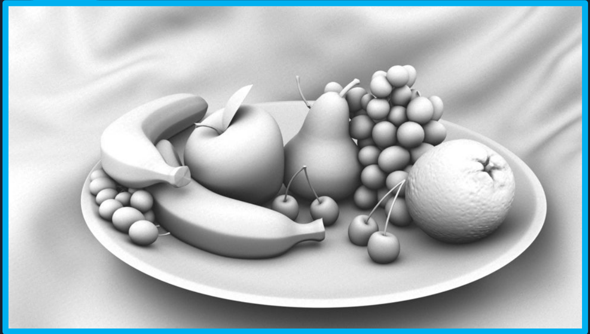
While this was a great advance in the early days of CG, it's basis in reality is slim.

This is not physically based rendering.

PBR & Renderman|History

1

3



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As time progressed, other features were added to typical shaders in an attempt to achieve some of the phenomena seen in real surfaces. Some of these features included:

- Reflection maps
- Shadow maps
- Ambient lights and occlusion
- Alpha transparency
- Bump and Normal mapping

These features were added to materials over many years, and were focused on achieving a particular visual effect at the lowest computational cost.

PBR & Renderman|PBR/PPS Overview

A non-PPS setup.
Washed out highlights,
dark diffuse values

Materials tuned to
desired result

Tuned materials don't
hold up in new scene

PPS setup.
Materials look correct
out of the box

In a new lighting setup,
materials respond
correctly.

Physically based rendering(PBR) and physically plausible shading(PPS) are two terms that describe the same concept.

The traditional approaches to shading in CG led to many problems and inconsistencies regarding the way materials responded to lighting between scenes.

PBR/PPS works with many aspects of CG to ensure that the shading maintains its integrity in different lighting scenarios. This requires a unified approach to:

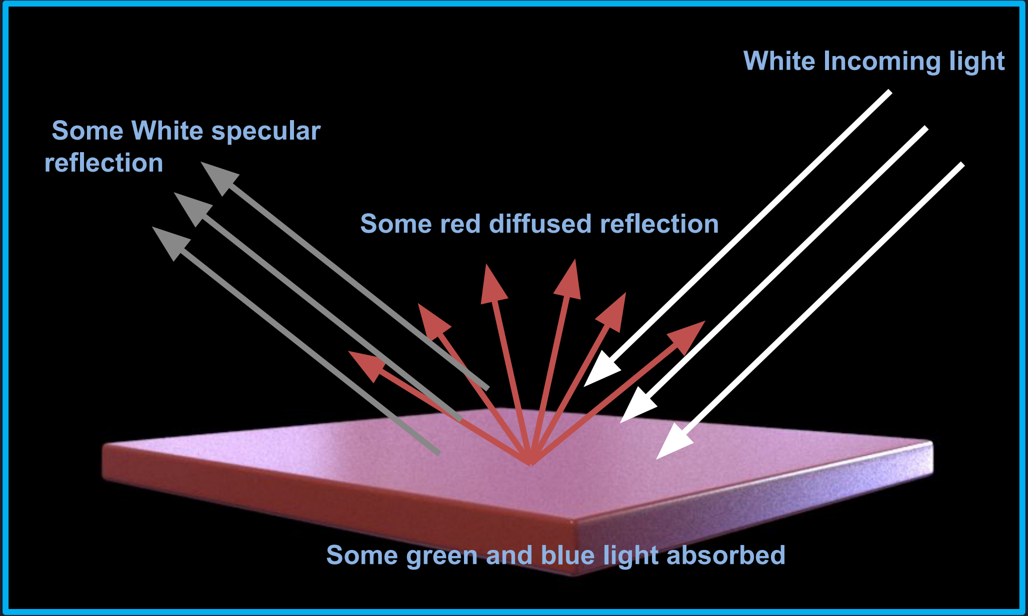
1. Material properties
2. Light physics
3. Color management

For an in depth look at how these elements are taken into account, see this detailed explanation

PBR & Renderman|PBR/PPS Overview

A key concept in physically plausible shading:

- **A surface can not reflect more light than it receives.**
- **This is called the law of energy conservation**



Light is either reflected or absorbed by, or transmitted through a surface.

The reflected light is what we see and it may be divided into two sub-types of reflected light:

- scattered diffused reflection
- coherent specular reflection

PBR makes an important assumption:
A surface can not reflect more light than it receives.

In PBR shaders, reflections and highlights are not mutually exclusive, but are part of the same system.

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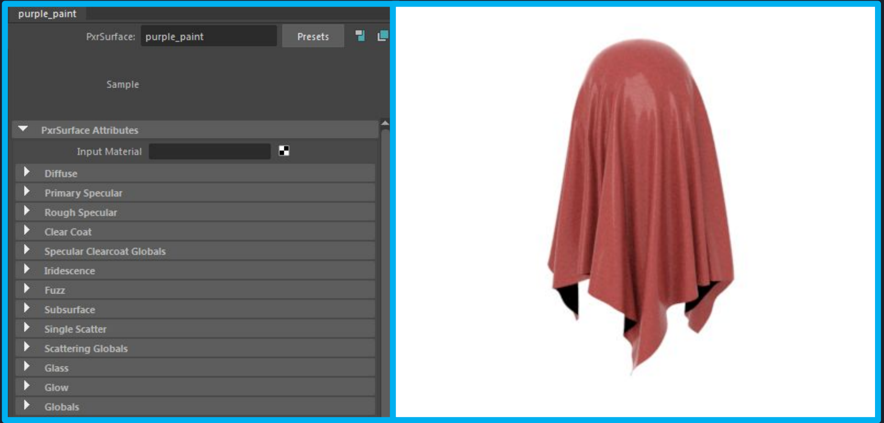
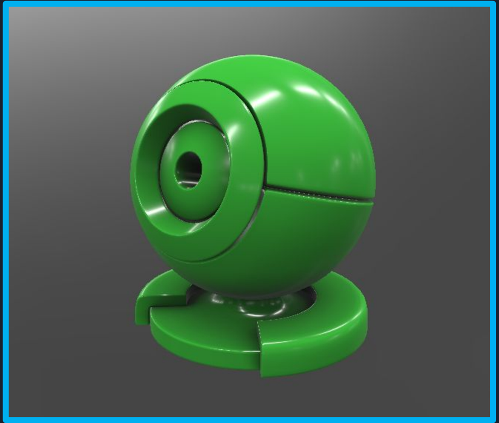
PBR & Renderman|PBR/PPS Overview

PBR is a rendering paradigm, not a specific shader.



Renderman's PxrSurface material is an advanced shader with many attributes that are weighted in order to maintain physical plausibility.



Many real-time engines use a simplified shader that also balances diffuse and specular reflection in order to remain physical plausibility.

Not all PBR materials have the same attributes to describe the material. Two common material workflows include the roughness/metalness and the glossiness/specular workflows. They each rely on different types of textures.

A roughness/metalness workflow uses:

- An albedo map
- A roughness map
- A metalness map

A coloured specular workflow uses:

- A diffuse map
- A coloured specular map
- A gloss map

While these are common workflows for texture creation, many shaders will have their own input requirements.

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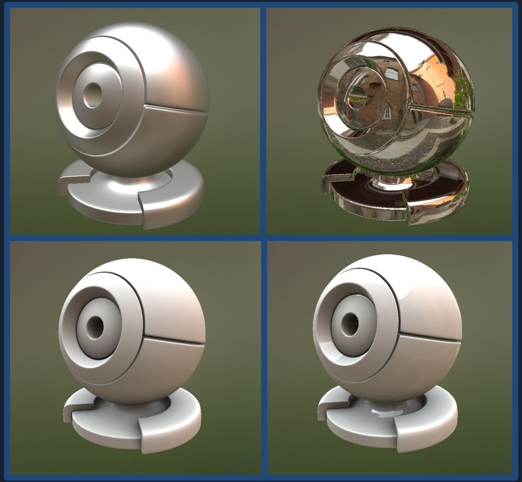
PBR & Renderman|Albedo Vs Diffuse

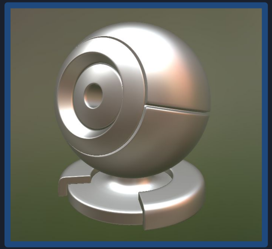
Metalness Workflow



Each of these objects has a white Albedo map.
In each, the reflectance is 100%, with varying degrees of roughness and metalness.

Specular Workflow

Diffuse = black
Specular = white
Gloss = dark grey



Diffuse = black
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Diffuse = white
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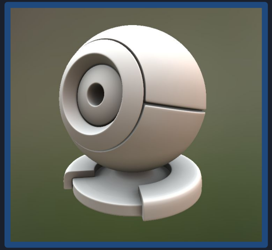

Diffuse = white
Specular = dark grey
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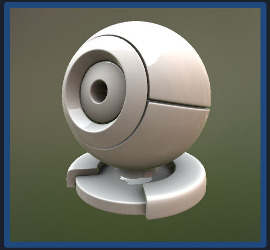

Metals tend to have no diffuse shading and will use a black diffuse map. This must be balanced by increasing the values in the specular map.

The metalness workflow uses Albedo maps.
Albedo maps represent the total reflected color of a surface.

The reflections could be rough or smooth, conductive(metallic) or dielectric(non-metallic).

A white albedo, could represent chalk, chrome, porcelain or brushed metal.

The specular workflow uses diffuse maps.
A diffuse map represents the colour of the diffuse reflections.
A chrome effect would be achieved by a black diffuse map combined with a white specular map.

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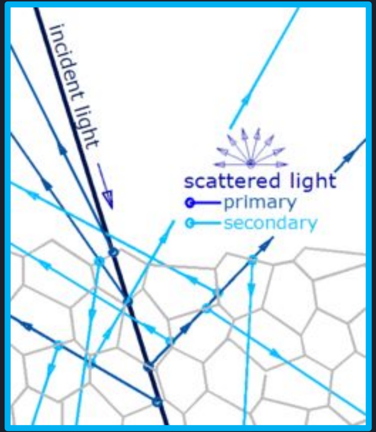
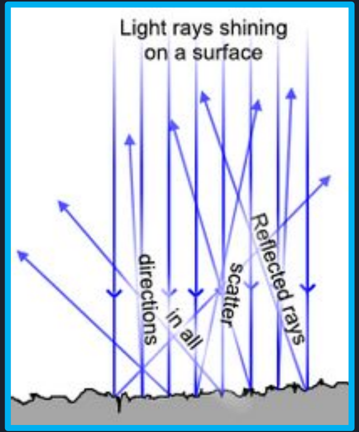
PBR & Renderman|Dielectric Materials

Dielectric materials

These are all examples of dielectric materials. Notice the diffuse reflection even on polished materials.





The primary cause of diffuse reflection is the scattering of light as it penetrates slightly into the surface. Roughness also plays a role in diffuse scattering of reflections.

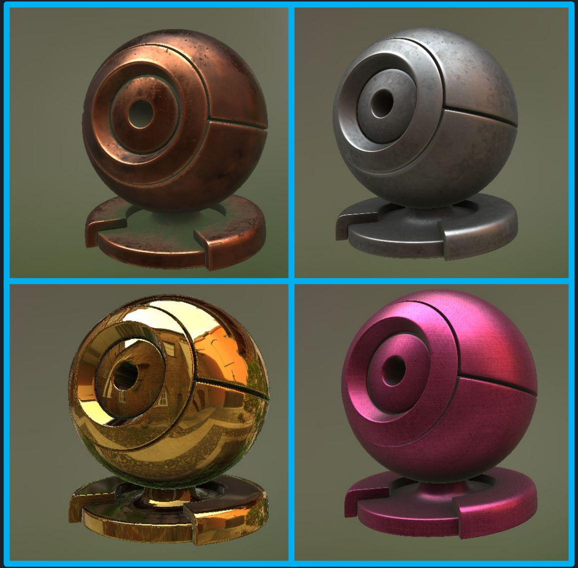
Dielectric materials include most materials that are not metals. This includes woods, ceramics plastics, chalks etc. It also includes glasses and clear liquids, but for purpose of this lesson, we'll be talking mostly about opaque materials.

While these materials can be polished smooth, they typically have poor surface reflection(around 5%) and will still have a high level of diffuse shading.

Diffuse shading is mostly caused by light slightly penetrating a surface and bouncing in many directions before exiting the surface again.

PBR & Renderman|Conductive materials

Conductive materials



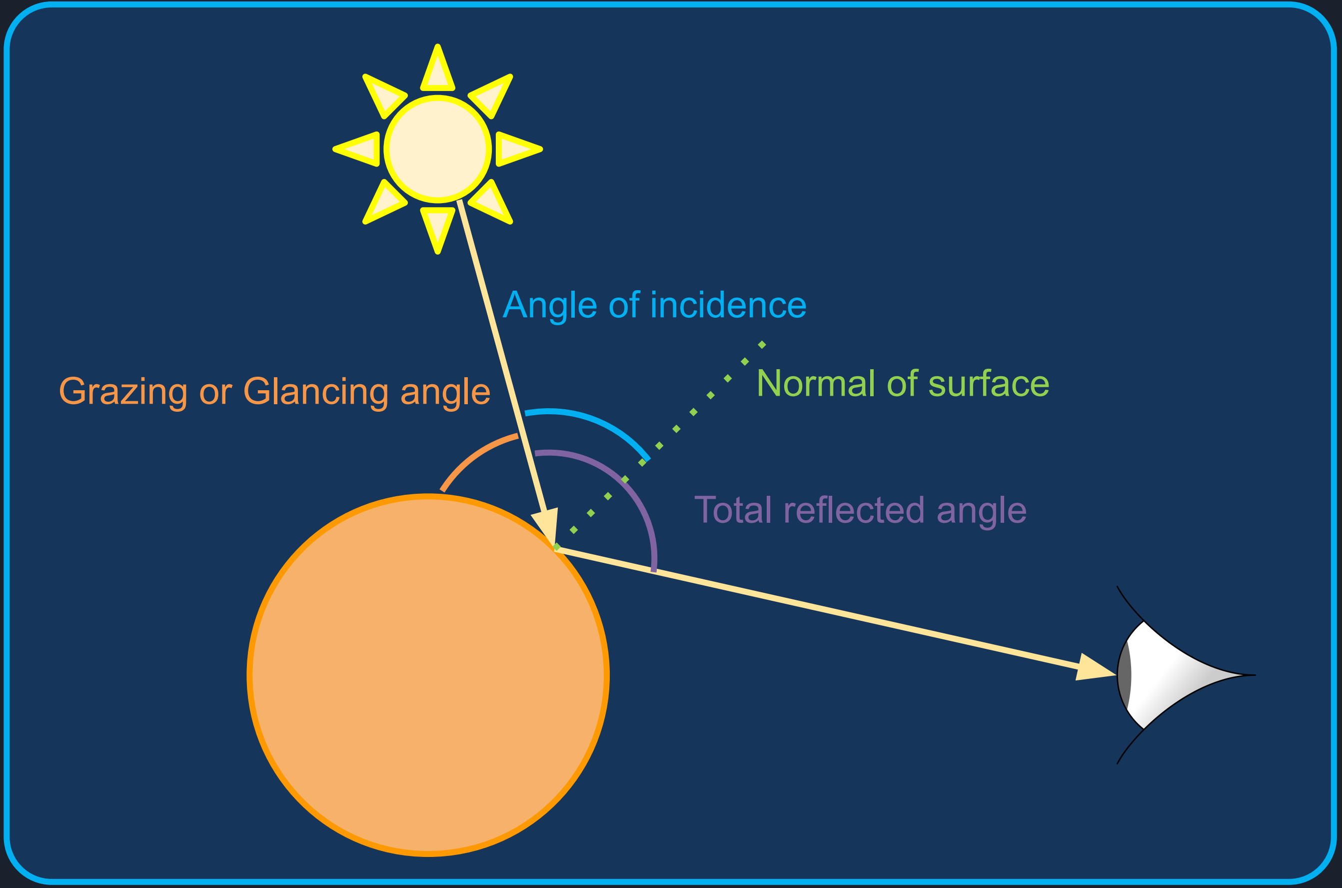
These are all examples of conductive materials. The colour comes entirely from the surface reflectance as the light does not penetrate into the object.

Specular reflections appear to be tinted in conductive materials, but reflect white light in dielectric materials.

Light on conductive materials does not penetrate the surface and scatter as it does in dielectric materials. Instead, some frequencies are absorbed and others reflected at the surface.

Unlike in dielectric materials, the specular reflections will be tinted the colour of the material.

PBR & Renderman|Terminology of reflectance



In order to understand some of key concepts regarding reflection, it is important to understand the law of reflection and be familiar with the terminology of reflection.

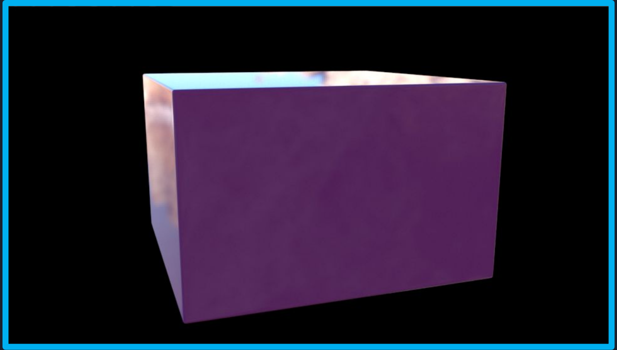
When using a single ray of light to describe how it interacts with a surface, we call it the **incident ray.** Where the ray intersects a surface is referred to as the **Point of Incidence.**

The angle between the incident ray and the surface normal gives us the **Angle of Incidence**.

Double the angle of incidence to get the **Total reflected angle.**
This is the **Law of Reflection**

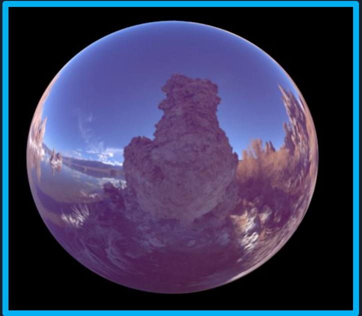
When the incident ray runs close to parallel to the surface, it can be more useful to talk about the **Grazing** or **Glancing Angle.**

PBR & Renderman|Fresnel effect

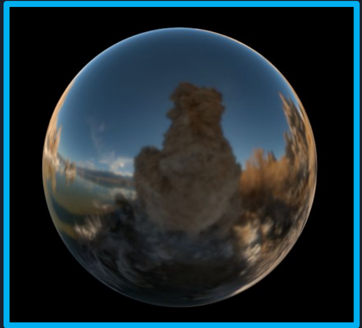


In this image the faces that rest at a glancing angle illustrate the Fresnel effect.

On a curved surface, the effect transition is evident.



When the effect is not used, the shading does not look correct, and has the appearance of a metallic glaze.



By contrast, metals do not have a diffuse component, and do not exhibit the fresnel effect.

One of the most important distinctions between dielectric and conductive materials is concerned with the way reflections are treated at the surface.

Surface reflection of dielectric materials change based on the angle of incidence.

That is to say, a surface viewed from a grazing angle, will appear highly reflective, while a surface viewed straight on will appear only slightly reflective.

A standard dielectric material will be 100% reflective at a perfect glancing angle.
It will be only 4-5% reflective at a perfect facing angle.

By contrast a metal will have the same reflectivity at a both steep and shallow glancing angles.

Exercise|Material analysis

Look at these objects and discuss the following as a class:

- Is it dielectric?
- Is it conductive?
- Is it a little more complex than that?
- How do you arrive at your conclusion?
- How does the colour, roughness and metalness change across the surface?

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Exercise|Material analysis

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Exercise|Material analysis

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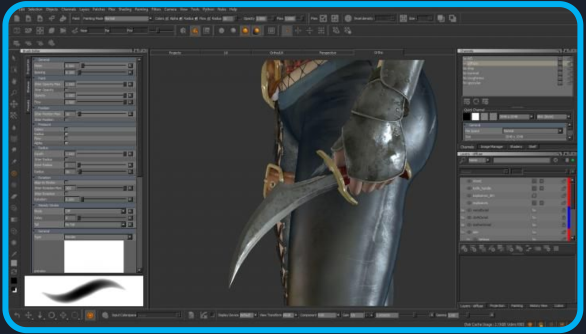
- How does the colour, roughness and metalness change across the surface?

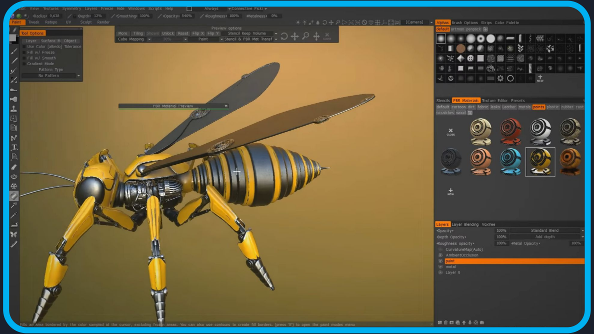
PBR & Renderman|PBR in texturing apps

3d painting programs that use PBR include:

- Mari
- Substance Designer/Painter
- 3d Coat



Mari by The Foundry



3d Coat by Pilgway

Substance Painter by Allegorithmic

PBR has played a major role in the advancement of 3d texture painting programs.

Three popular programs that support PBR shading are:

- Mari
- Substance designer/painter
- 3d Coat

Each of these use a shading and lighting system that can be setup to create textures that are usable in the metalness/roughness workflow.

The realtime shaders in these programs give close approximations of how an object will look in any PBR/PPS environment.

This “What you see is what you get” functionality is incredibly beneficial and allows much of the look development to be undertaken at the texturing stage of a project.

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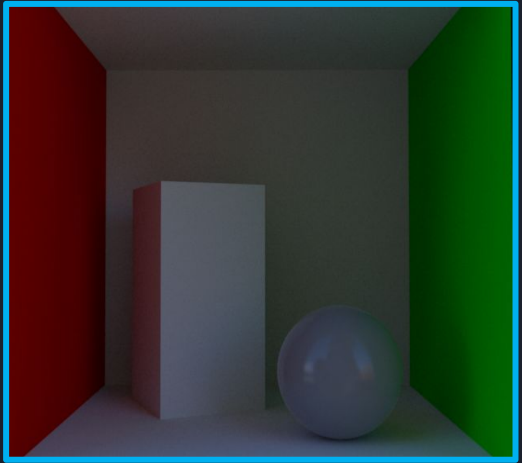
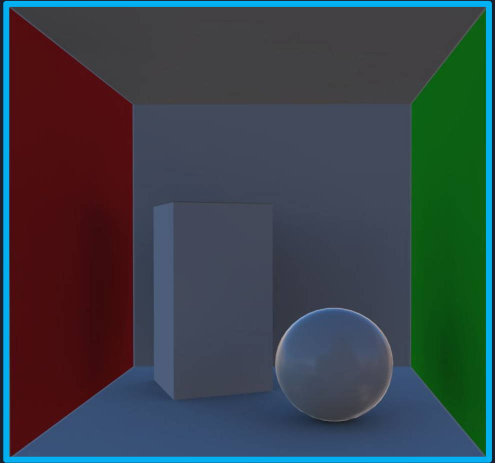
PBR & Renderman|Renderman shaders



Renderman render. Note the occluded reflection of geometry and the light bouncing between objects.



Realtime render of the same scene. Note the unoccluded environment reflections and lack of complex light interactions.

Real-time rendering used in these texturing applications and game engines are heavily optimised for acceptable frame rates and as such, have limitations.

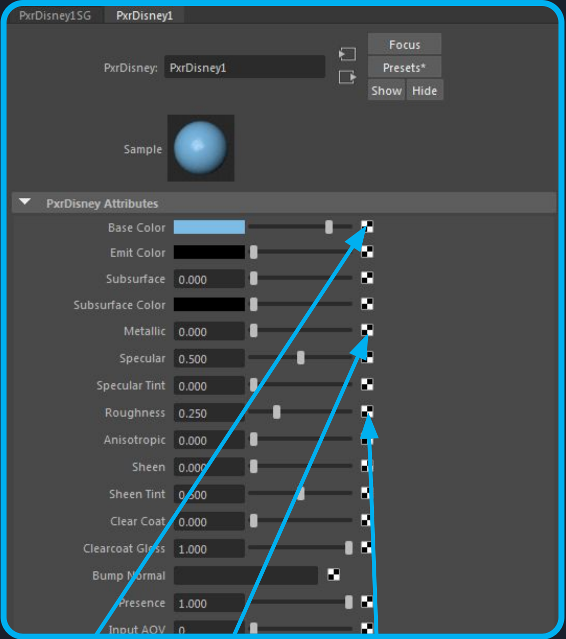
Rendering in renderman allows for the use of advanced lighting effects such as accurate soft shadows, simulated bounced light, true inter-object reflections/refraction etc.

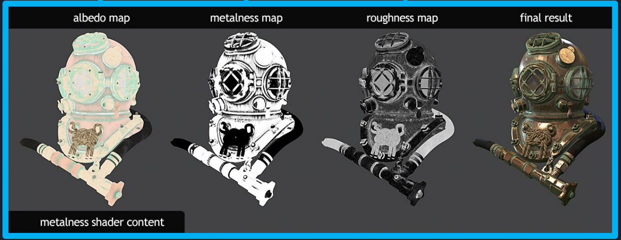
Renderman includes two shaders that support files created as part of the metal roughness workflow.

The PxrDisney node is a simplified material that contains inputs for metalness, roughness and color.

The PxrSurface shader is much more complex and capable of more art direction. But is also more complex to set up.

PBR & Renderman| PxrDisney material





The PxrDisney shader was based on the shader used in the movie *Wreck-it Ralph* by Walt Disney Animation Studios.

The PxrDisney shader was developed to be an artist friendly, plausible shader that was designed to have the fewest amount of controls required to describe a large variety of materials.

It's based on the shader that was used by Disney in the production of Wreckit Ralph.
In the production they used the shader on just about every surface except for hair.
For more information, see this white paper.

To use this shader, you can simply connect:

- Albedo map into the **Base Color**
- Metalness map into **Metallic**
- Roughness map into **Roughness**

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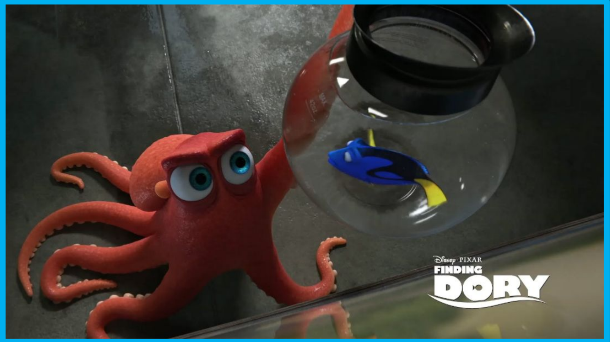
PBR & Renderman| PxrSurface material

The PxrSurface shader setup is more complex, but allows for more flexibility.



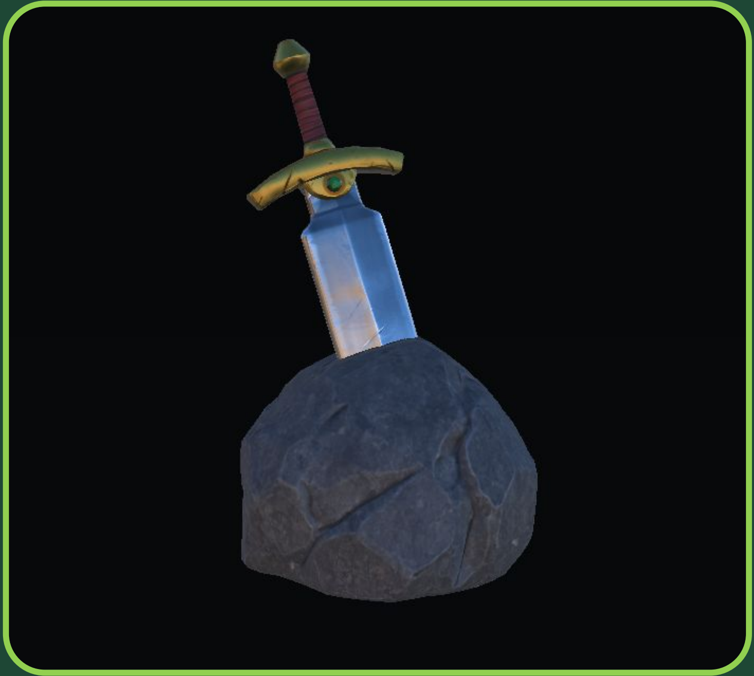
The PxrSurface shader was the primary shader of choice in the Pixar Animation Studios film *Finding Dory*.

The PxrSurface material is a complex material that is capable of mimicking almost any type of material through a multitude of controls.
It has been designed to allow for physically accurate simulation of materials, or be controlled intuitively by artists.

The PxrSurface shader was the primary shader used in Pixar Animation Studios film Finding Dory.

With this shader, you can approach different materials with a layer based approach.
This is more complex to set up, but can make look development much more flexible.

PBR & Renderman | Renderman shaders



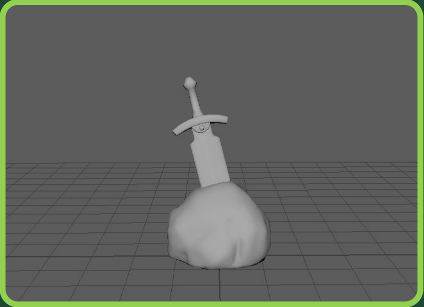
In this tutorial, we'll be taking a simple object and rendering it in Renderman.

The surface has variations in materials including different metals and dielectrics.

We'll first set up a material using the PxrDisney material, and then set up the same material using a PxrSurface material.

PBR & Renderman|Renderman shaders

1



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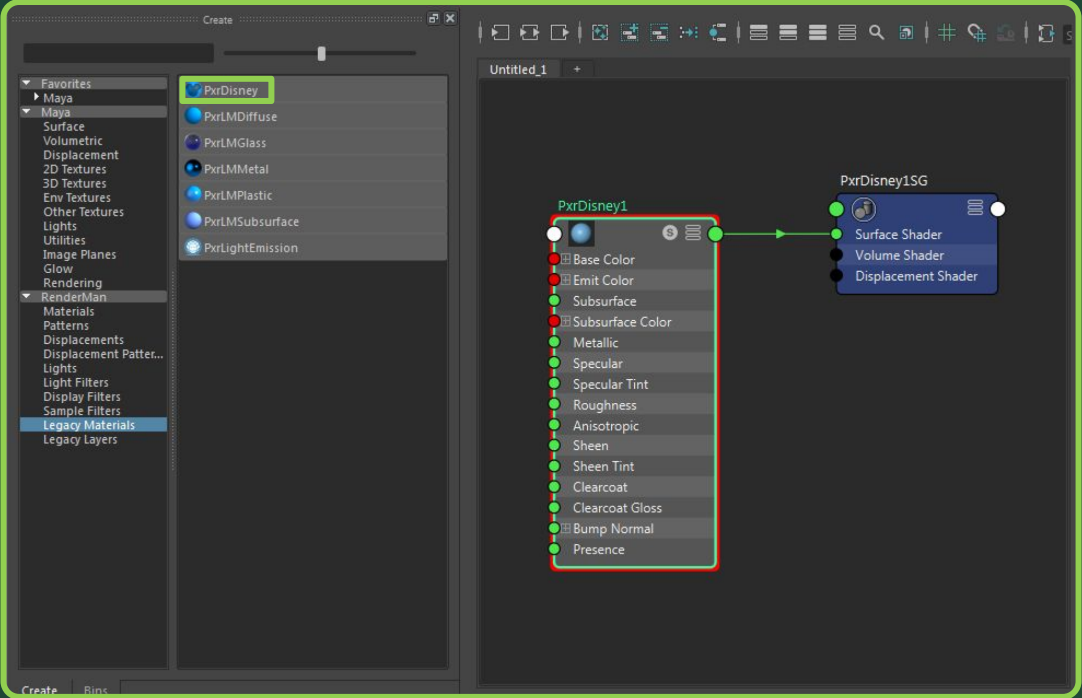
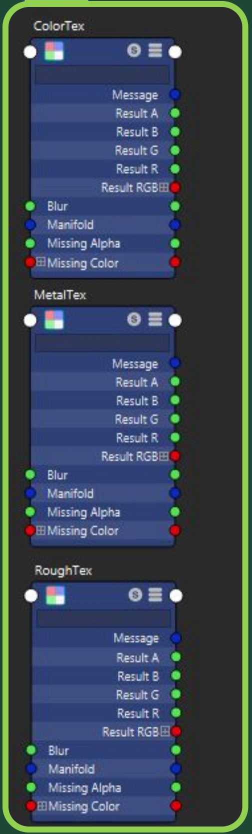


1. Download the lesson files and load the **BasicMaps_projectFiles** Maya projet. Open **Sword in the Stone.mb** scene.
2. Open the **Hypershade** and in the **Create panel** click **PxrDisney** in the Legacy Materials under the Renderman nodes.

PBR & Renderman|Renderman shaders

1



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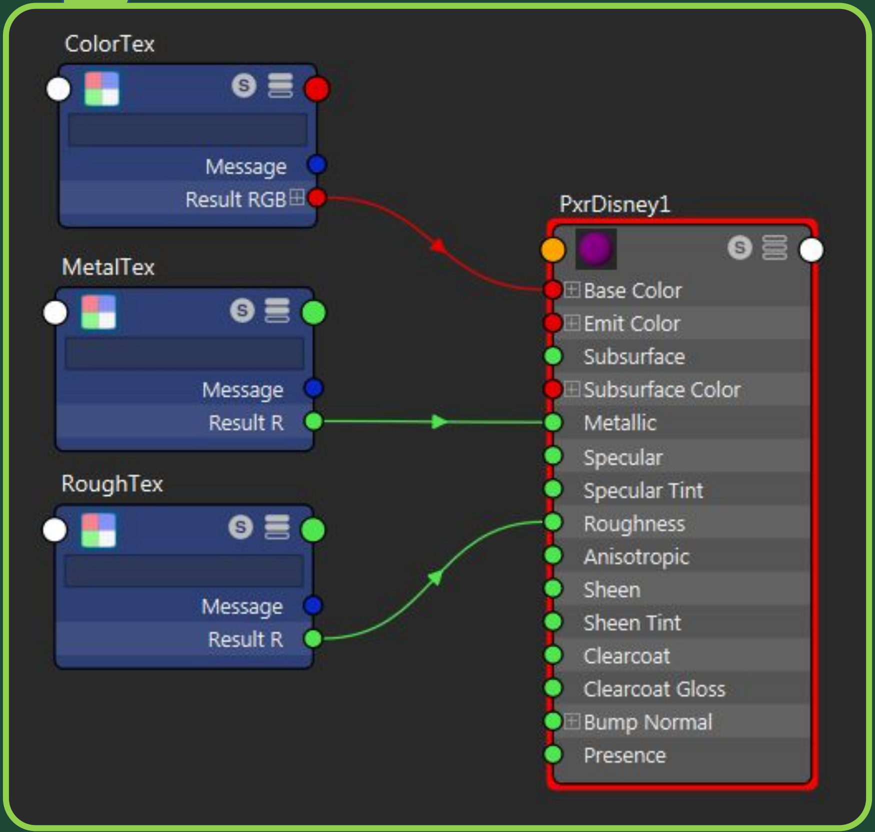
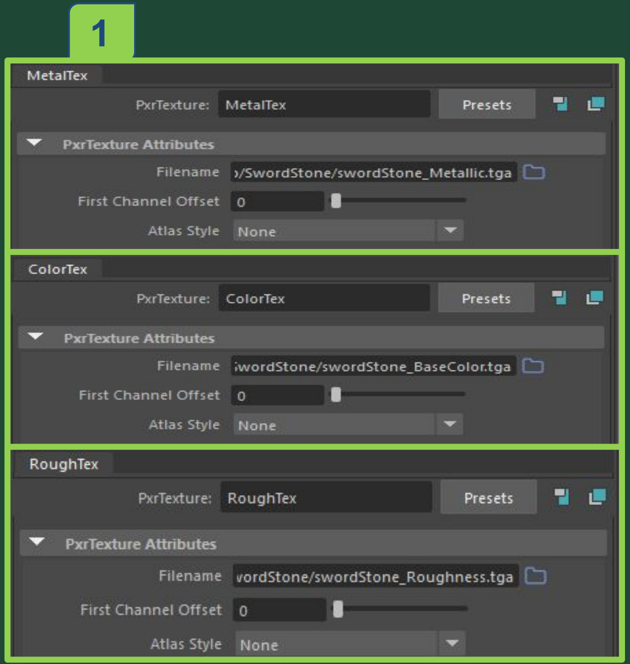


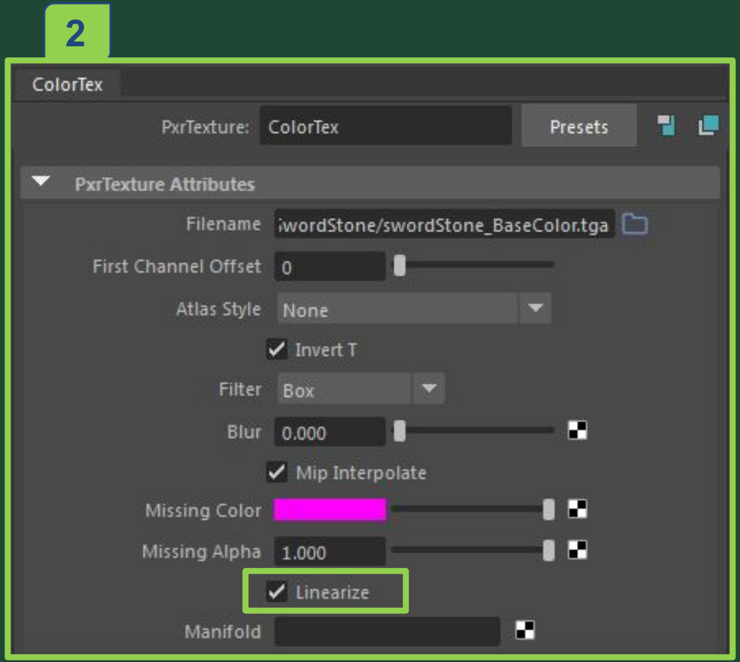
1. Create three PxrTexture nodes and name them ColorTex, MetalTex and RoughTex(or something similar) Press 3 to see their inputs and outputs.

2. Make the following connections to the PxrDisney material:

    - ColorTex **Result RGB->Base Color**
    - MetalTex **Result R->Metallic**
    - RoughTex **Result R->Roughness**

PBR & Renderman|Renderman shaders

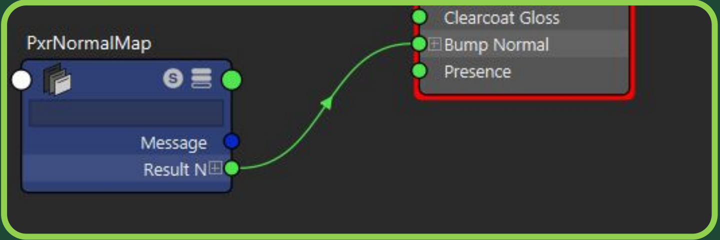




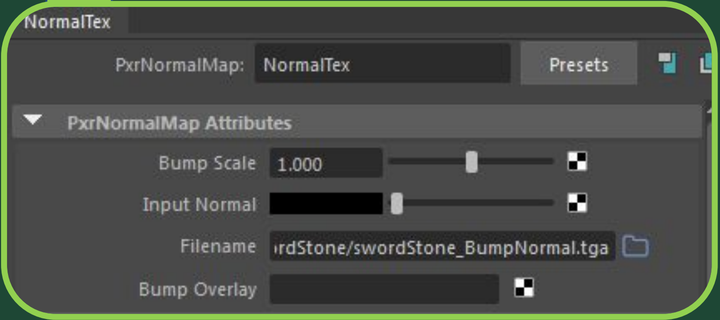
1. In the three PxrTexture nodes, load the appropriate texture file into the **Filename** field.
2. In the ColorTex properties turn on **Linearize.** This will accomodate for the SRGB colorspace that the file uses.

PBR & Renderman|Renderman shaders

1



2



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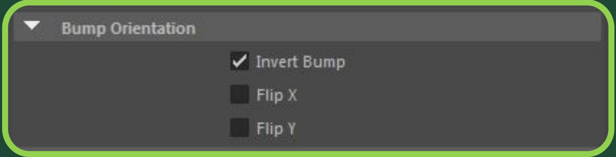
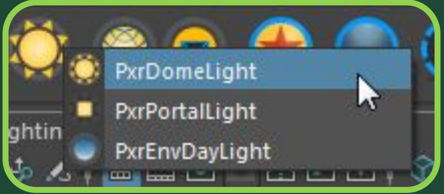


1. Create a PxrNormalMap node and connect it the **Result N->Bump Normal** of the PxrDisney material.
2. In the **Property Editor**, load **SwordStone_BumpNormal.tga.**
3. Turn on **Invert Bump** under the Bump Orientation rollout.

PBR & Renderman|Renderman shaders

1



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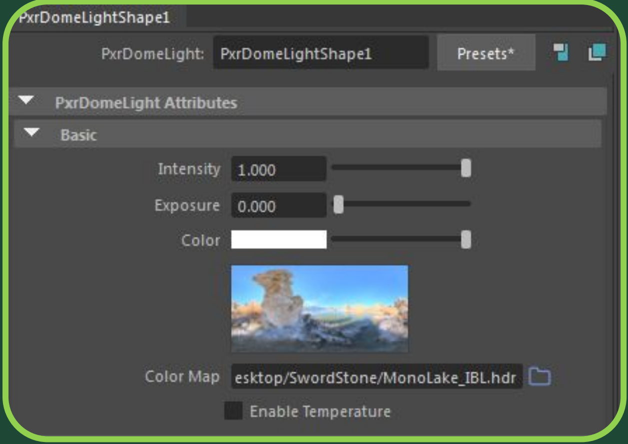

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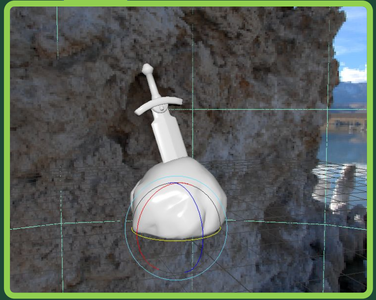

4

1. In the Renderman shelf, right click the environment lighting icon(the sun) and select **PxrDomeLight** from the options. This creates an environment light in the scene.
2. Load the MonoLake_IBL.hdr into the light's color map field.
3. A feedback object will be created in the 3d scene.This can be rotated to orient the lighting.
4. The setup is complete and you can render to see the results.

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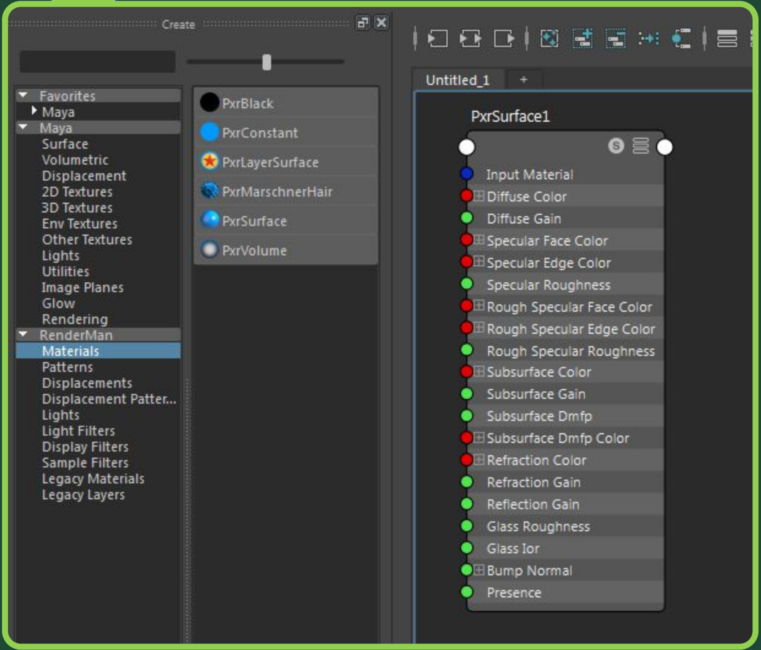
1



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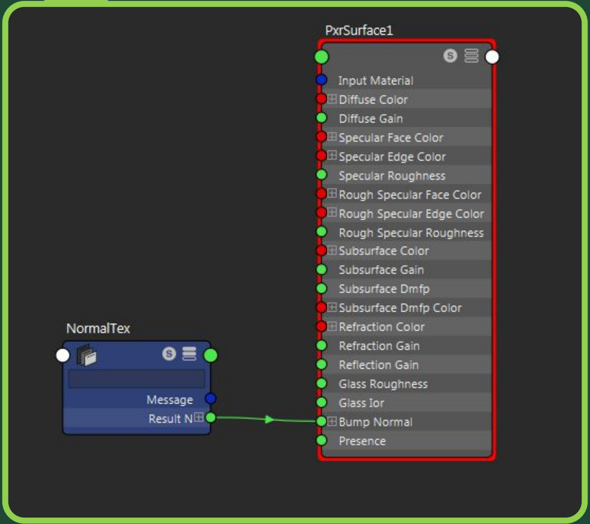

Now let's setup the PxrSurface Material.
We can continue on with the scene.

1. In the Hypershade, clear the graph and create a PxrSurface material.
2. Add your NormalTex to the graph and connect the **Result N** to the **Bump Normal** of the PxrSurface.

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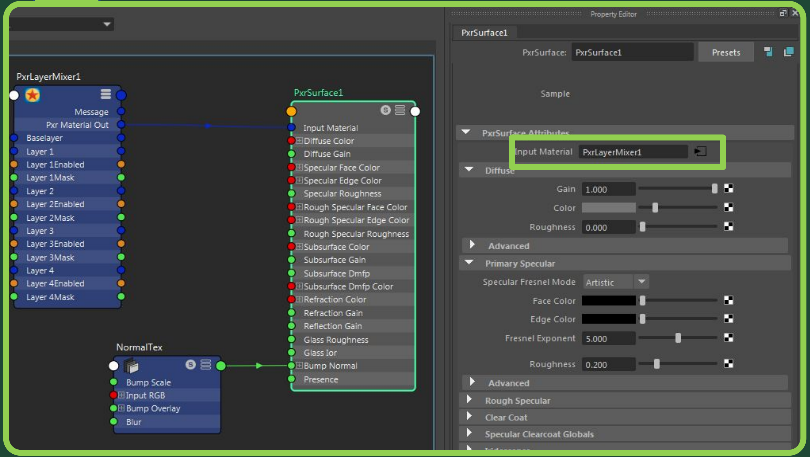
1



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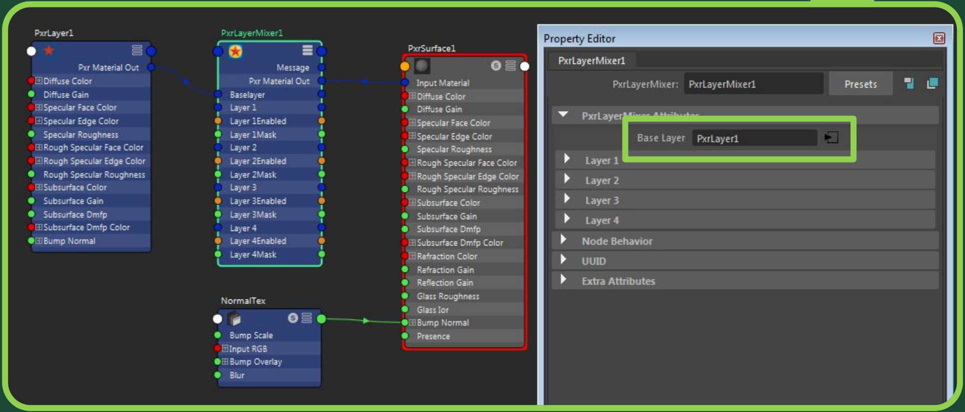

1. In the PxrSurface material properties, click on the **Input Material** attribute. A **PxrLayerMixer** node will be created and connected.
2. In the **PxrLayerMixer** properties, click the swatch for the **Base Layer** attribute. This creates and **PxrLayer** node that will act as our substrate material. In this case, this will be the dielectric material.

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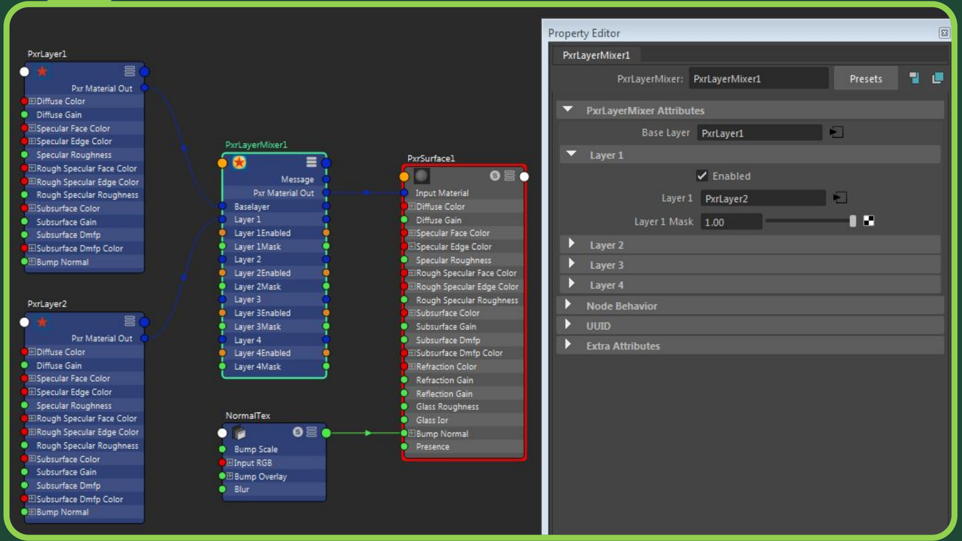
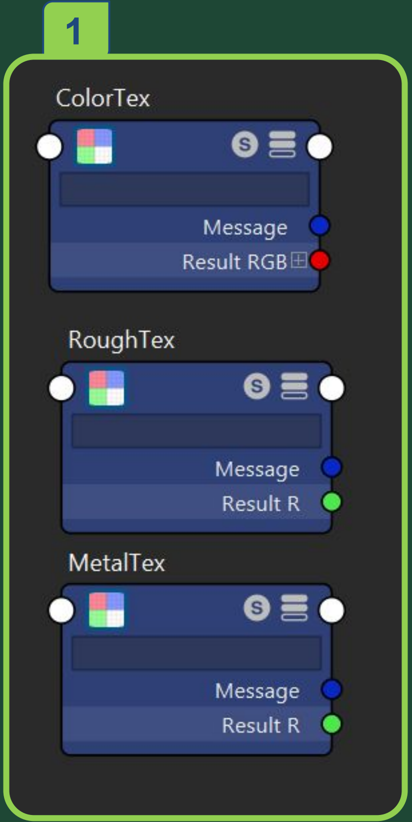
1

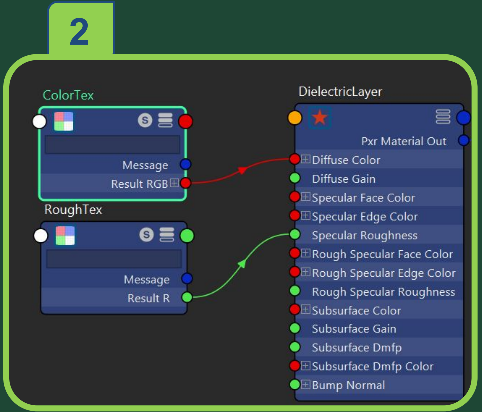


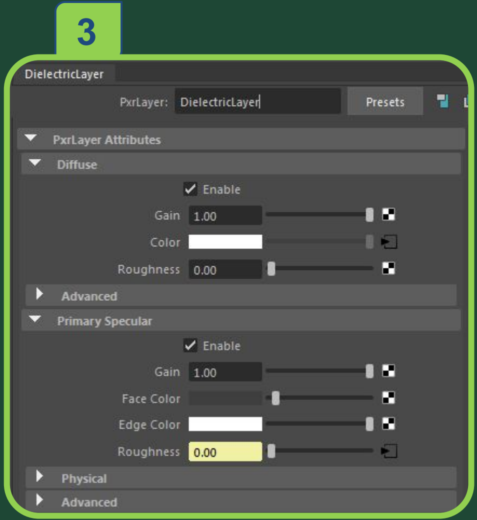
2

1. In the **PxrLayerMixer** properties, click the swatch for the **Layer 1** attribute. This creates and **PxrLayer** node that will overlay the base layer. In this case, this will be the conductive metal material.
2. Name your layer nodes to be more descriptive(e.g. DielectricLayer and MetalLayer).

PBR & Renderman|Renderman shaders







1. Bring the your colour, roughness and metalness textures into your graph.
2. Working with the dielectric layer, connect the **ColorTex ResultRGB** to the **DielectricLayer Diffuse Color**. Also connect the **RoughTex Result R** to the **DielectricLayer Specular Roughness**.
3. In the **DielectricLayer** properties, ensure that both **Diffuse** and **Primary Specular** are **Enabled**. Set the **Face Color** to have a value of **0.05** and the **Edge Color** to have a value of **1**(to simulate the Fresnel effect). Also set the gain of both **Diffuse** and **Primary Specular** to **1**.

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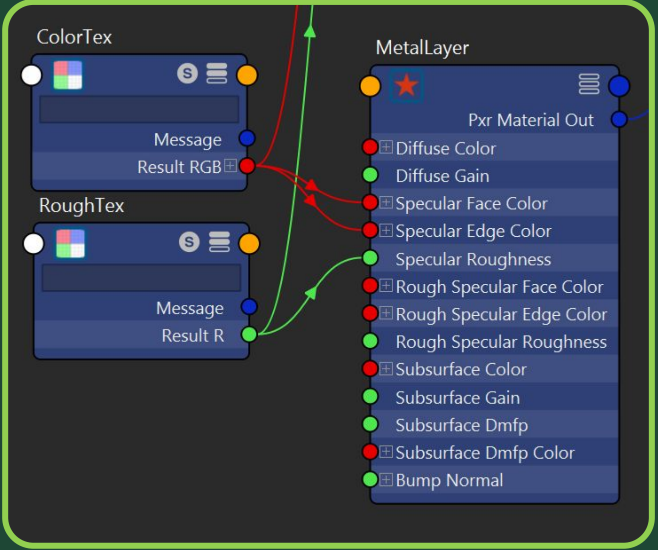
PBR & Renderman|Renderman shaders

1



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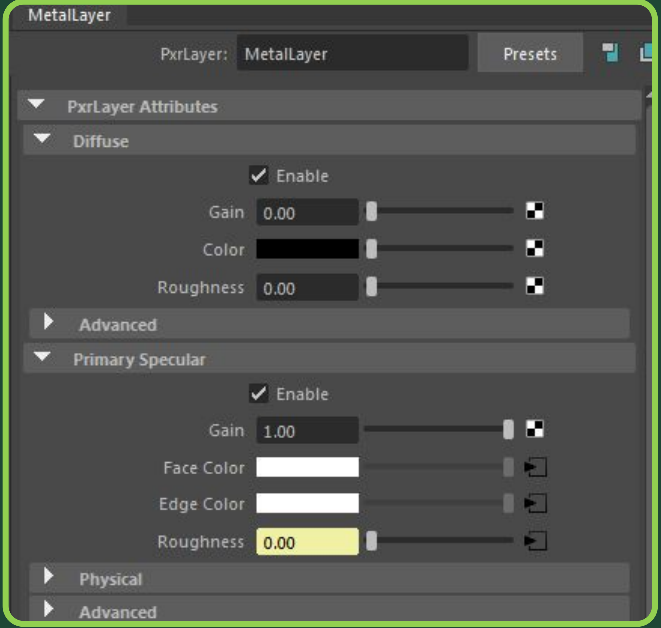
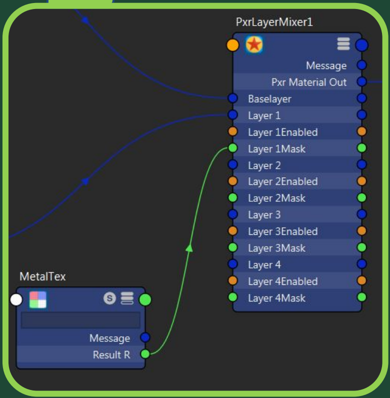


1. Working with the Metal layer, connect the **ColorTex ResultRGB** to the **MetalLayer Specular Facing Color** and the **Specular Edge Color**. Also connect the **RoughTex Result R** to the **MetalLayer Specular Roughness**.

2. In the **MetalLayer** properties, ensure that both **Diffuse** and **Primary specular** are **Enabled**. Set the **Diffuse Gain** to **0** and the **Primary Specular Gain** to **1**.

PBR & Renderman | Renderman shaders

1



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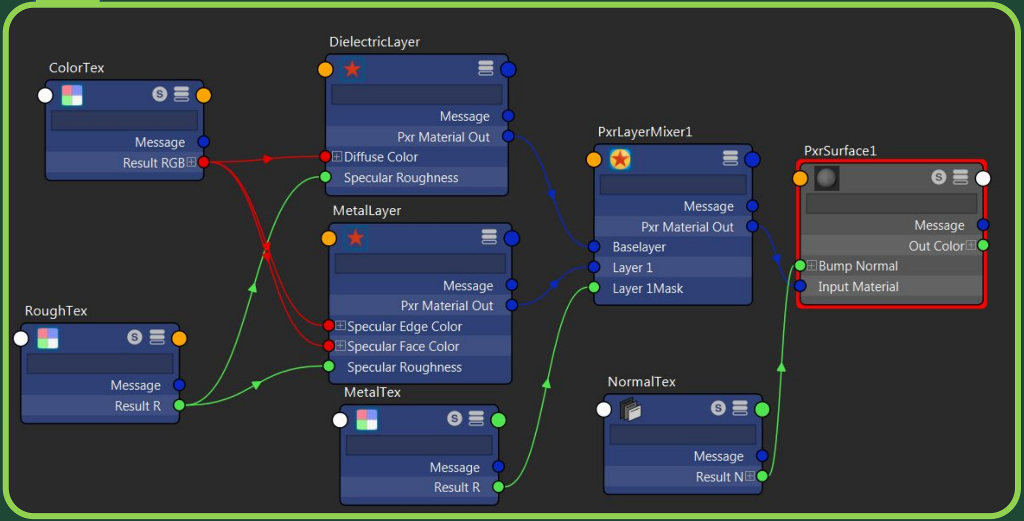

3

1. Connect the **MetalTex Result R** to the **Layer1 Mask** of the **PxrLayerMixer** node.
2. This is what the final graph should look like. Press **2** on the keyboard view just the connected inputs and outputs in the graph.
3. Rendering will once again yield very similar results as before, but with the added benefit that material attributes can be more art directed and tweaked.

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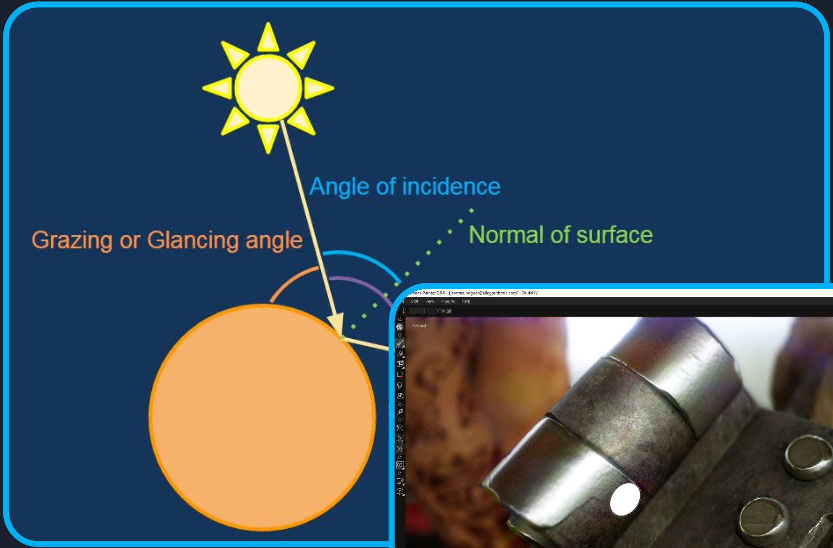
PBR & Renderman|Summary



This lesson introduced some core concepts in physically based rendering:

- Complete:

You have discussed concepts in PBR and gained an understanding of core concepts of plausible shading. You've put this information into practice through analysis and the setting up of PBR shaders in Renderman.

- Usability:

You can now use any number of PBR rendering solutions(offline and realtime) with confidence.

- What next:

Apply these concepts to a realistic model/scene of your own making. Find the constraints of the different methods.

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