Computer Graphics

Lecture 09 – Textures and Materials

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Materials, Shaders and Textures

- **Materials**: define how a surface should be rendered, including references to textures, tiling information, color, etc.
  - The options available depend on which Shader the Material is using.

- **Shaders**: small scripts that contain the mathematical calculations and algorithms for calculating the color of each pixel rendered, based on the lighting input and the Material configuration.

- **Textures**: are bitmap images.
  - A Material can contain references to textures, so that the Material's Shader can use the textures while calculating the surface color.
  - Textures can also represent other aspects of a Material's surface such as its reflectivity or roughness.

Unity Standard Shader

- **Standard Shader**: built-in shader with a comprehensive set of features.
  - Supports reflection, bump mapping, occlusion mapping, emission, transparency, shadows, indirect light, etc.
  - Physically Based Shading: render objects in a way that accurately simulates the flow of light of the real world.
  - Example of scene rendered using the standard shader on all models:

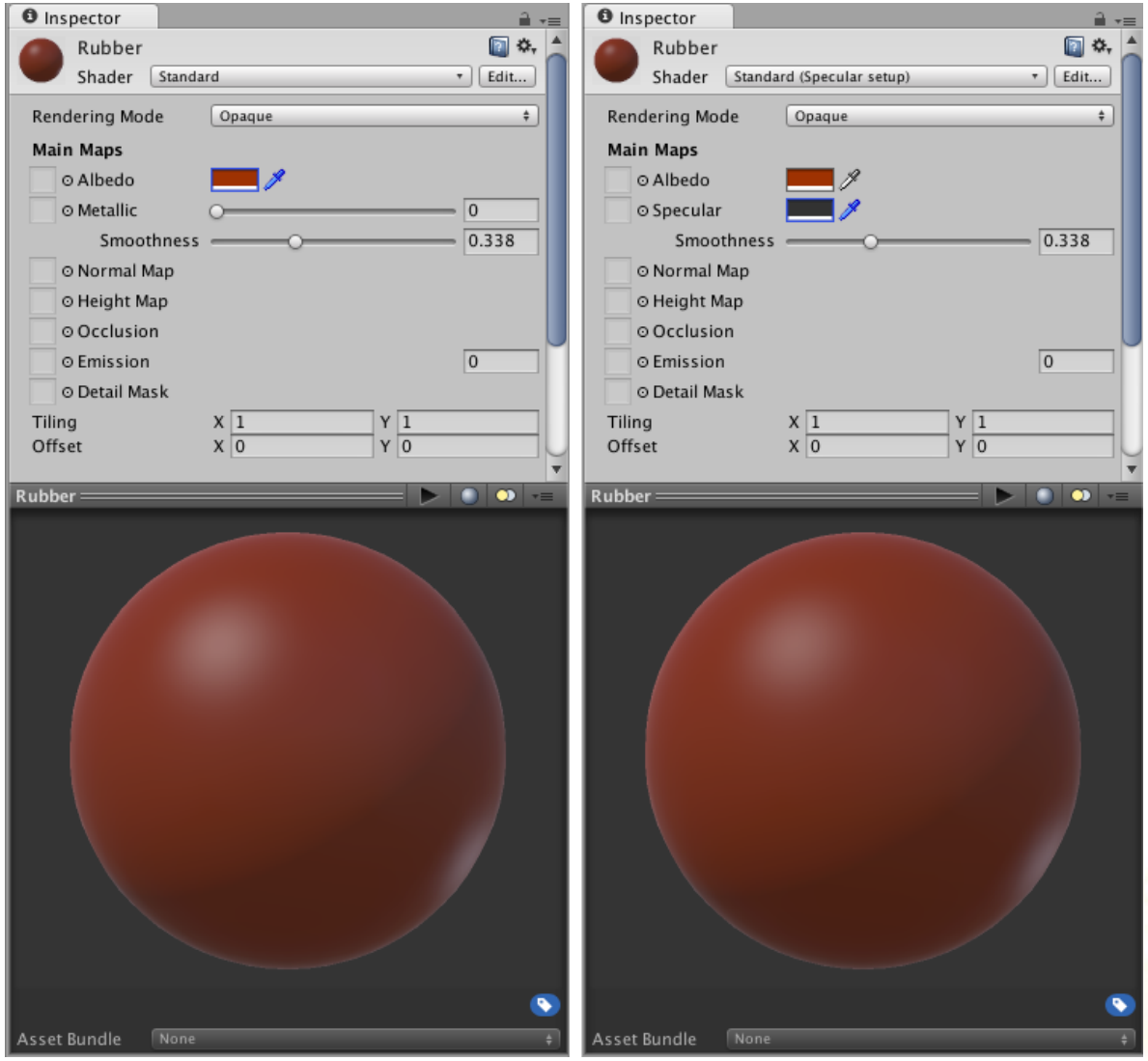
Standard Shader: Content and Context

- The appearance of material based on the Standard Shader is influenced by the content and context of the scene.
  - Context: light sources, skybox, indirect light, etc.
  - Content: scene objects, textures, etc.
- Example of scene with variations in context:

Metallic vs. Specular Workflow

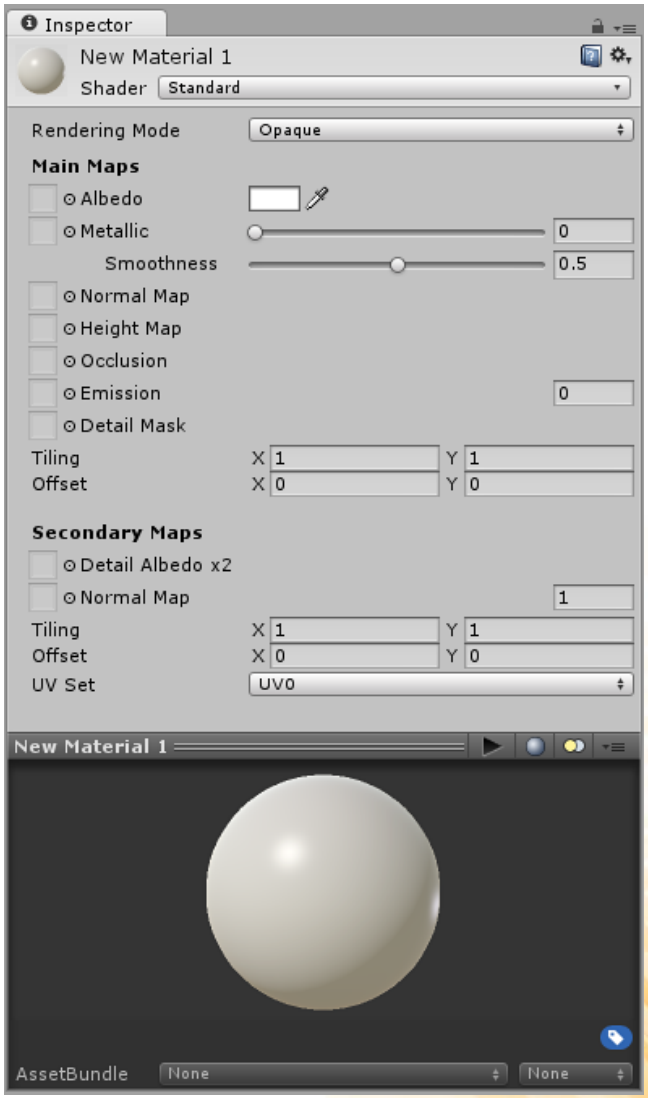
- There are two options of workflow when creating a material using the Standard shader: "Standard" and "Standard (Specular setup)“.
  - **Standard (Metallic setup)**: the shader exposes a “metallic” value that states whether the material is metallic or not.
    - The Albedo color will control the color of the specular reflection and most light will be reflected as specular reflections.
  - **Standard (Specular setup)**: a specular color is used to control the color and strength of specular reflections in the material.
    - This makes it possible to have a specular reflection of a different color than the diffuse reflection for instance.

Metallic vs. Specular Workflow



Standard Shader

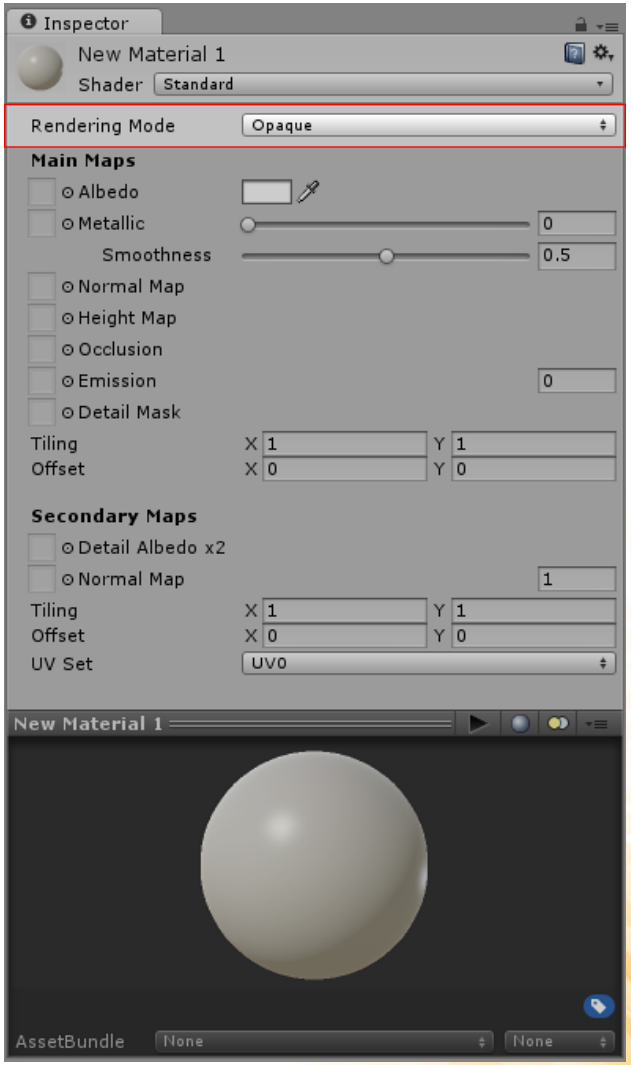
- Parameters:
  - Rendering Mode
  - Albedo
  - Specular Mode: Specular
  - Metallic Mode: Metallic
  - Smoothness
  - Normal Map (Bump Mapping)
  - Height Map (Parallax Mapping)
  - Occlusion Map
  - Emission
  - Detail Mask & Maps



Textures: http://www.inf.puc-rio.br/~elima/cg/textures.html

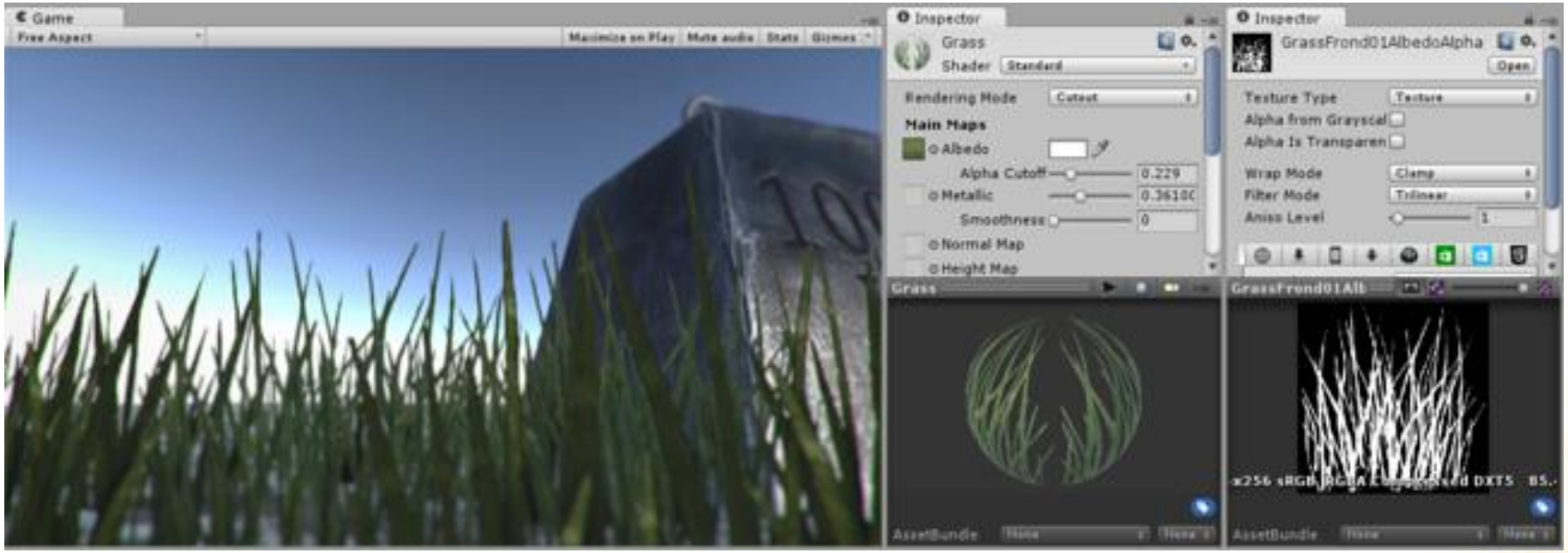
Standard Shader: Rendering Mode

- **Rendering Mode**: defines whether the object uses transparency, and if so, which type of blending mode to use.
  - **Opaque:** suitable for normal solid objects with no transparent areas.
  - **Cutout:** used to create a transparent effect that has hard edges between the opaque and transparent areas. Useful to create leaves or cloth with holes.
  - **Transparent:** suitable for rendering realistic transparent materials such as clear plastic or glass. Reflections and lighting highlights will remain visible.
  - **Fade:** allows the transparency values to entirely fade an object out, including any specular highlights or reflections it may have.



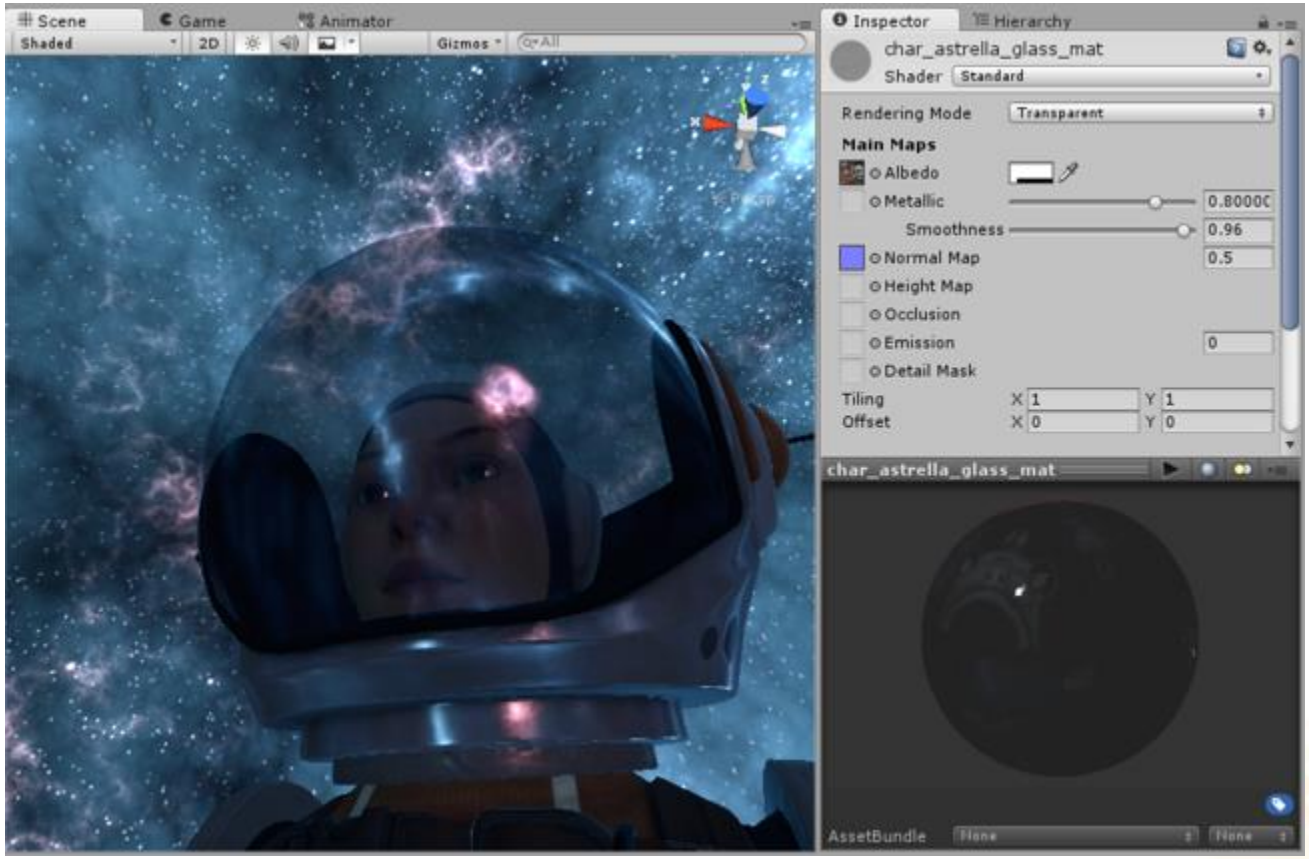
Standard Shader: Rendering Mode

- Cutout Mode – Example



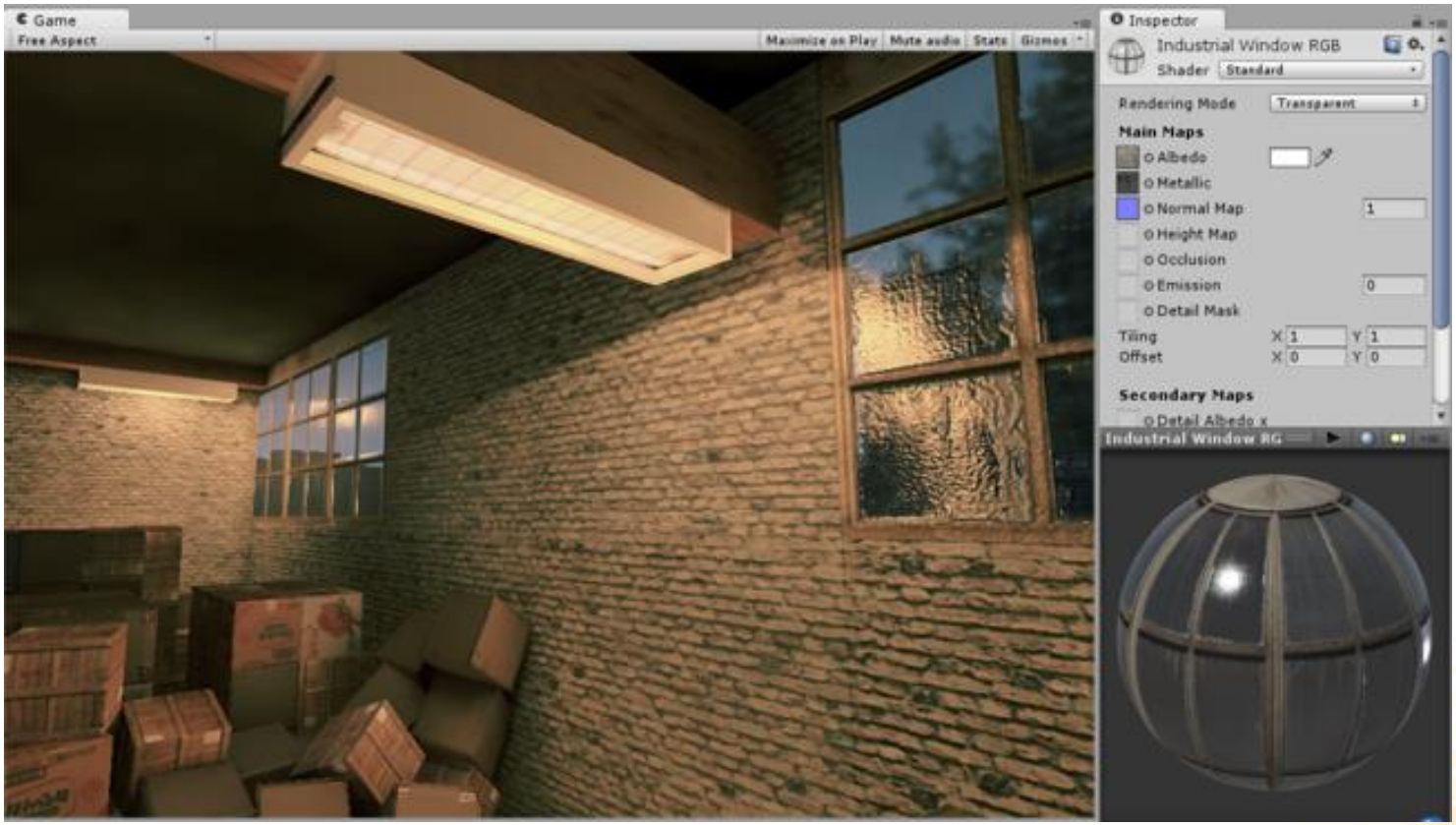
Standard Shader: Rendering Mode

- Transparent Mode – Example



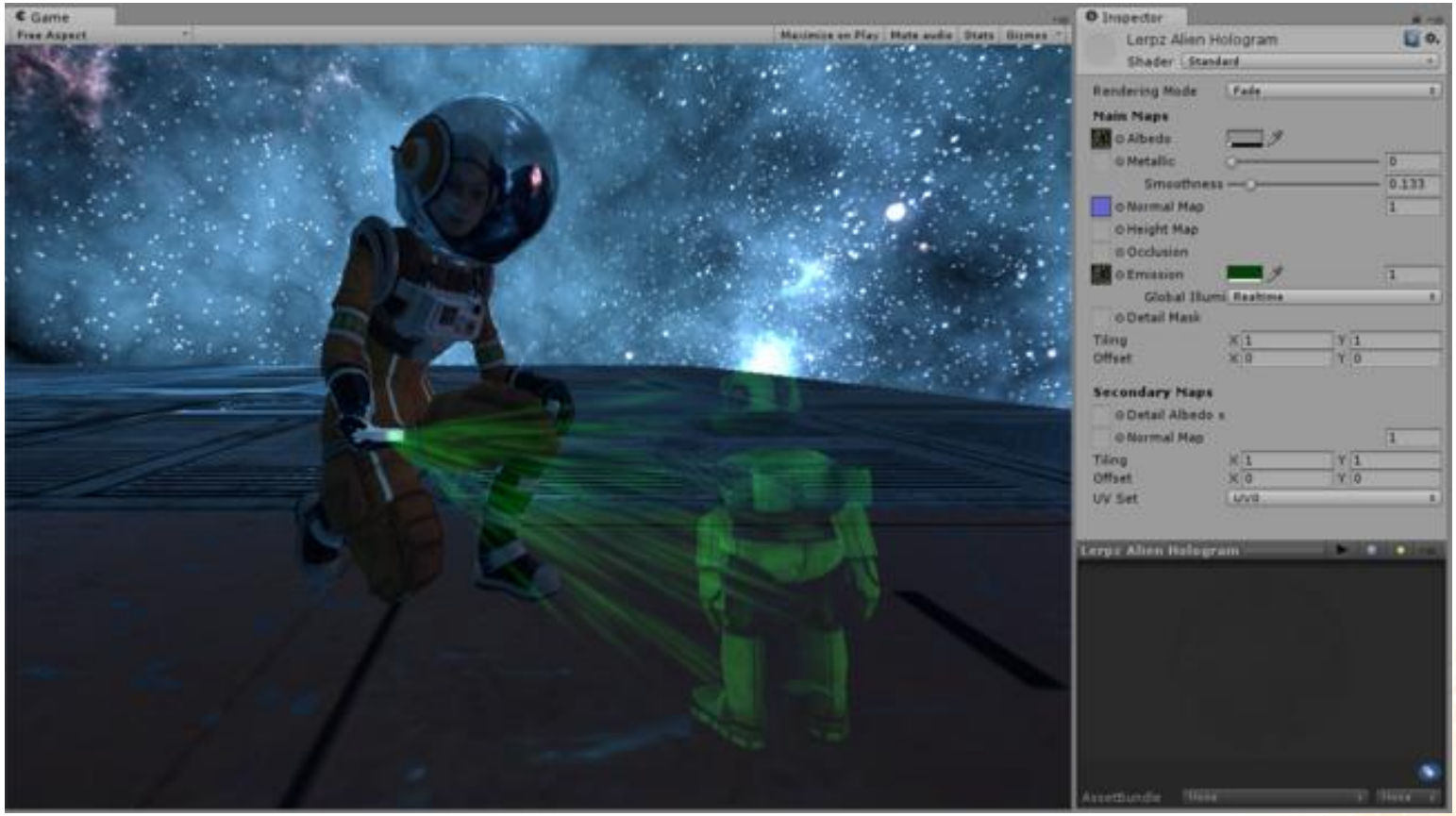
Standard Shader: Rendering Mode

- Transparent Mode – Example with fully opaque areas



Standard Shader: Rendering Mode

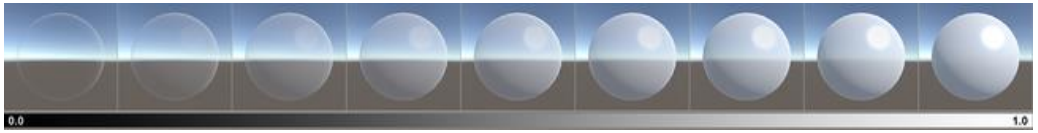
- Fade Mode – Example

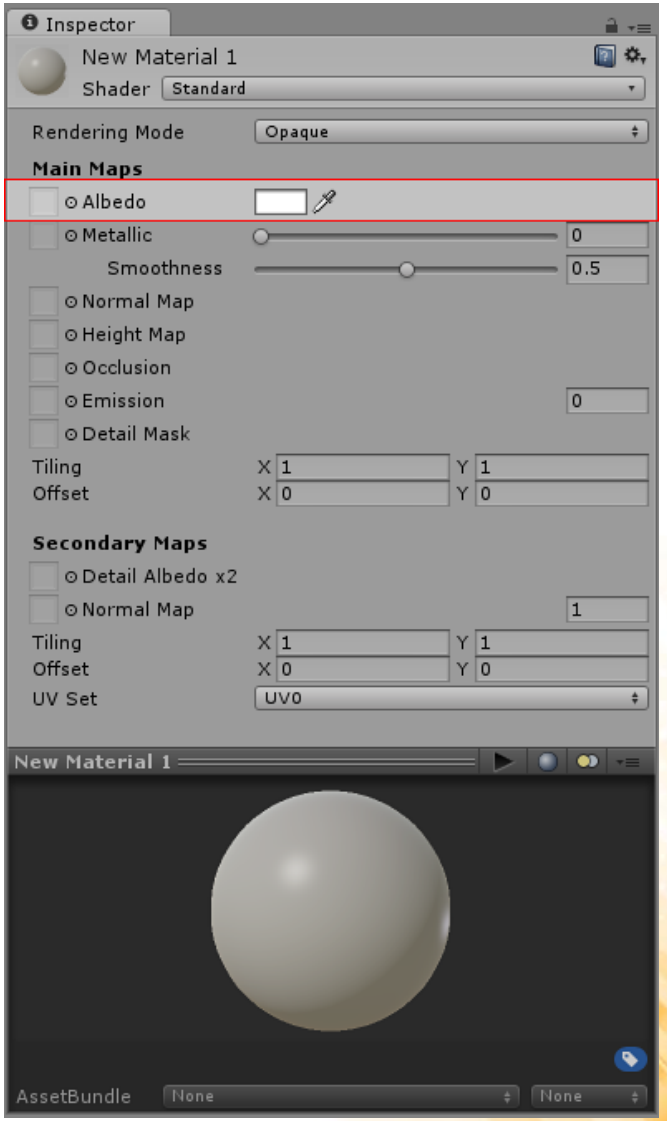


Standard Shader: Albedo

- **Albedo**: defines the base color or texture of the material.

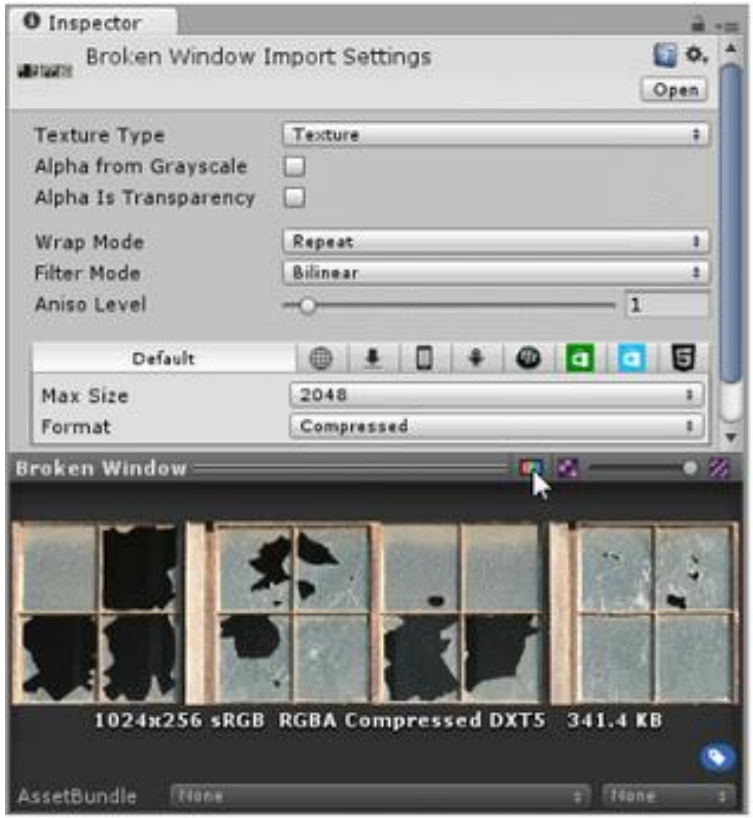
- The alpha value of the Albedo color controls the transparency level for the material.
  - This only has an effect if the Rendering Mode for the material is not set to opaque.

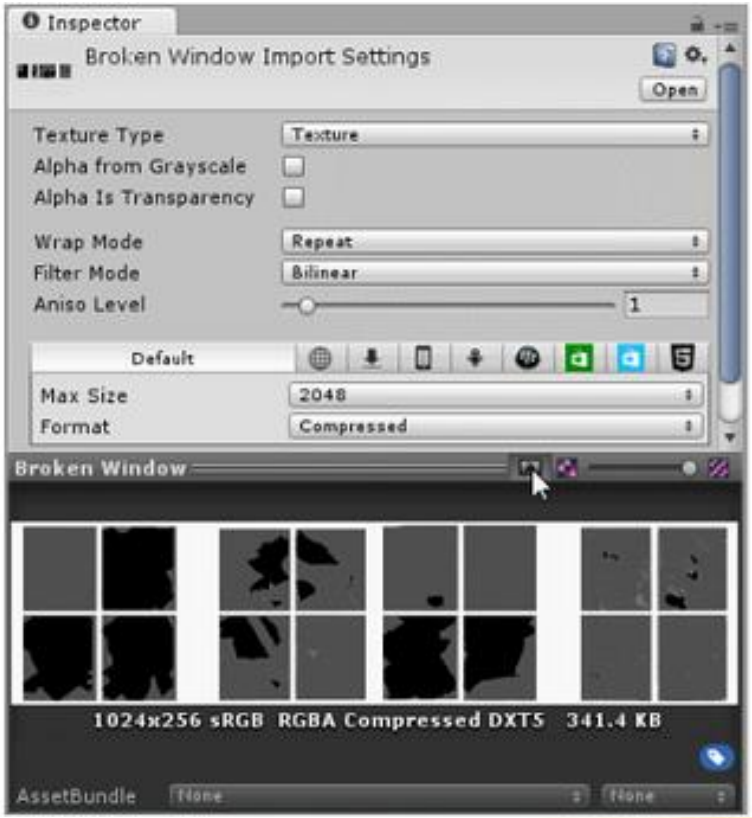




Standard Shader: Albedo

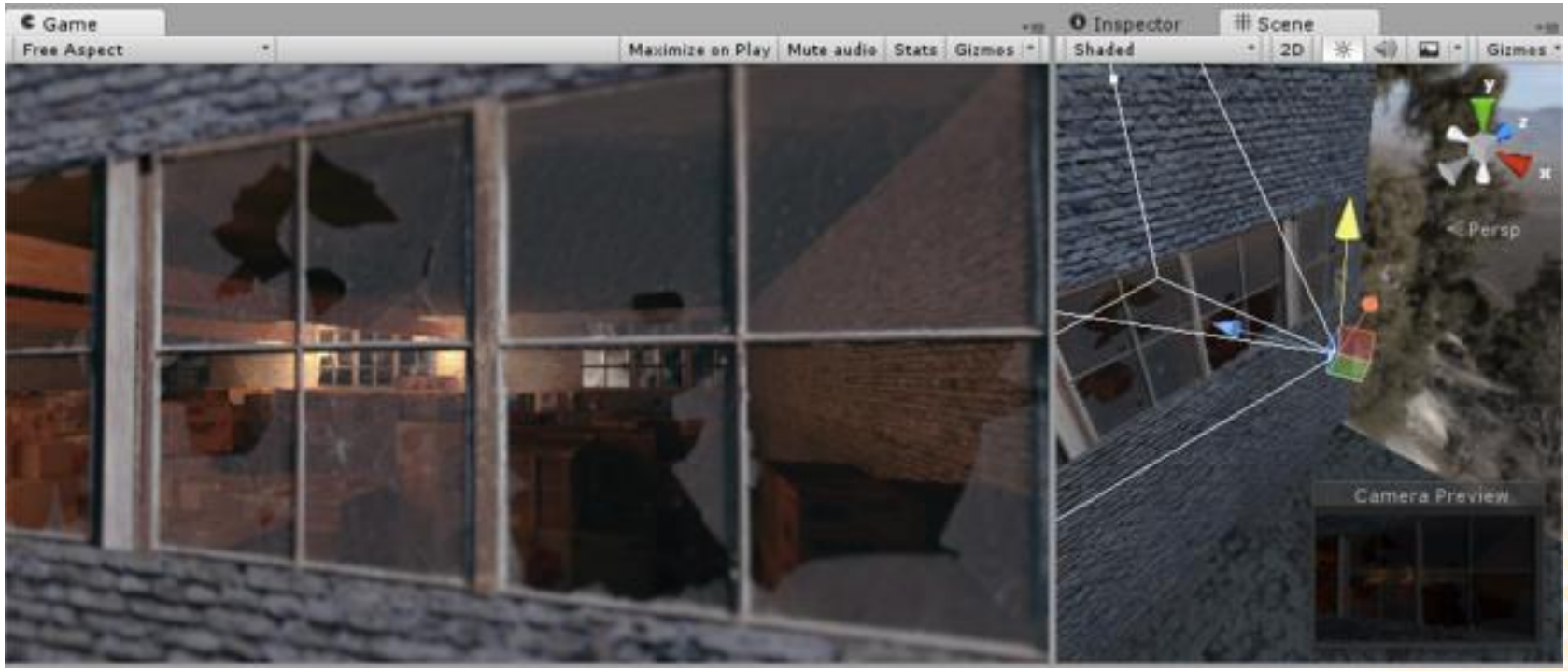
- Transparencies in areas of the material must be specified in the texture alpha channel.





Standard Shader: Albedo

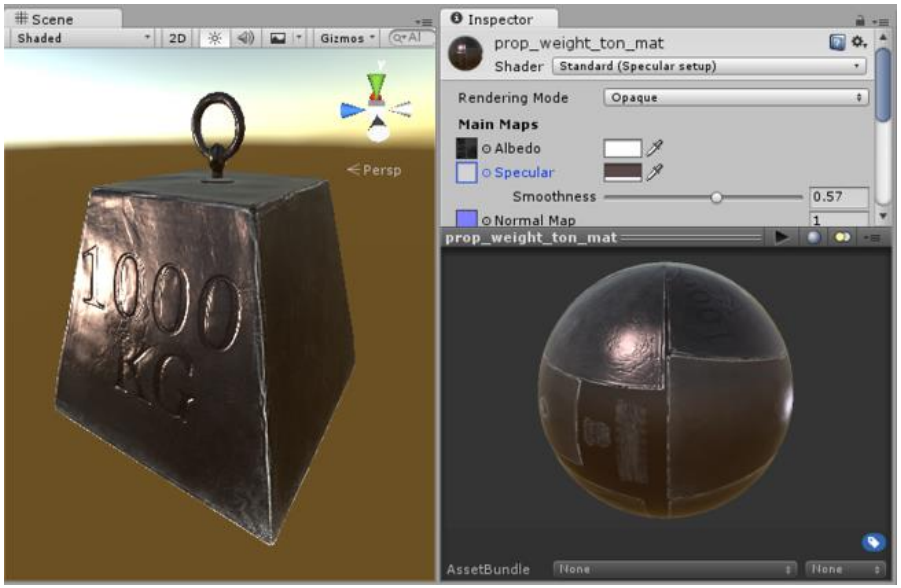
- Transparencies in areas of the material must be specified in the texture alpha channel.

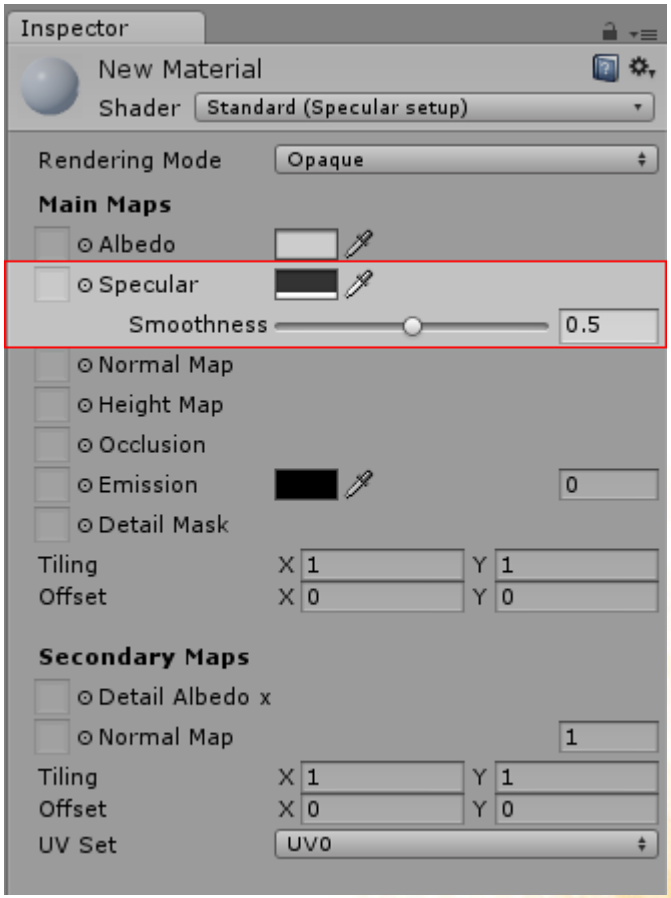


Standard Shader: Specular

- **Specular (Specular Mode)**: represents the direct reflections of light sources, which typically show up as bright highlights on the surface of objects.

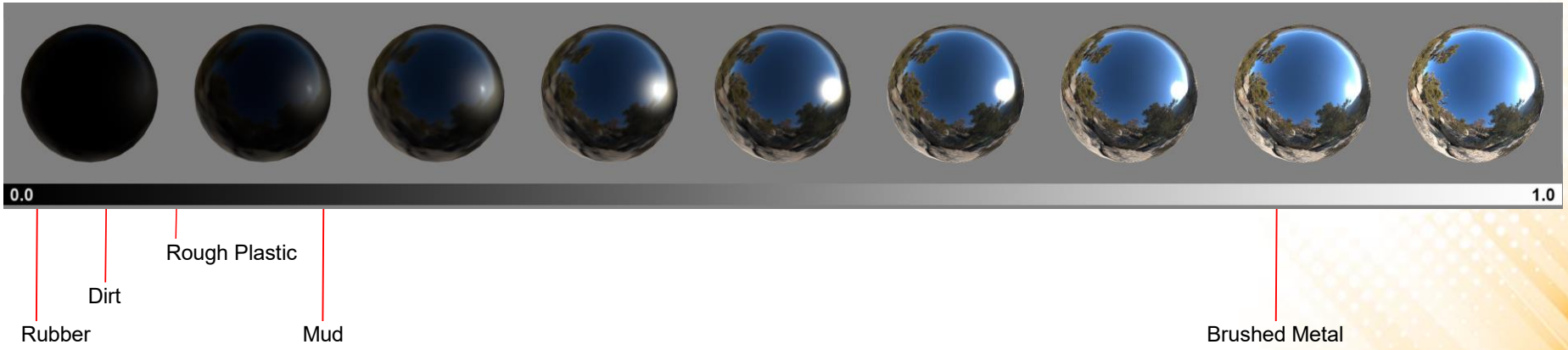
- Example:





Standard Shader: Specular

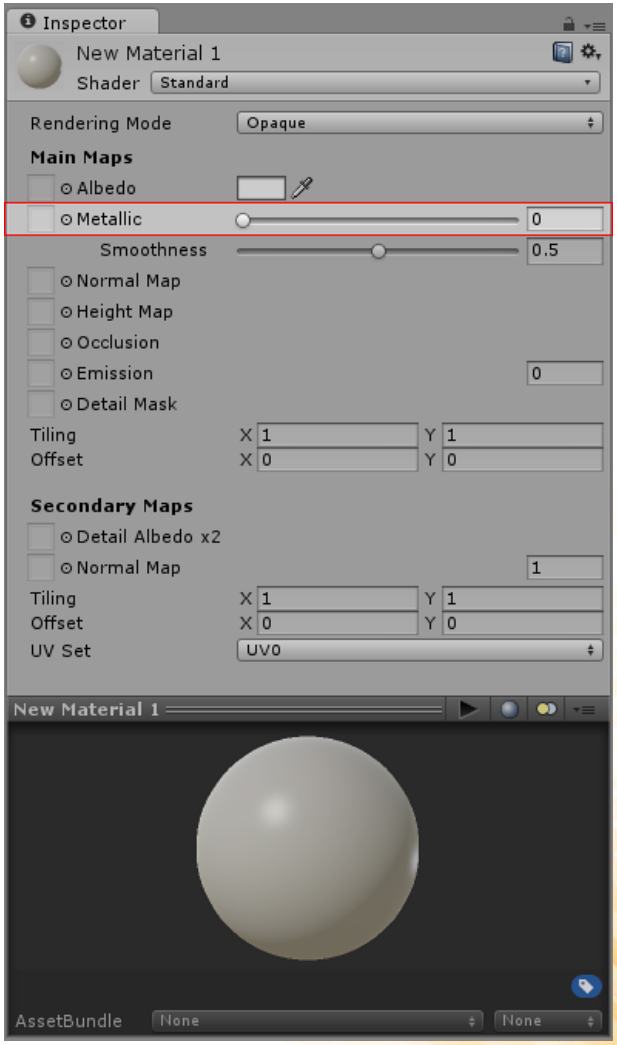
- The color of the Specular parameter controls the strength and color of the specular reflectivity.
- The Smoothness parameter controls the clarity of the specular effect.
  - Low smoothness value = even strong specular reflections appear blurred and diffuse.
  - High smoothness value = specular reflections are crisper and clearer.



Standard Shader: Metallic

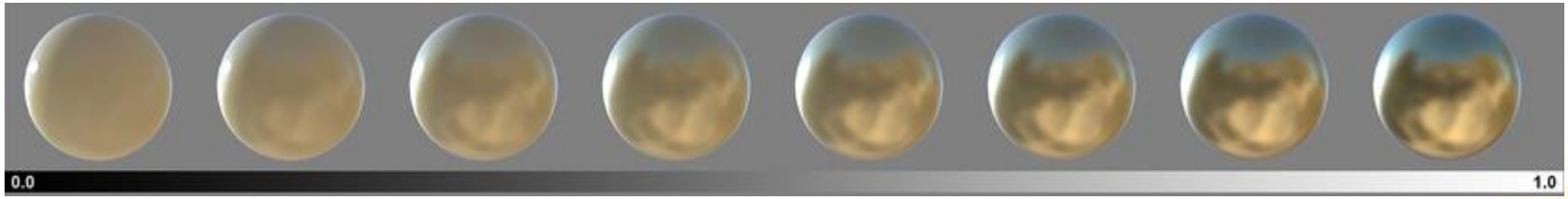
- **Metallic (Metallic Mode)**: specular reflections arise naturally depending on the settings of the Metallic and Smoothness levels (rather than being explicitly defined as in the specular mode).

- Example:



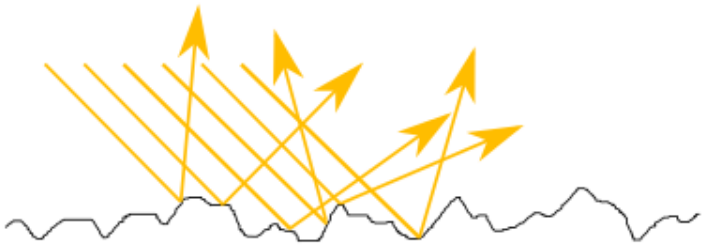
Standard Shader: Metallic

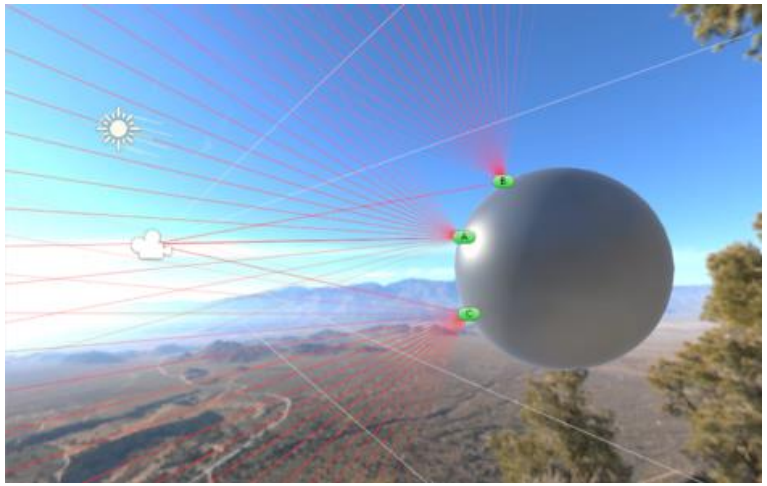
- The metallic parameter determines how “metal-like” the surface is.
  - When a surface is more metallic, it reflects the environment more and its albedo color becomes less visible.
  - When a surface is less metallic, its albedo color is more clear and any surface reflections are visible on top of the surface color.

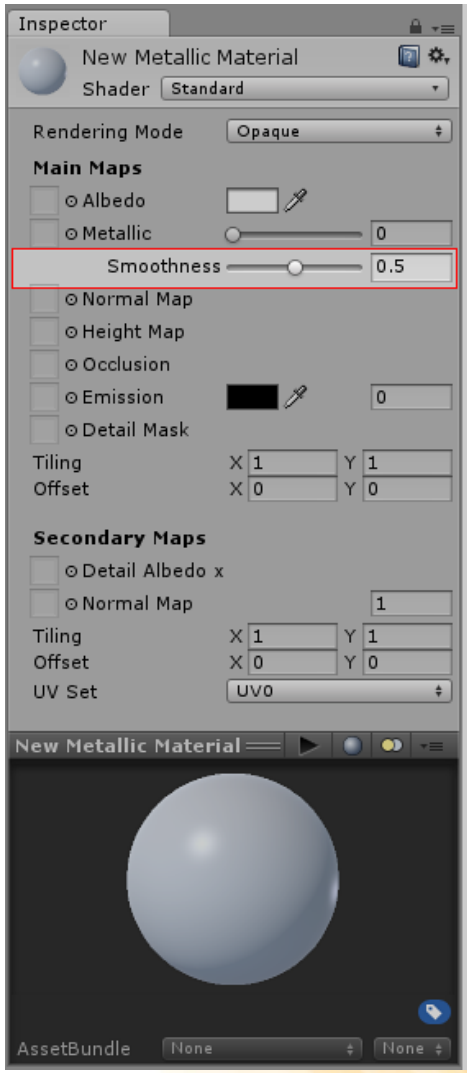


Standard Shader: Smoothness

- **Smoothness**: defines how light scatters when it hits the surface of the object. Represents "microsurface details" of the object.
- Low Smoothness:

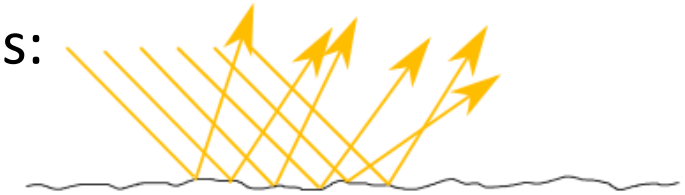


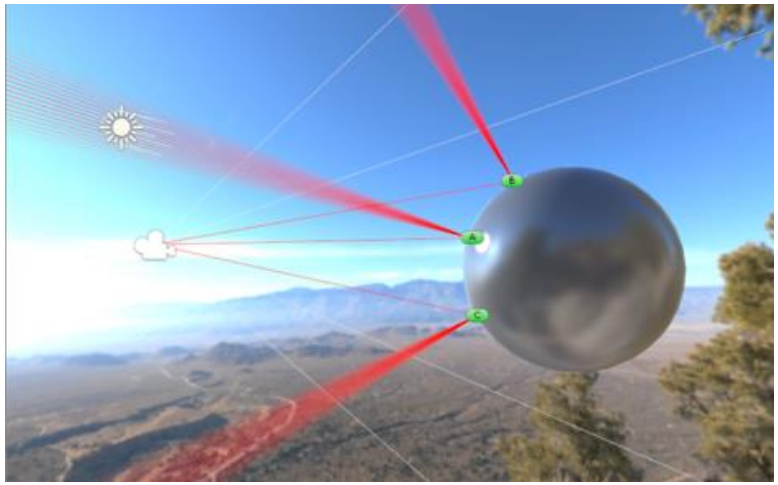


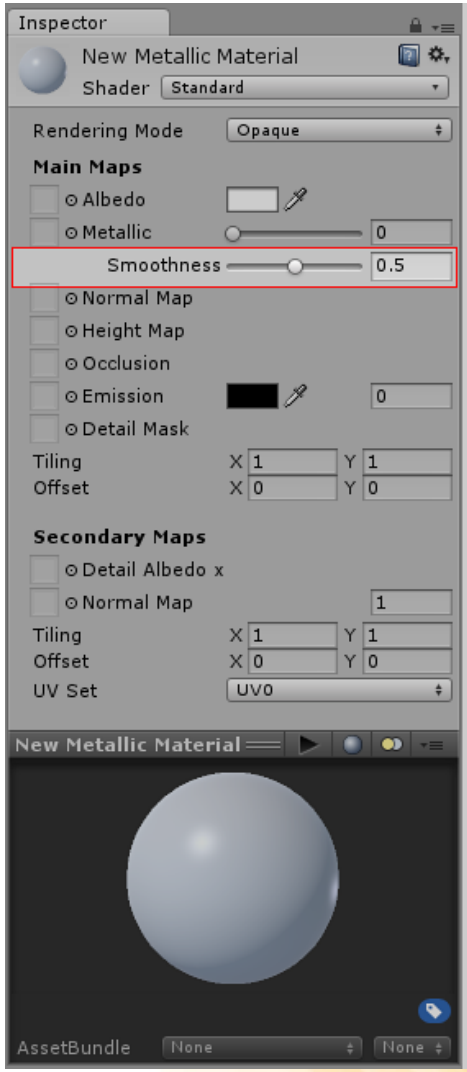


Standard Shader: Smoothness

- **Smoothness**: defines how light scatters when it hits the surface of the object. Represents "microsurface details" of the object.
- Median Smoothness:

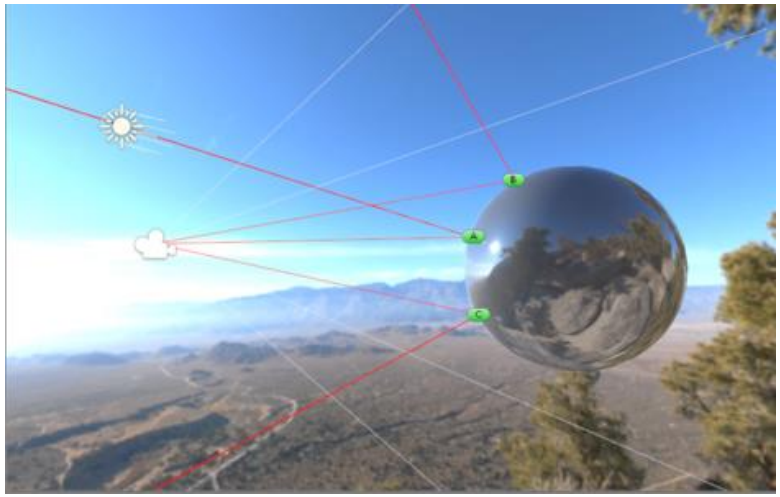


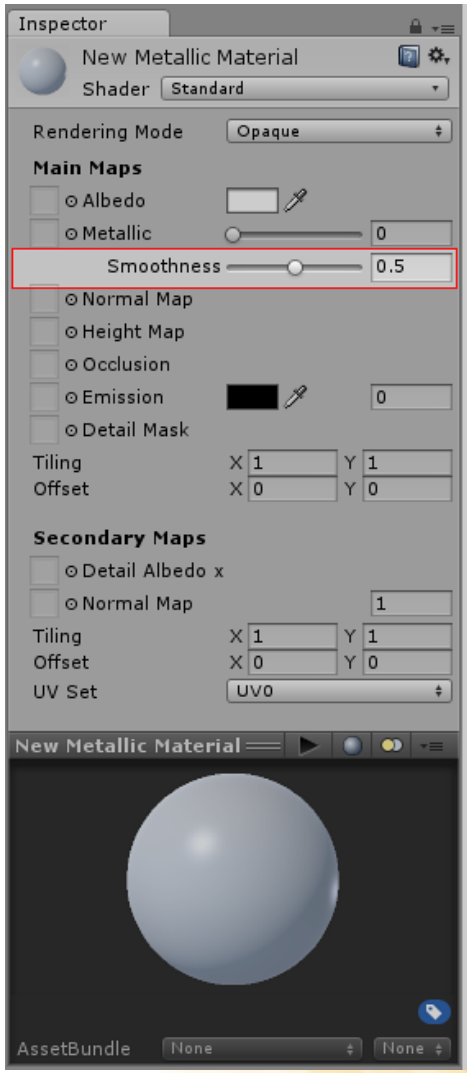




Standard Shader: Smoothness

- **Smoothness**: defines how light scatters when it hits the surface of the object. Represents "microsurface details" of the object.
- High Smoothness:

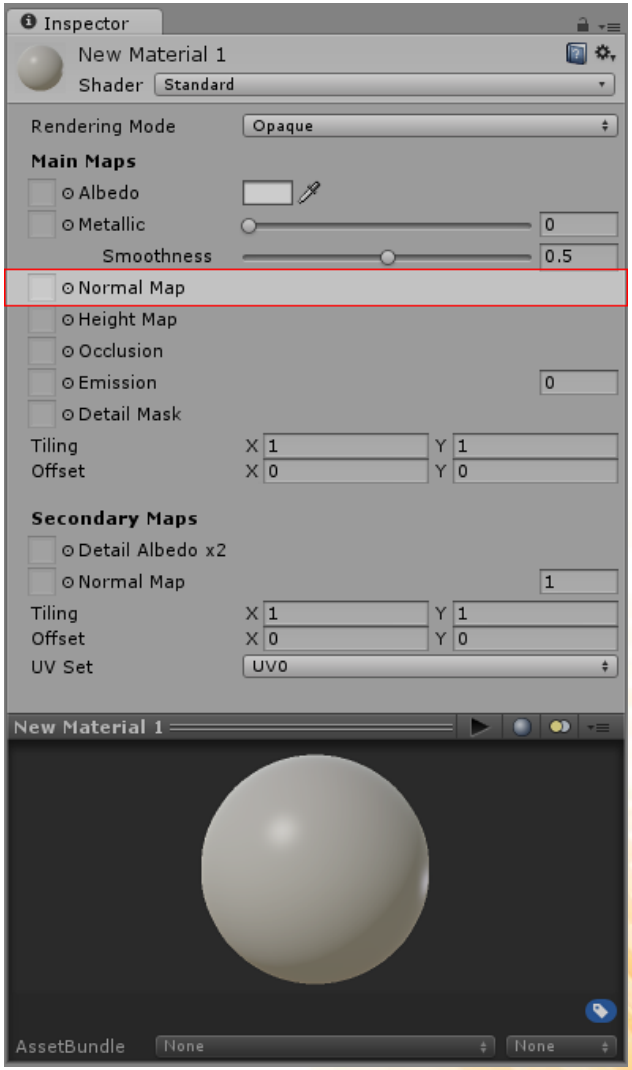




Standard Shader: Normal Map

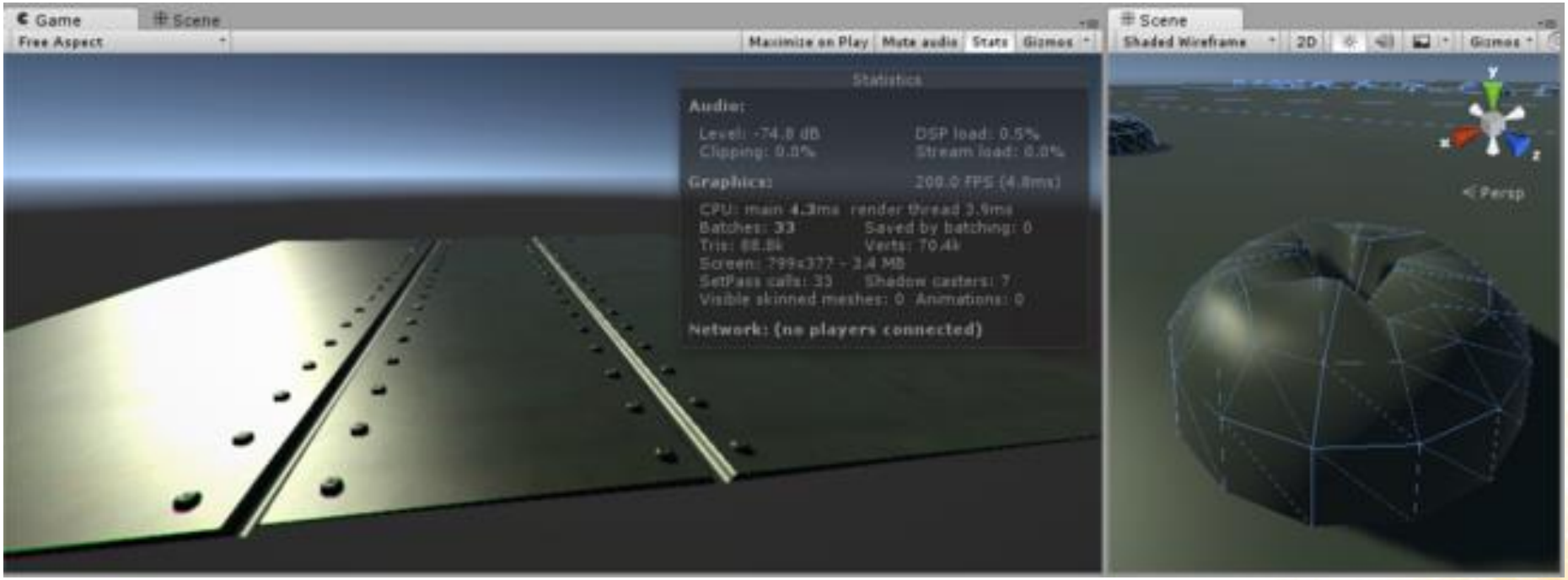
- **Normal Map (Bump Mapping)**: adds surface detail such as bumps, grooves, and scratches to a model which catch the light as if they are represented by real geometry.

- Example of Normal Map texture:



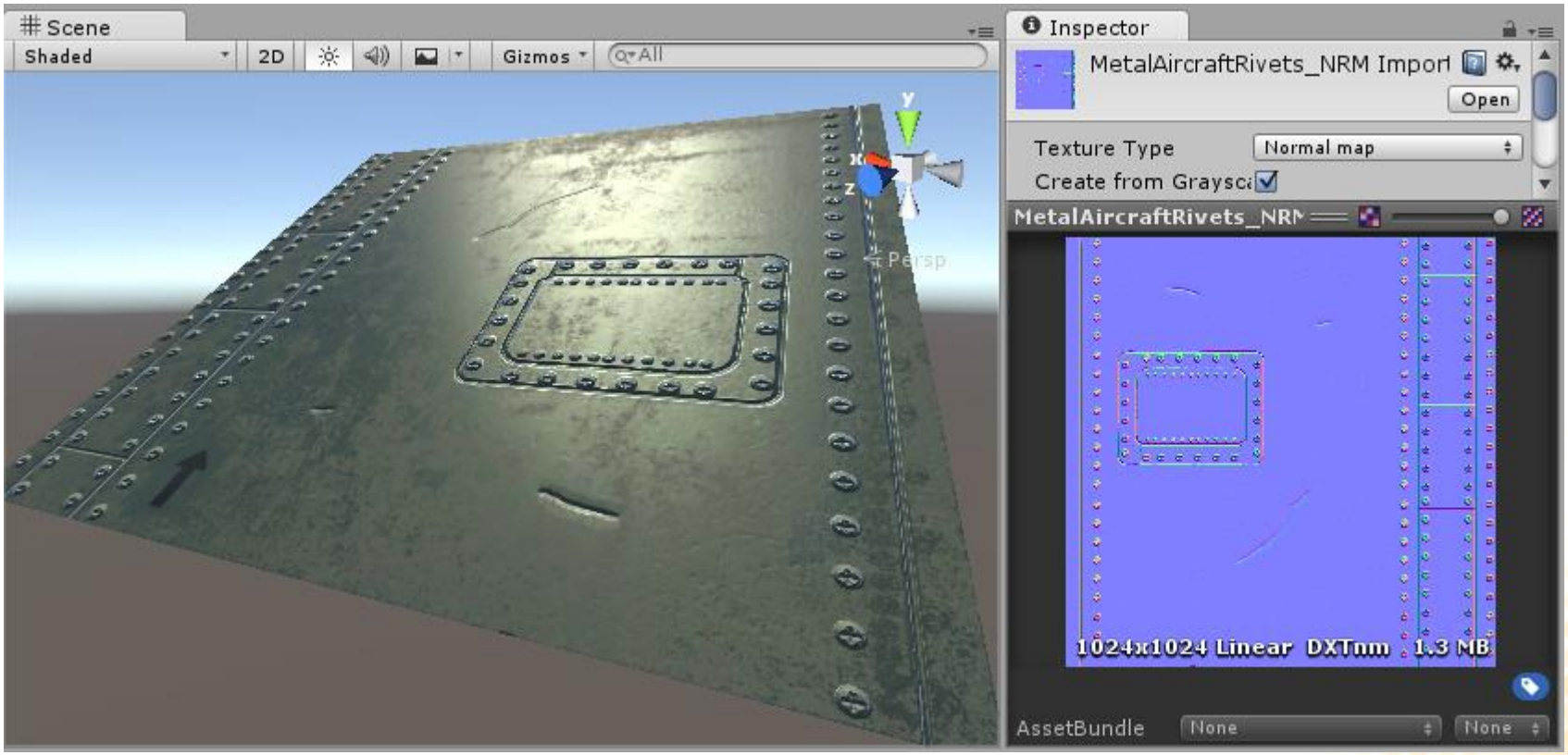
Standard Shader: Normal Map

- Example: screws in metal surface (without bump mapping)



Standard Shader: Normal Map

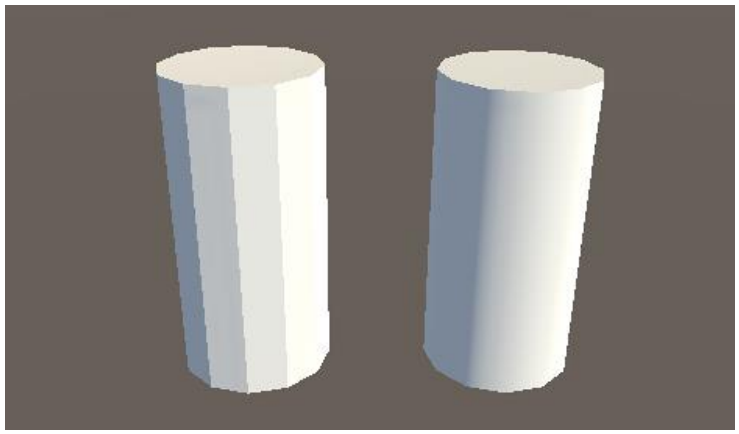
- Example: screws in metal surface (with bump mapping)

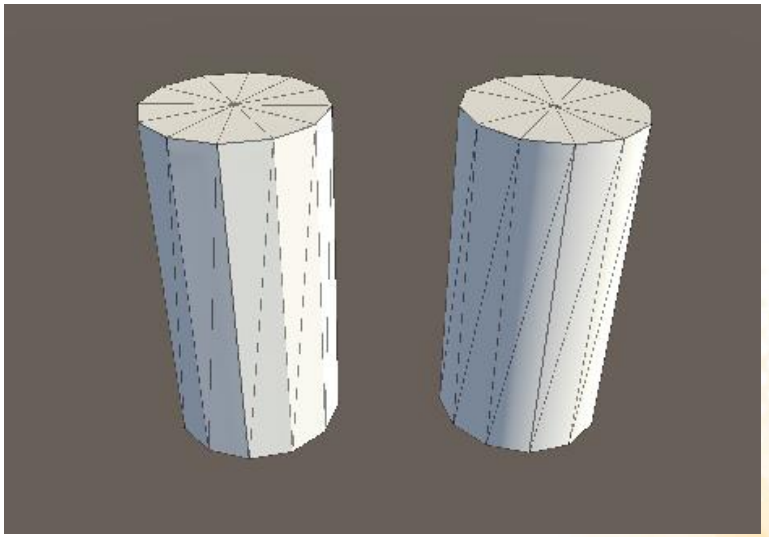


Standard Shader: Normal Map

- Bump mapping is a technique for simulating bumps on the surface of an object. This is achieved by perturbing the surface normals of the object and using the perturbed normal during lighting calculations.

- What are Surface Normals?

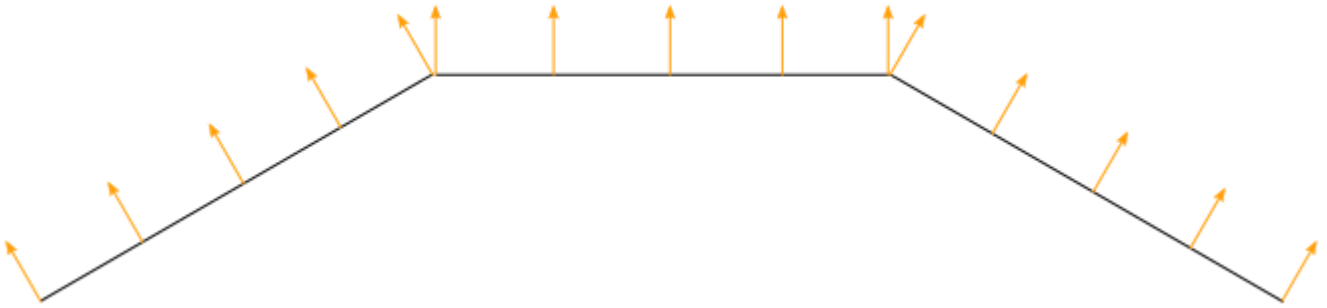




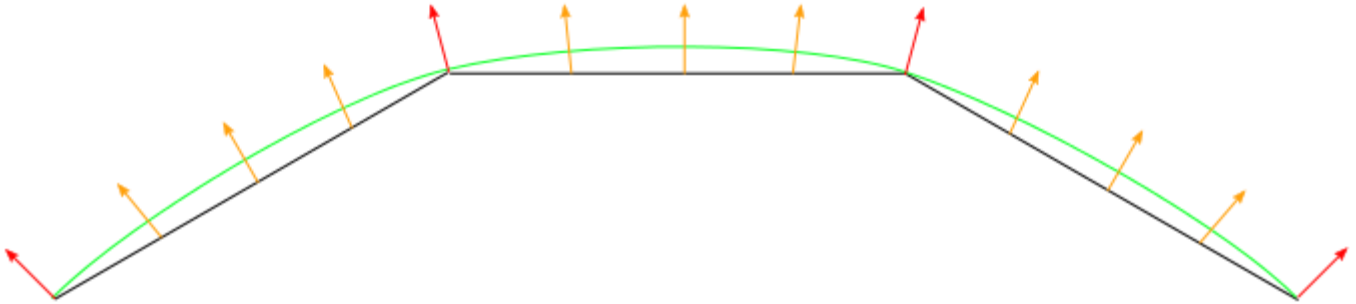
Standard Shader: Normal Map

- What are Surface Normals?

Flat Surface:

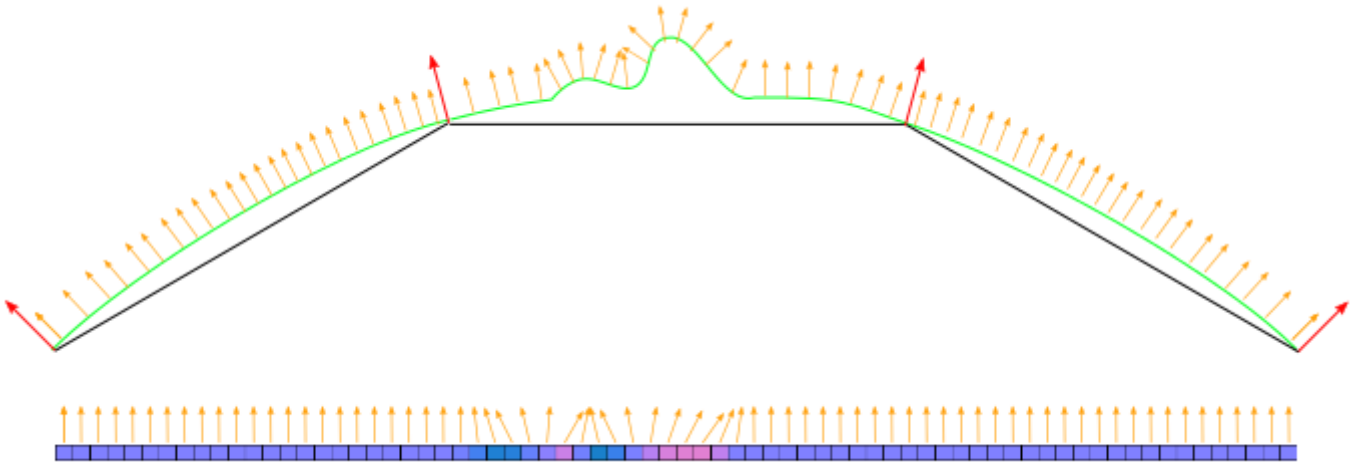


Smooth Surface:



Standard Shader: Normal Map

- What is Normal Mapping?



Standard Shader: Normal Map

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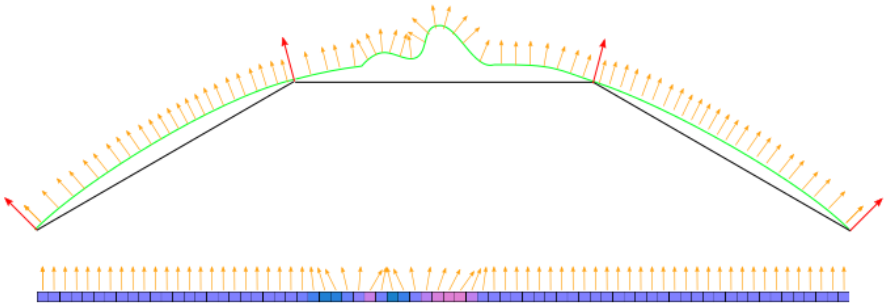
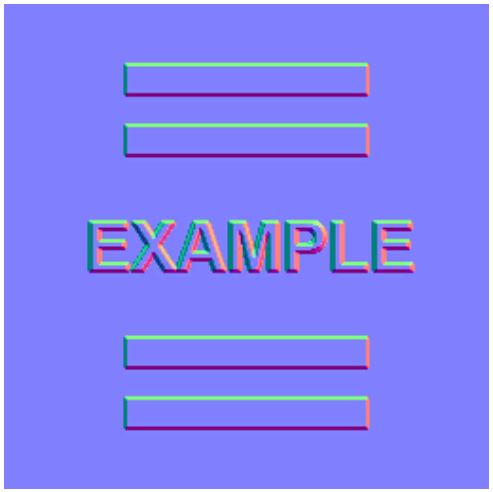
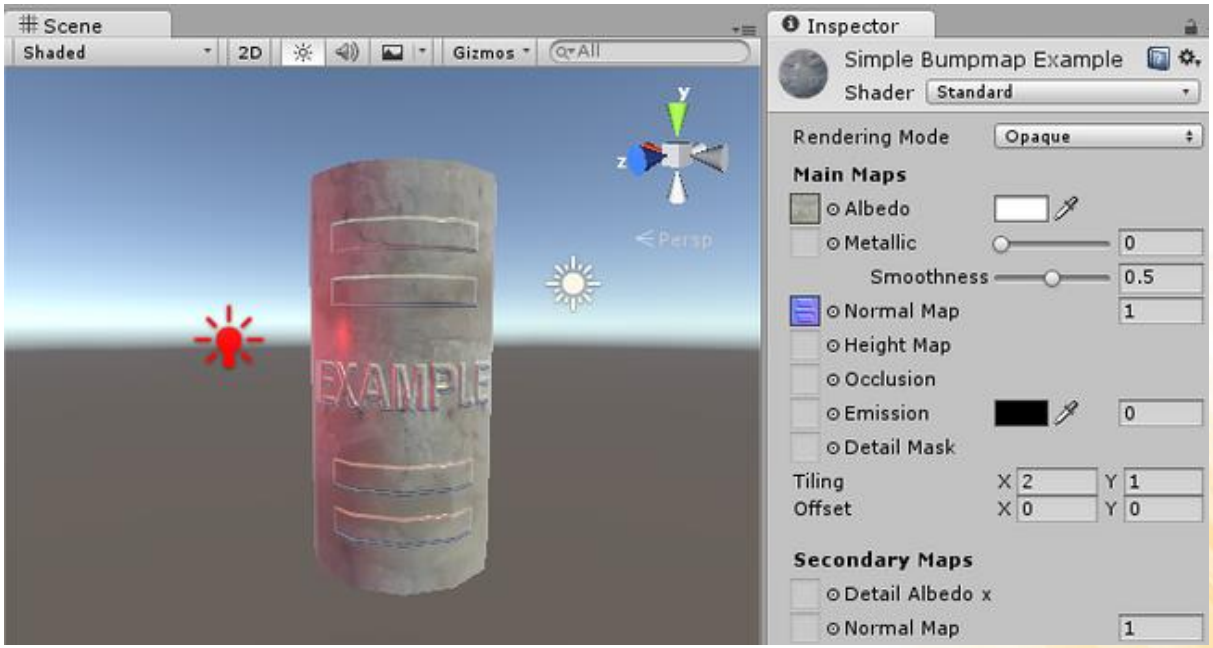
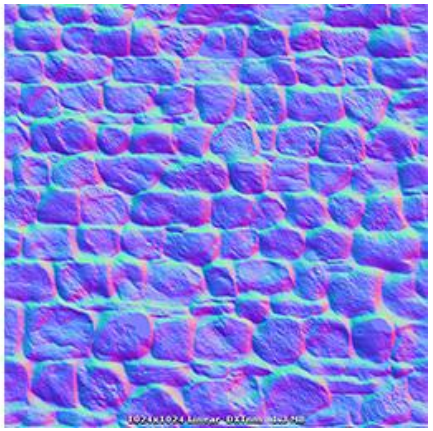






Standard Shader: Normal Map

- **How do I get or make normal maps?**
  - During the 3D modelling process:
    - Very high resolution model + lower resolution “game ready” model.
  - From a texture:
    - ShaderMap - http://shadermap.com/
  - Can be produced by hand.

Standard Shader: Normal Map

- **Result:**

Without Normal Mapping

Standard Shader: Normal Map

- **Result:**

With Normal Mapping (directional light)

Standard Shader: Normal Map

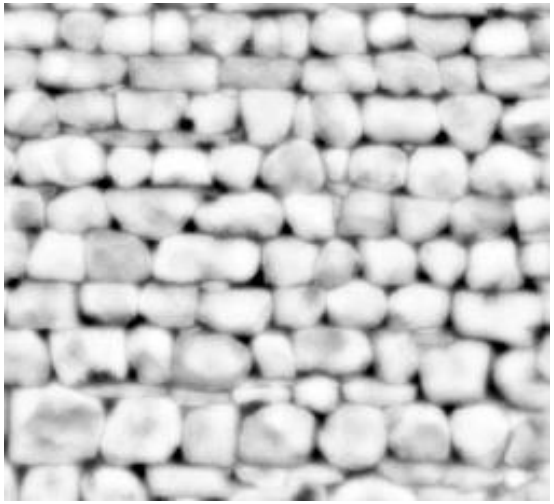
- **Result:**

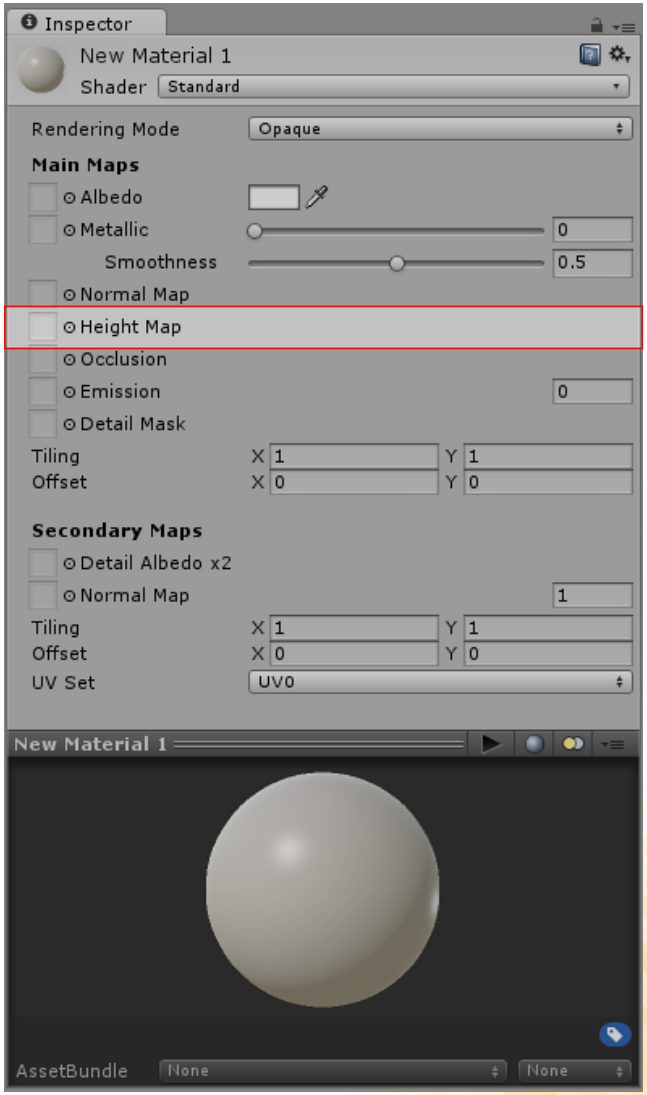
With Normal Mapping (point light)

Standard Shader: Height Map

- **Height Map**: as normal maps, height maps add surface details. Are used to give extra definition to surfaces and render large bumps and protrusions.

- Example of Height Map texture:

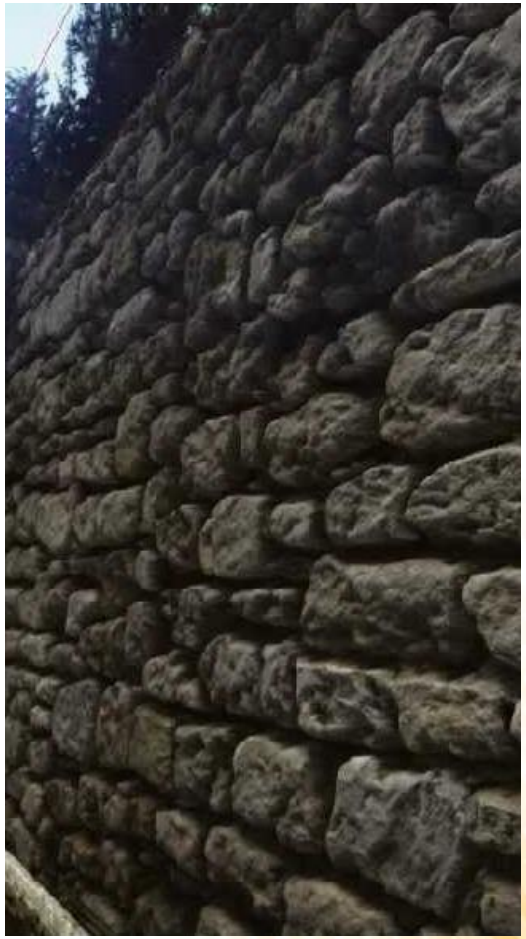




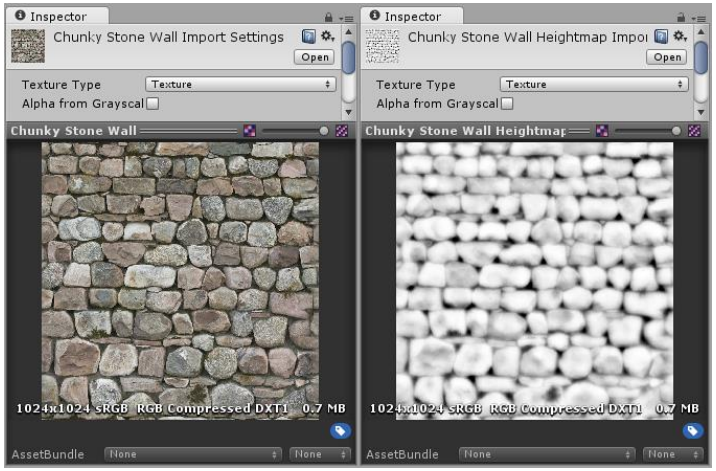
Standard Shader: Height Map

- Height mapping (also known as parallax mapping) is a similar concept to normal mapping, however this technique is more complex - and therefore also more performance-expensive.

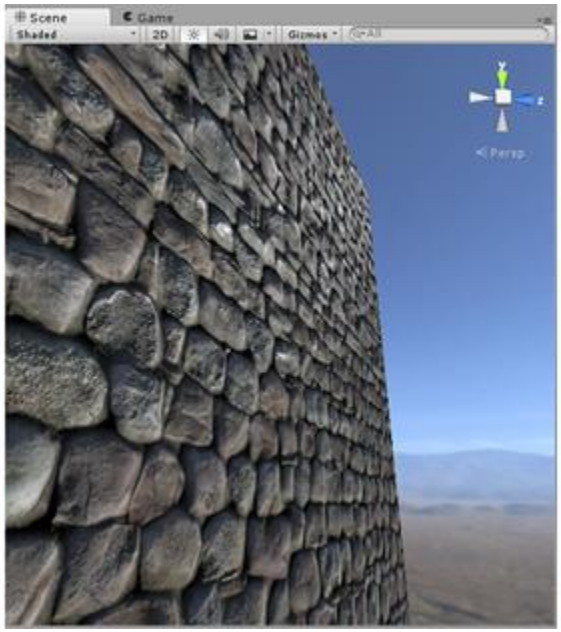
- While normal mapping modifies the lighting across the surface of the texture, parallax height mapping goes a step further and actually shifts the areas of the visible surface texture around.
  - The effect is drawn onto the surface of the model and does not modify the actual geometry.



Standard Shader: Height Map



Without Bump Mapping

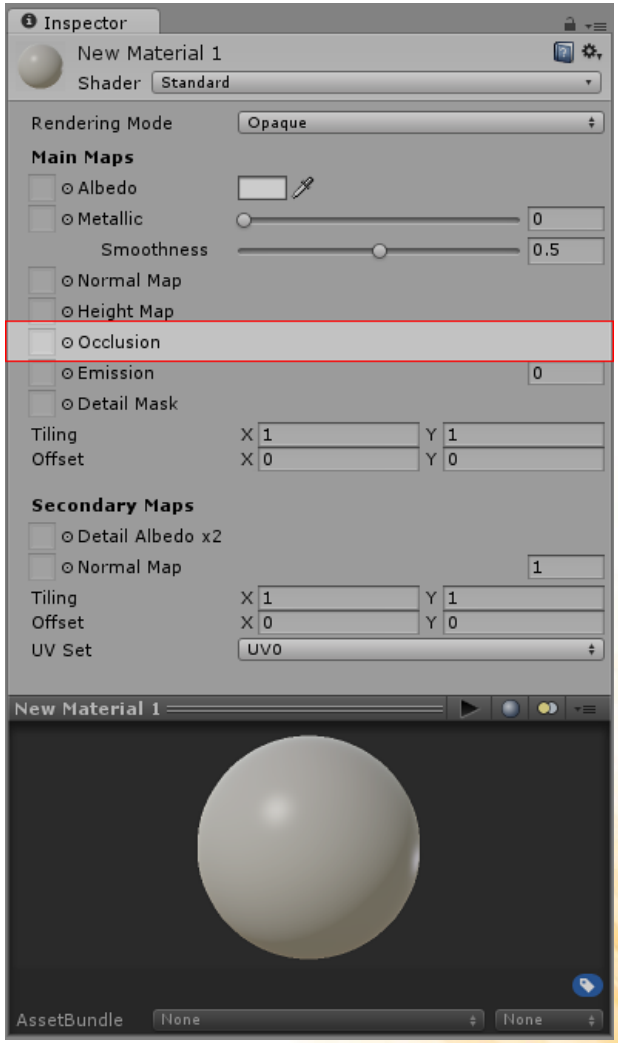


With Normal Mapping

With Hight Mapping

Standard Shader: Occlusion Map

- **Occlusion Map**: used to provide information about which areas of the model should receive high or low indirect lighting.
  - Example: concave areas usually do not receive much indirect light.
- Example of Occlusion Map texture:



Standard Shader: Occlusion Map

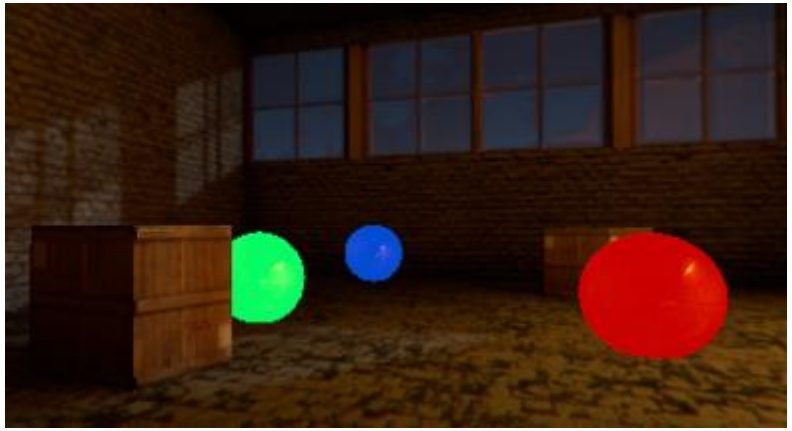
Without Occlusion Mapping

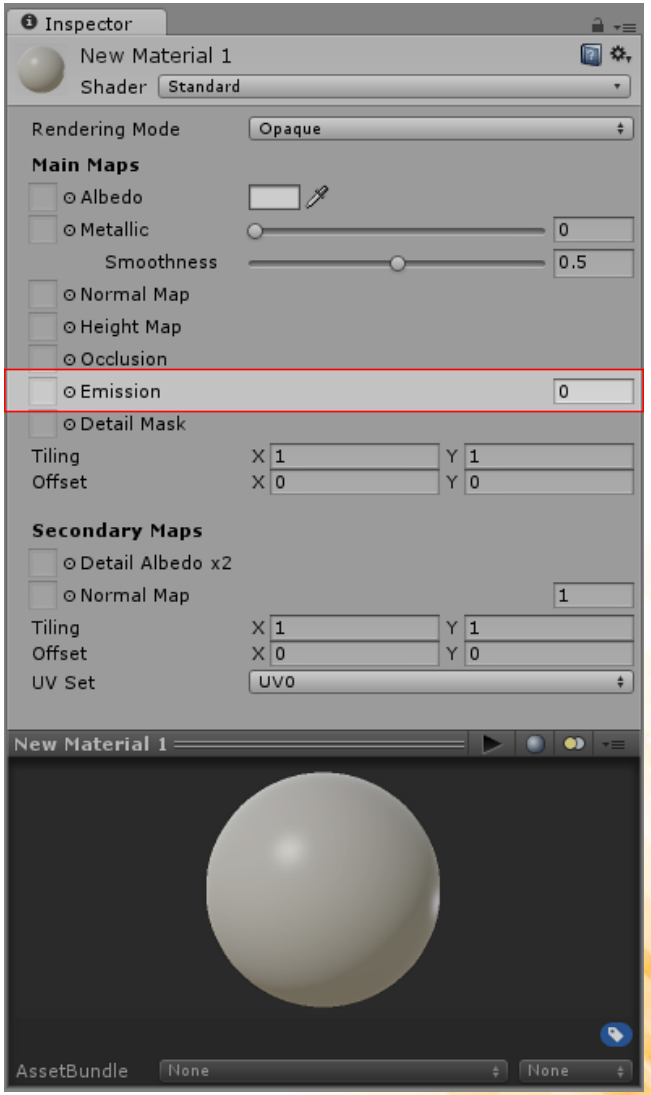
With Occlusion Mapping

Standard Shader: Emission

- **Emission**: controls color and intensity of light emitted from the surface. When an emissive material is used in your scene, it appears to be a visible source of light itself.

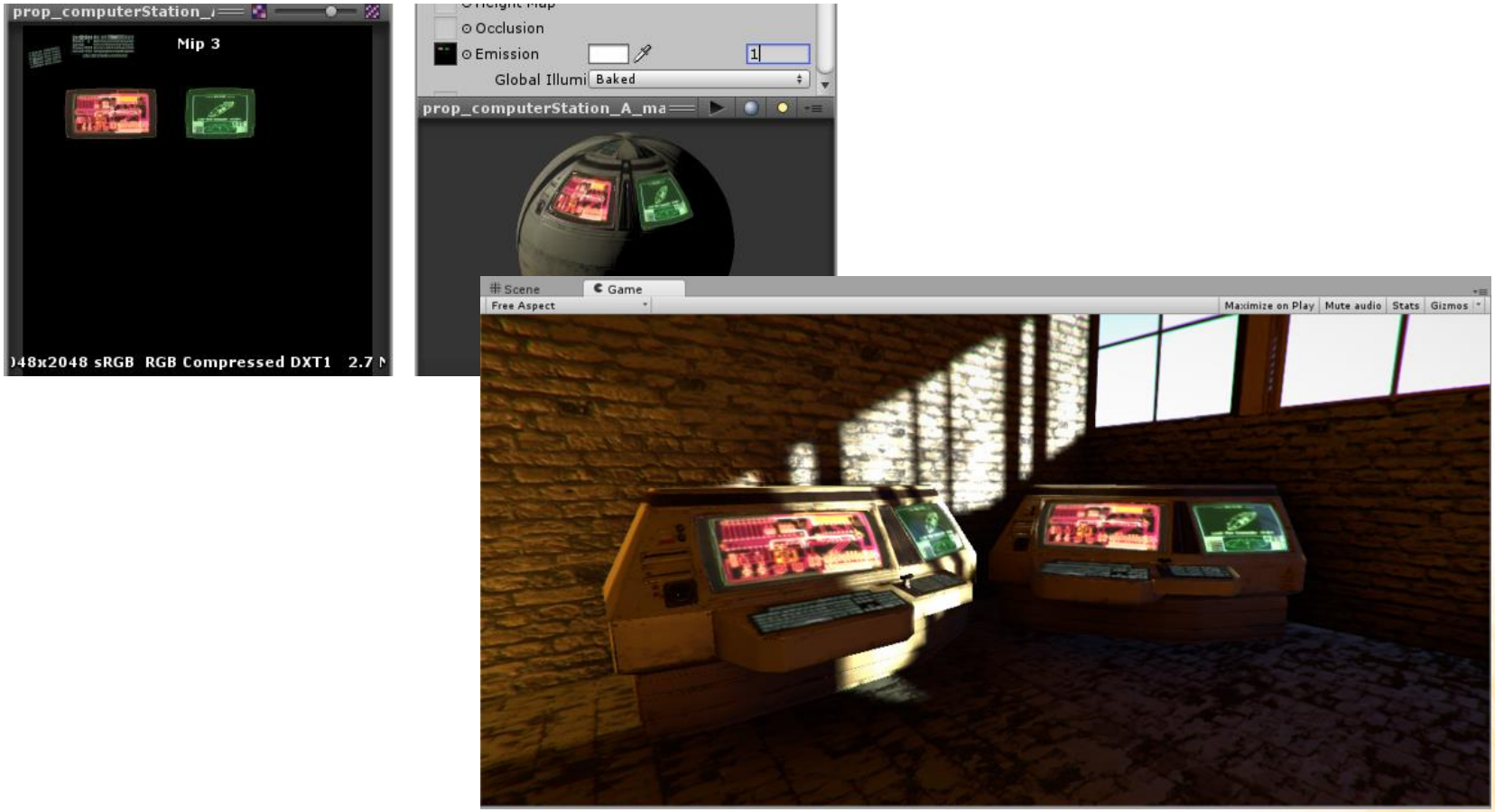
- Example:





Standard Shader: Emission

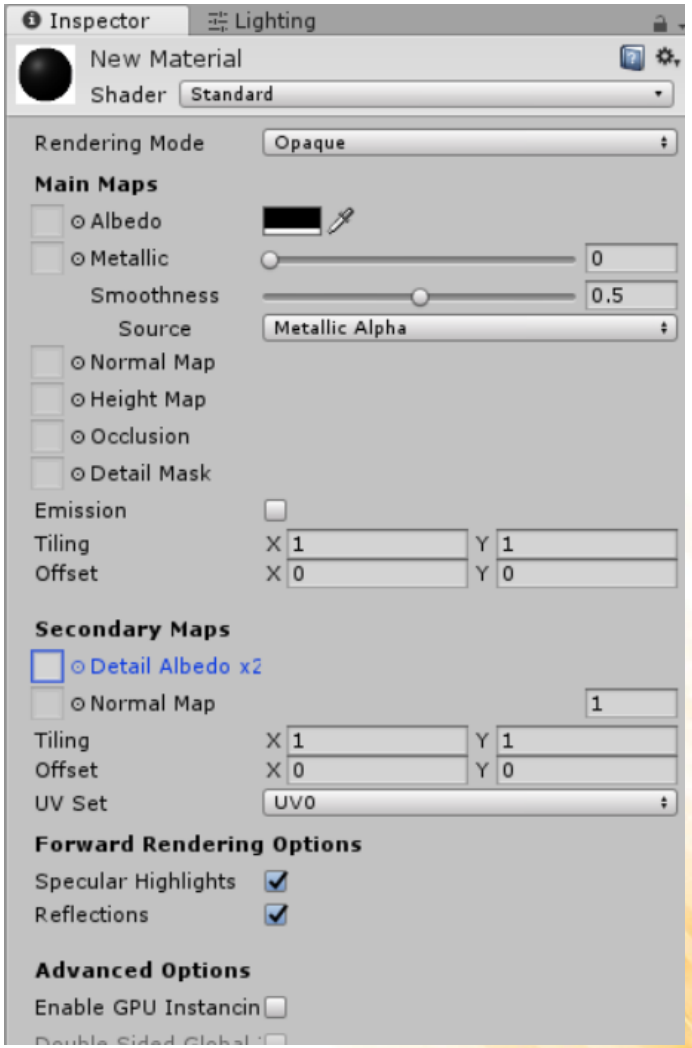
- It is also possible to assign an emission map texture:



Standard Shader: Secondary Maps & Detail Mask

- **Secondary Maps**: allows the overlay of a second set of textures on top of the main textures (second Albedo color map and a second Normal map).

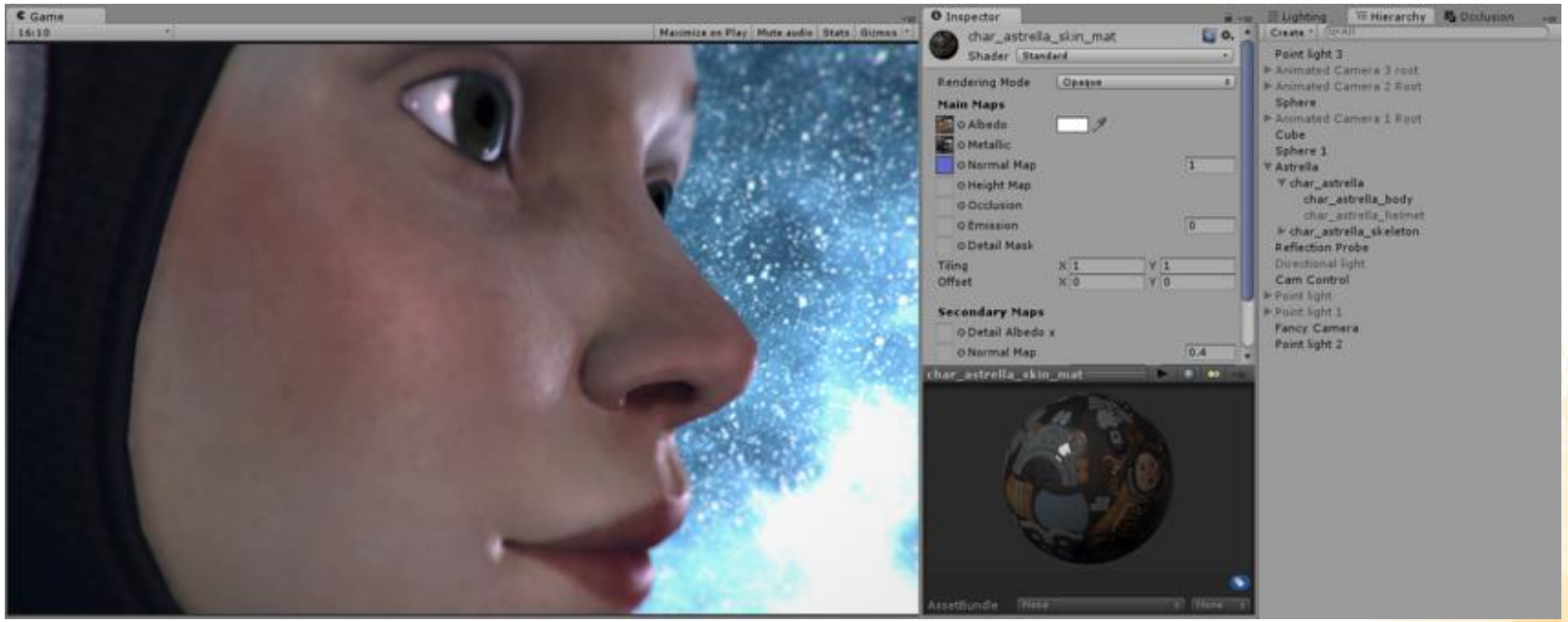
- The reason to use secondary maps is to allow the material to have sharp detail when viewed up close, while also having a normal level of detail when viewed from further away.
  - Without using a single extremely high texture map to achieve both goals.



Standard Shader: Secondary Maps & Detail Mask

- Typical uses for detail textures are: adding skin detail, adding tiny cracks and lichen growth to brick walls, adding small scratches to metal containers.

- Example (without secondary maps):



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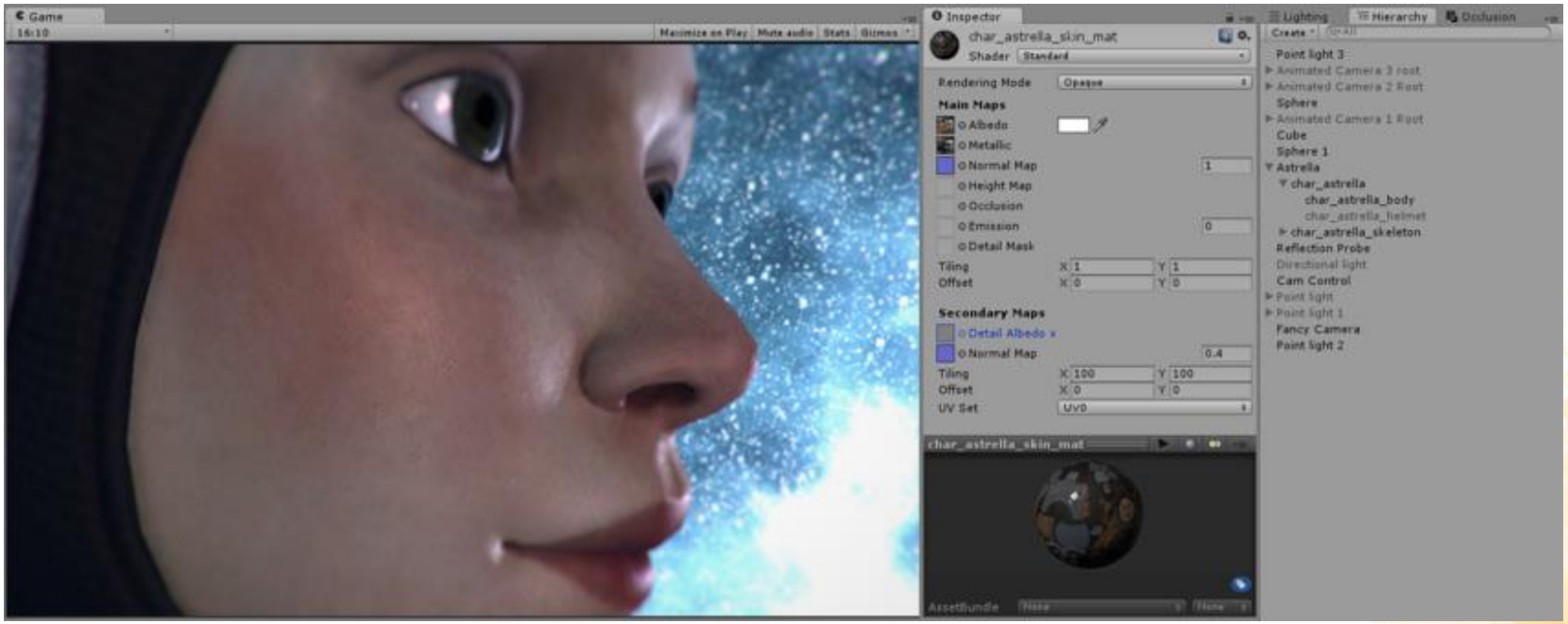


Other Built-in Shaders

- **FX**: Lighting and glass effects.
- **GUI and UI**: For user interface graphics.
- **Mobile**: Simplified high-performance shader for mobile devices.
- **Nature**: For trees and terrain.
- **Particles**: Particle system effects.
- **Skybox**: For rendering background environments behind all geometry.
- **Sprites**: For use with the 2D sprite system.
- **Toon**: Cartoon-style rendering.
- **Unlit**: For rendering that entirely bypasses all light & shadowing.
- **Legacy**: The large collection of older shaders which were superseded by the Standard Shader.

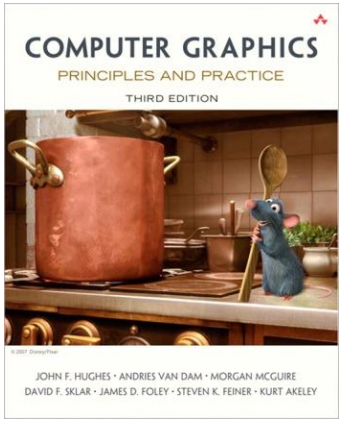
Exercise 1

1) Update the “Make Your Fantasy Game - Lite” demo scene to make better use of the Standard Shader features.
   - Download: https://assetstore.unity.com/packages/3d/environments/fantasy/make-your-fantasy-game-lite-8312

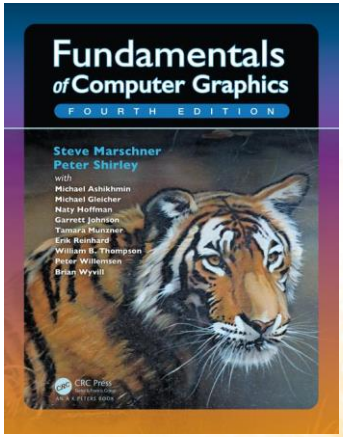
   - The updated scene must:
     - Use normal mapping;
     - Improve specular configuration;
   - You can find better textures in the asset store. Examples:
     - https://assetstore.unity.com/packages/2d/textures-materials/floors/outdoor-ground-textures-12555
     - https://assetstore.unity.com/packages/2d/textures-materials/brick/18-high-resolution-wall-textures-12567
     - https://assetstore.unity.com/packages/2d/textures-materials/concrete/yughues-free-concrete-materials-12951

Further Reading

- Hughes, J. F., et al. (2013). **Computer Graphics: Principles and Practice** (3rd ed.). Upper Saddle River, NJ: Addison-Wesley Professional. ISBN: 978-0-321-39952-6.
  - **Chapter 20: Textures and Texture Mapping;**



- Marschner, S., et al. (2015). **Fundamentals of Computer Graphics** (4th ed.). A K Peters/CRC Press. ISBN: 978-1482229394.
  - **Chapter 11: Texture Mapping**



- **Web:**
  - https://docs.unity3d.com/Manual/Shaders.html